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THE WEST FORK GALLATIN RIVER WATERSHED TOTAL MAXIMUM DAILY LOADS (TMDLS) AND FRAMEWORK WATERSHED WATER QUALITY IMPROVEMENT PLAN

Montana Department of
Environmental Quality

Version 1.0

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EXECUTIVE SUMMARY

This document presents a Total Maximum Daily Load (TMDL) and framework water quality restoration plan for three impaired streams in the West Fork Gallatin River watershed: the West Fork Gallatin River, the Middle Fork West Fork Gallatin River and the South Fork West Fork Gallatin River. The West Fork Gallatin River watershed is located within the Gallatin Range south of Bozeman, Montana and encompasses the mountain community of Big Sky as well as several mountain resorts. This plan was developed by the Montana Department of Environmental Quality (DEQ) and submitted to the U.S. Environmental Protection Agency (U.S. 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 water body can receive and still meet water quality standards. The goal of TMDLs is to eventually attain and maintain water quality standards in all of Montana’s streams and lakes, and to improve water quality to levels that support all state-designated beneficial water uses.

DEQ has performed assessments determining that the above streams do not meet the applicable water quality standards. The scope of the TMDLs in this document address sediment, nutrients, and e.coli related problems on the three aforementioned streams (See **Table 1-1**). 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 West Fork Gallatin River watershed and developing implementation plans to remedy known water quality problems related to sediment, nutrients and e.coli. Below is a brief synopsis of water quality issues addressed by the Plan.

Sediment

Sediment-related impacts were identified as a cause of impairment on the West Fork Gallatin River, the Middle Fork West Fork Gallatin River and the South Fork West Fork Gallatin River. Anthropogenic sources of sediment include upland and bank erosion associated with residential/resort development, ski areas, logging, and removal of riparian vegetation, stormwater from construction sites, and unpaved roads, culvert failure, and traction sand.

Recommended strategies for reducing sediment inputs include applying Best Management Practices (BMPs) to developed lands that will enhance and maintain riparian vegetation, improve ground protection in disturbed areas and construction sites, lessen the risk of culvert failure, and reduce the transport of traction sand and unpaved road sediment into streams.

Nutrients

Nutrient-related impacts were identified as a cause of impairment on the West Fork Gallatin River, the Middle Fork West Fork Gallatin River and the South Fork West Fork Gallatin River. Soluble nitrogen (NO3+NO2) has been identified as the primary pollutant affecting nutrient-related water quality impairments. Anthropogenic sources of NO3+NO2 include nitrogen released to groundwater from residential and recreational development, which includes ubiquitous land-clearing, maintenance and management activities within the watershed. In addition to residential and recreational sources of nitrogen, wastewater-derived nitrogen loads were identified as a significant source of nitrogen contributing to the West Fork Gallatin River through the area of the Big Sky Golf Course: wastewater sources are believed to be related to spray-irrigation of wastewater and/or sewer infrastructure failures within the reach.

Recommended strategies for reducing residential and recreational nitrogen inputs include applying Best Management Practices (BMPs) to developed lands that will reduce groundwater infiltration of soluble nitrogen, and to encourage building and development practices that incorporate water quality planning and pollutant mitigation into development planning. Further investigation into wastewater-derived nitrogen sources in the West Fork and South Fork West Fork Gallatin Rivers is recommended in order to refine source assessment findings and inform restoration and mitigation planning.

E. Coli

E. coli-related impacts were identified as a cause of impairment on the Middle Fork West Fork Gallatin River. Anthropogenic sources of e. coli are primarily non-point sources related to residential and recreational development, and include pet waste, waterfowl, and various non-point sources associated with developed landscapes. Discrete e. coli point sources were not identified in sampling or source assessment activities.

Recommended strategies for reducing residential and recreational e. coli inputs include applying Best Management Practices (BMPs) to developed lands that will maintain riparian buffer zones, and limit overland flow to streams from parking lots, streets, and other impervious developed areas. Public education regarding e. coli impacts and how tourists and residents may limit e. coli inputs is also recommended.

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 within this document will be used by local watershed groups, stakeholders and regulatory agencies as a tool to guide and prioritize local water quality improvement activities. These implementation and mitigation activities should be addressed further within a detailed watershed restoration plan consistent with DEQ and EPA recommendations. Presently, the Blue Water Task Force, a local collaborative watershed group, is leading stakeholder involvement and development of a comprehensive watershed restoration plan for the West Fork Gallatin River watershed.

It is recognized that a flexible and adaptive approach to most TMDL implementation and mitigation activities may become necessary as additional information 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.

SECTION 1.0
INTRODUCTION

1.1 Background

This document, *The West Fork Gallatin River Watershed Total Maximum Daily Loads (TMDLs) and Framework Watershed Water Quality Improvement Plan*, describes the Montana Department of Environmental Quality's (DEQ) understanding of pollutant-related water quality problems for pollutant-impaired streams in the West Fork Gallatin River watershed and presents a general framework for resolving them. Guidance for completing the plan is contained in the Montana Water Quality Act and the federal Clean Water Act.

In 1972 Congress passed the Water Pollution Control Act, more commonly known as the Clean Water Act. Its goal is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The Clean Water Act 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. Streams and lakes (also referred to as waterbodies) that do not meet the established standards are called "impaired waters." These waters are identified on the 303(d) List, named after Section 303(d) of the Clean Water Act, which mandates the monitoring, assessment, and listing of water quality limited waterbodies. The 303(d) List is contained within a biennial integrated water quality report. (See **Table 1-1** for a list of waters identified on the 2008 303(d) List as having impairments in the West Fork Gallatin Watershed, their impaired uses and probable impairment causes.)

Both Montana state law (75 MCA § 5-703) and section 303(d) of the federal Clean Water Act require the development of total maximum daily loads (TMDLs) for impaired waters where a measurable pollutant (e.g., sediment, nutrients, e. coli) is the cause of the impairment. A TMDL is a loading capacity and 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 "pollutant/waterbody combination"). These steps include:

- Characterizing the existing waterbody conditions and comparing these conditions to water quality standards. Measurable targets are defined as numeric values and set to help evaluate the stream's condition in relation to the standards.
- Quantifying the magnitude of pollutant contribution from sources.
- Establishing allowable loading limits (or total maximum daily loads) for each pollutant
- Comparing the current pollutant load to the loading capacity (or maximum loading limit/TMDL) of the particular waterbody.
- Determining the allowable loads or the necessary load reduction for each source (called "pollutant allocations").

In Montana framework restoration strategies and recommendations are also incorporated to help facilitate TMDL implementation.

In some cases the TMDLs may not be capable of fully restoring the designated beneficial uses without the addition of other restoration measures. For example, impairment causes such as streamflow alterations or dewatering, habitat degradation, and streambank or stream channel alterations may prevent a waterbody from fully attaining its beneficial uses even after TMDLs have been implemented. These are referred to as "pollution" problems, as opposed to impairments caused by any type of discrete "pollutant," such as sediment or metals. TMDLs, per se, are not intended to address water use support problems that are not directly associated with specific pollutants. However, many water quality restoration plans describe strategies that consider and address habitat, streamflow, and other conditions that may impair beneficial uses, in addition to problems caused by more conventional water pollutants. The desired goal of any well designed water quality improvement strategy is to enable restoration of impaired waters such that they support all designated beneficial uses and achieve and maintain full water quality standards by using comprehensive restoration approaches.

1.2 303(d) List Summary and TMDLs Written

Per federal court order, by 2012 DEQ must address all pollutant/waterbody combinations appearing on the 2008 303(d) List and which were also identified on the 1996 303(d) List. Three stream segments on the 2008 303(d) List were listed as impaired in the West Fork Gallatin River watershed. Waterbodies can become impaired from pollution (e.g., flow alterations and habitat degradation) and from pollutants (e.g., nutrients, sediment, e. coli). However, because only pollutants are associated with a load, the EPA restricts TMDL development to pollutants. Pollution is commonly—but not always—associated with a pollutant, and a TMDL may be written (but is not required) for a waterbody that is only on the 303(d) List for pollution.

Table 1-1. 2008 303(d) Listed Waterbodies, Impairment Causes, and Impaired Beneficial Uses in the West Fork Gallatin River Watershed.

Waterbody & Location Description	Waterbody ID	Impairment Cause	Pollutant Category	Impaired Uses
MIDDLE FORK OF WEST FORK GALLATIN RIVER, headwaters to mouth (West Fork Gallatin River)	MT41H005_050	Solids (Suspended/Bedload)	**Sediment***	Aquatic Life, Cold Water Fishery
		Alteration in stream-side or littoral vegetative covers	Not a Pollutant	Aquatic Life Cold Water Fishery
		Nitrate/Nitrite	**Nutrients***	Aquatic Life Cold Water Fishery Primary Contact Recreation
		Fecal Coliform	**Pathogens***	Aquatic Life Cold Water Fishery Primary Contact Recreation

Table 1-1. 2008 303(d) Listed Waterbodies, Impairment Causes, and Impaired Beneficial Uses in the West Fork Gallatin River Watershed.

Waterbody & Location Description	Waterbody ID	Impairment Cause	Pollutant Category	Impaired Uses
SOUTH FORK OF WEST FORK GALLATIN RIVER, headwaters to mouth (West Fork Gallatin River)	MT41H005_060	Siltation, Sedimentation	**Sediment***	Aquatic Life, Cold Water Fishery
		Alteration in stream-side or littoral vegetative covers	Not a Pollutant	Aquatic Life Cold Water Fishery
		Physical substrate habitat alterations	Not a Pollutant	Aquatic Life Cold Water Fishery
		Nitrate/Nitrite, Total Phosphorus, Chlorophyll-*a*	**Nutrients***	Aquatic Life Cold Water Fishery Primary Contact Recreation
WEST FORK GALLATIN RIVER, Confluence Mid & N Forks West Gallatin to mouth (Gallatin River)	MT41H005_040	Siltation, Sedimentation	**Sediment***	Aquatic Life, Cold Water Fishery
		Nitrate/Nitrite, Total Phosphorus, Chlorophyll-*a*	**Nutrients***	Aquatic Life Cold Water Fishery Primary Contact Recreation
* This document only addresses the pollutant categories in bold.				

Pollutant categories shown in bold in **Table 1-1** are associated with specific pollutants and are addressed within this document (see **Section 5.0, 6.0, 7.0**). Based on the 2008 303(d) List and a review of existing data for streams of the West Fork Gallatin River watershed, TMDLs were written for sediment, e.coli and nitrogen (NO_3+NO_2 and Total Nitrogen). **Table 1-2** provides a list of waterbodies and pollutants for which TMDLs are prepared.

Table 1-2. West Fork Gallatin River Watershed – TMDLs Prepared

Waterbody	Pollutant
Middle Fork West Fork Gallatin River - MT41H005_050	Sediment Nitrate+Nitrite (NO3+NO2) E.coli
South Fork West Fork Gallatin River - MT41H005_060	Sediment Nitrate+Nitrite (NO3+NO2)
West Fork Gallatin River - MT41H005_040	Sediment Nitrate+Nitrite (NO3+NO2) Total Nitrogen

1.3 Document Description

The document addresses all of the required components of a TMDL and includes an implementation and monitoring strategy as well as a description of the public involvement process. The main body of the document provides a summary of the TMDL components. Additional technical details are found in the Appendices. The document is organized as follows:

- Watershed Characterization: **Section 2.0**
- Montana Water Quality Standards: **Section 3.0**
- Description of TMDL Components: **Section 4.0**
- Sediment – Comparison of Existing Data to Water Quality Targets, Sources and Loads, and TMDLs and Allocations: **Section 5.0**

- Nutrients - Comparison of Existing Data to Water Quality Targets, Sources and Loads, and TMDLs and Allocations: **Section 6.0**
- E.coli - Comparison of Existing Data to Water Quality Targets, Sources and Loads, and TMDLs and Allocations: **Section 7.0**
- Framework Water Quality Restoration and Monitoring Strategy: **Section 8.0**
- Stakeholder and Public Involvement: **Section 9.0**

The Appendices include:

- Appendix A: Watershed Characterization Report
- Appendix B: Regulatory Framework and Reference Condition Approach
- Appendix C: Sediment and Habitat Assessment
- Appendix D: Streambank Erosion Source Assessment
- Appendix E: Sediment Contribution from Upland Erosion
- Appendix F: Unpaved Road Sediment Assessment
- Appendix G: Daily TMDLs
- Appendix H: Response to Public Comments

SECTION 2.0

UPPER GALLATIN TMDL PLANNING AREA WATERSHED DESCRIPTION

Although the scope of this document is in the West Fork Gallatin River watershed, the watershed description in this section applies to the entire Upper Gallatin TMDL Planning Area. This was done to provide a context for conditions within the West Fork watershed, because some reference data were collected within the Upper Gallatin watershed but outside of the West Fork watershed, and to facilitate future work in other parts of the watershed. This report describes the physical, ecological, and cultural characteristics of the Upper Gallatin River watershed. The characterization establishes a context for impaired waters to support total maximum daily load (TMDL) planning in the Upper Gallatin TMDL Planning Area (TPA). **Appendix A, Figure 2-1**.

2.1 Physical Characteristics

2.1.1 Location

The TPA is located in the Missouri Headwaters (Accounting Unit 100200) of western Montana, and within the Gallatin River (HUC 1002008) hydrologic unit, as shown in **Appendix A**, **Figure 2-2**. The TPA is located in the Middle Rockies Level III Ecoregion. Five Level IV Ecoregions are mapped within the Upper Gallatin River TPA (Woods et al., 2002), as shown in **Appendix A**, **Figure 2-3**. These include: Mid Elevation Sedimentary Mountains (17g), Gneissic-Schistose Forested Mountains (17l), Absaroka-Gallatin Volcanic Mountains (17i), Dry Gneissic-Schistose Volcanic Hills (17ab) and Alpine zone (17h). The majority of the Upper Gallatin TPA is within Gallatin County, with a minor area in Madison and Park Counties.

The TPA is bounded by the Madison Range to the west, the Gallatin Range to the east and the Wyoming state border to the south. The total area is 483,461 acres, or approximately 755 square miles. The West Fork Gallatin River watershed comprises 51,272 acres of the Upper Gallatin TPA.

2.1.2 Topography

Elevations in the Upper Gallatin TPA range from approximately 1,582 to 3,403 meters (5,190 - 11,166 feet) above mean sea level (**Appendix A**, **Figure 2-4**). The lowest point is where the Gallatin River exits the canyon at the northern end of the TPA. The highest point is Lone Mountain, along the western margin of the TPA. The lowest elevation in the West Fork Gallatin River watershed is 1,822 meters (5,976 feet) at the confluence of the West Fork Gallatin River and the mainstem Gallatin River. The TPA geography is characterized by alpine valleys draining into the Gallatin River canyon. The broadest valley by far is the West Fork Gallatin River drainage.

2.1.3 Geology

Appendix A, **Figure 2-5** provides an overview of the geology, based on the 1:500,000 scale statewide map (Ross et al., 1955).

Bedrock

The bedrock within the TPA includes Precambrian metamorphic and metasedimentary rocks, Paleozoic and Mesozoic sedimentary rocks, Cretaceous igneous intrusions, and Tertiary volcanic rocks (Ross et al., 1955). Lone Mountain is an igneous intrusion of dacite porphyry, and this erosion-resistant rock is responsible for the high topography. North of the Spanish Peaks Fault, Precambrian metamorphic rocks dominate the Madison Range; south of the fault the bedrock is mostly Mesozoic sedimentary rocks, with the underlying Paleozoic sedimentary rocks exposed in the southern and lower elevation portions of the watershed. The Gallatin Range is dominated by volcanic rocks.

The Mesozoic sedimentary rocks, particularly those of Cretaceous age, are more susceptible to erosion as they are not as indurated as the other units. The Cretaceous units include terrestrial, nearshore and offshore facies, and commonly feature weakly lithified fine-grained sediments. In contrast, the older sedimentary rocks, by virtue of their greater age, have been subject to further consolidation and lithification. The watersheds of the West Fork Gallatin River, Taylor Fork and Cache Creek are underlain predominantly by Mesozoic sedimentary rocks.

Valley Sediments

Sediments in the valleys are primarily alluvial and glacial deposits. Due to the narrow width of these high-elevation valleys, the alluvial deposits are limited in extent. Glacial deposits are more widespread.

Landslide deposits are widespread in the West Fork Gallatin TPA (Vuke, 2009). These deposits consist largely of reworked glacial sediments and eroded sedimentary rock. By their nature, landslide deposits are likely to be more susceptible to erosion than alluvium or glacial deposits.

2.1.4 Soils

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

Soil permeability is reported in inches per hour, and is mapped in **Appendix A**, **Figure 2-6**. The majority of the TPA (78%) is mapped with permeability of less than 2 inches per hour. Thirteen percent of the TPA is mapped with infiltration rates of 6.53 inches per hour. These higher-permeability areas are associated with the highest elevations and probably correspond to exposed fractured bedrock or areas with very thin soil cover. Much of the West Fork Gallatin TPA (62%) is mapped with permeability less than 2 inches per hour. However, most of the area north of the Middle Fork of the West Fork of the Gallatin is mapped with a permeability of 5.1 inches per hour.

Soil erodibility is based on the Universal Soil Loss Equation (USLE) K-factor (Wischmeier & Smith 1978). K-factor values range from 0 to 1, with a greater value corresponding to greater potential for erosion. Susceptibility to erosion is mapped in **Appendix A**, **Figure 2-7**, 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 0.4 are mapped in the TPA.

The majority of the TPA (78%) is mapped with moderate-low susceptibility soils. A minor percentage (15%) is mapped with low susceptibility, and only 7% is mapped with moderate-high susceptibility soils. In the West Fork Gallatin TPA, 46% of the TPA is mapped with moderate-low susceptibility soils; 37% is mapped with moderate-high susceptibility.

2.1.5 Surface Water

Within the Upper Gallatin TPA, the Gallatin River flows from the Wyoming border to Gallatin Gateway, a distance of approximately 47 miles. The West Fork Gallatin River is the major tributary within this reach. Upper Gallatin watershed hydrography is illustrated in **Appendix A**, **Figure2-8.**

Stream Gaging Stations
The United States Geological Survey (USGS) maintains one gaging station within the TPA, as detailed below in **Table 2-1**. One inactive station was formerly present in the TPA. The USGS gaging stations are listed below (**Table 2-1**), and shown in **Appendix A**, **Figure 2-8**.

Table 2-1. USGS Stream Gages in the Upper Gallatin

Name	Number	Drainage Area	Agency	Period of Record
Gallatin River near Gallatin Gateway	06043500	825 miles2	USGS	1889-
Taylor Creek near Grayling	12323200	98 miles2	USGS	1946 - 1967

Stream Flow
Stream flow data is based on records from the USGS stream gauges described above, and is available on the Internet from the USGS. Flows in the Gallatin River vary considerably over a calendar year. A hydrograph summarizing flows at this station is provided in **Figure 2-9**. The hydrograph is based on weekly mean flows over a 78-year period of record.

Peak annual discharges in the Gallatin River vary over nearly an order of magnitude. Statistically, flow peaks in July (2,920 cfs) and is lowest in February (300 cfs). During the period of record annual peaks have ranged from 9,160 cfs (June 2, 1997) to 1,740 cfs (May 8, 1934). The mean peak annual discharge during the period of record is 5,234 cfs. Of the annual peak discharges, 20 occurred in May, and 1 occurred in July. Annual peaks have occurred as early as May 8 and late as July 4.

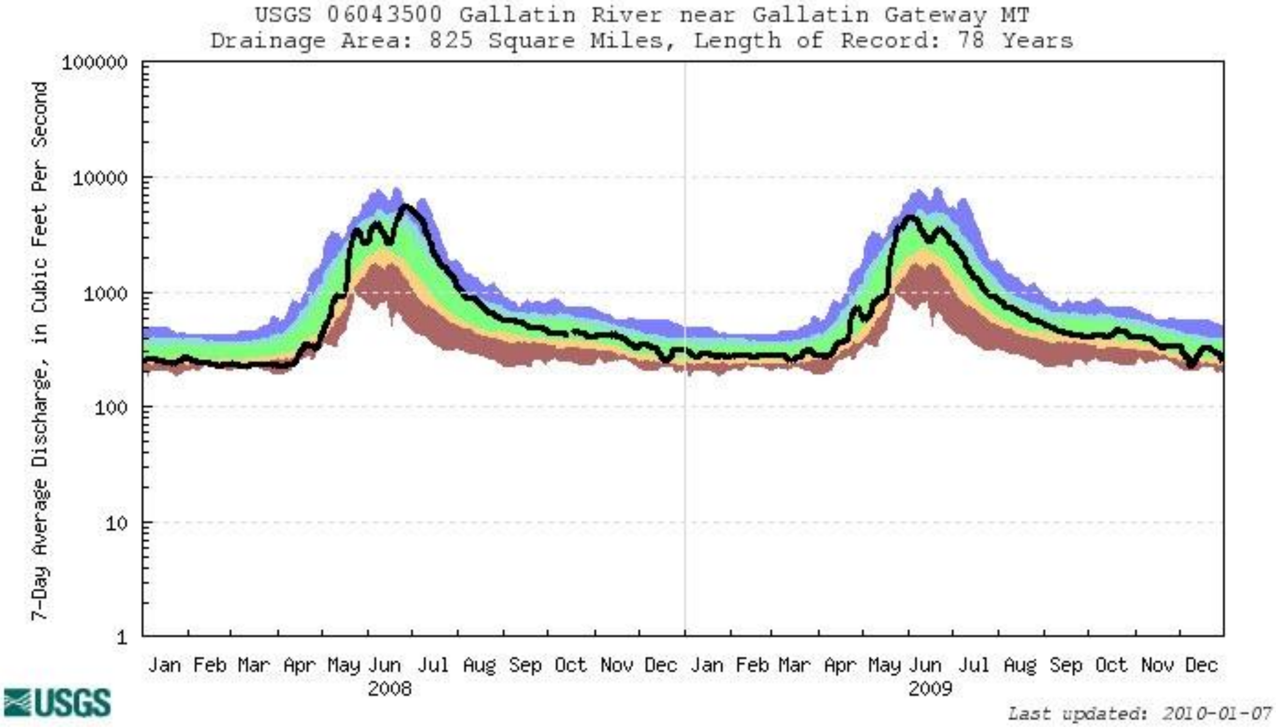

Figure 2-9. Hydrograph summarizing Gallatin River flows at gaging station 06043500 at Gallatin gateway based on weekly flows over a 78-year period of record

Surface Water Quality
Water quality and chemistry data are available from the USGS gaging station in the Upper Gallatin TPA and are included in the most recent USGS Water-Data Report (United States Geological Survey, 2008). For further description of surface water quality, see **Sections 5.0, 6.0** and **7.0** as they pertain to pollutant listings and data evaluation for each cause of impairment.

2.1.6 Ground Water

Hydrogeology
Ground water occurs in both shallow alluvial and bedrock aquifers. Porosity in bedrock aquifers is of two types: primary (interstitial spaces between sediment grains) and secondary (void space created by dissolution or structural deformation). Natural recharge occurs from infiltration of precipitation, stream loss, and flow out of the adjacent bedrock aquifers.

The average ground water flow velocity in the bedrock is probably several orders of magnitude lower than in the valley fill sediments. Bedrock ground water 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. No studies of the Gallatin Canyon hydrogeology were identified.

Due to the commercial development in and around Big Sky, the West Fork Gallatin TPA is better studied. In general, ground water flows from the margins of the West Fork valley towards the center, where flow is along the axis of the valley. The West Fork Middle Fork Gallatin is a gaining stream to its confluence with the North Fork West Fork Gallatin. Infiltration into the alluvial aquifer beneath the Meadow Village area results in a losing reach of the West Fork (Baldwin, 1996).

Ground Water Quality
The Montana Bureau of Mines and Geology (MBMG) Ground Water Information Center (GWIC) program monitors and samples a statewide network of wells. As of October 2009, the GWIC database reports 828 wells within the TPA. Water quality data are available for 16 of those wells and available from the MBMG GWIC clearinghouse. The locations of these data points are shown in **Appendix A**, **Figure 2-10**. 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 ground water samples for organic compounds.

There are 35 public water supplies within the TPA, all of which use ground water for their supply. 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 14 community water systems within the TPA. Water quality data are available from these utilities via the SDWIS State database, although these data reflect the finished water provided to the public, not raw water at the source.

Baldwin (1996) reports on water quality from 27 wells sampled in the Big Sky area. Wells completed in alluvium yielded water with a calcium-magnesium-bicarbonate chemistry. Bedrock wells commonly produced water with a higher sodium content. Baldwin suggested that the carbonate concentrations reported in siliciclastic rocks may be evidence of recharge from the Madison Group limestones exposed on higher elevations north of Big Sky.

2.1.7 Climate

Climate in the TPA is typical of high-elevation mountain valleys in southern Montana. Precipitation is most abundant in March and April. Annual average precipitation ranges from 19-61 inches in the Upper Gallatin River watershed. The mountains receive most of the moisture, and the mouth receives the least. The precipitation data are mapped by Oregon State University's PRISM Group, using records from NOAA stations. See **Tables 2-2** and **2-3** for climate summaries; **Appendix A**, **Figure 2-11** shows the distribution of average annual precipitation.

Climate Stations
National Oceanographic and Atmospheric Administration (NOAA) currently operates three weather stations in the TPA, and several more have been discontinued. The USDA Natural Resources Conservation Service (NRCS) operates 9 SNOTEL snowpack monitoring stations within the TPA. **Appendix A**, **Figure 2-11** shows the locations of the NOAA and SNOTEL stations, in addition to average annual precipitation. Climate data are provided by the Western Regional Climate Center, operated by the Desert Research Institute of Reno, Nevada.

Table 2-2. Monthly Climate Summary: Big Sky

Big Sky 3S, Montana (240775) Period of Record : 3/ 1/1984 to 12/31/2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave. Max. Temp (F)	31.2	35.2	43.2	51.5	61.8	69.2	77.8	78.0	68.6	55.6	37.9	29.5	53.3
Ave. Min. Temp. (F)	7.8	7.2	15.5	22.8	29.6	35.6	40.1	38.2	32.0	23.7	13.6	6.6	22.7
Ave Tot. Precip. (in.)	1.42	1.16	1.23	1.33	2.75	2.82	1.69	1.64	1.57	1.52	1.39	1.4	19.90
Ave.. Snowfall (in.)	31.9	20.7	21.1	8.2	4.9	1.2	0.2	0.0	0.3	5.5	19.0	31.4	144.3
Ave Snow Depth (in.)	23	27	26	5	0	0	0	0	0	0	3	15	8
Gallatin Gateway 26SSW (243372) Period of Record : 7/1/1967 to 2/29/1984													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Ave. Max. Temp (F)	28.4	35.4	40.3	48.1	57.9	67.8	77.6	77.5	67.6	54.8	38.1	28.9	51.9
Ave. Min. Temp. (F)	4.9	8.3	12.9	19.9	28.8	35.0	38.7	37.8	30.8	23.5	14.0	6.4	21.8
Ave Tot. Precip. (in.)	1.71	1.12	1.75	1.51	2.61	3.15	1.85	1.77	2.08	1.64	1.50	1.85	22.55
Ave.. Snowfall (in.)	12.0	18.5	25.0	10.8	2.7	0.0	0.0	0.0	1.2	2.9	-	25.2	-
Ave Snow Depth (in.)	19	26	25	18	3	0	0	0	0	0	4	14	9

Table 2-3. Monthly Climate Summary: Gallatin Gateway

Gallatin Gateway 10SSW, Montana (243366) Period of Record : 6/1/1950 to 12/31/2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave. Max. Temp (F)	Insufficient Data												
Ave. Min. Temp. (F)	Insufficient Data												
Ave Tot. Precip. (in.)	1.05	0.94	1.73	2.45	3.55	3.26	1.65	1.73	2.01	1.89	1.28	1.08	22.60
Ave. Snowfall (in.)	13.5	11.0	16.3	12.4	4.4	0.4	0.0	0.0	1.7	6.0	11.6	12.9	90.1
Ave Snow Depth (in.)	4	5	5	2	0	0	0	0	0	0	2	4	2

2.2 Ecological Parameters

2.2.1 Vegetation

The primary cover in the TPA is conifer forest. Conifers are dominated by Lodgepole pine, giving way to Douglas fir at lower elevations. Landcover is shown in **Appendix A**, **Figure 2-12**. Data sources include the USGS National Land Cover Dataset (NLCD).

2.2.2 Aquatic Life

Native fish species present in the TPA include: westslope cutthroat trout, mountain whitefish, longnose dace, longnose sucker, mountain sucker, white sucker, and mottled scuplin. Westslope cutthroat trout are designated “Species of Concern” by Montana Department of Fish, Wildlife and Parks (FWP). Introduced species are also present in streams, including: brook, brown, golden and rainbow trout. Hybrids (rainbow-cutthroat) are reported in streams. Data on fish species distribution are collected, maintained and provided by FWP. Fish species distribution is shown in **Appendix A**, **Figure 2-13**.

2.2.3 Fires

The United States Forest Service (USFS) Region 1 office and the USFS remote sensing applications center provide data on fire locations from 1940 to the present. Relatively few fires have occurred in the TPA in recent years. Fires data is mapped in **Appendix A**, **Figure 2-14**.

2.3 Cultural parameters

2.3.1 Population

An estimated 1,150 persons lived within the TPA in 2000. Population estimates are derived from census data (US Census Bureau, 2000), based upon the populations reported from census blocks within and intersecting the TPA boundary. The majority of the population is located within the West Fork Gallatin TPA. The remainder of the population is sparsely distributed and much of the TPA is unpopulated. Census data are mapped in **Appendix A**, **Figure 2-15**.

2.3.2 Land Ownership

Land ownership data are provided by the State of Montana CAMA database via the NRIS website and are shown in **Appendix A**, **Figure 2-16**. The dominant landholder is the USFS, which administers 72% of the Upper Gallatin TPA. Yellowstone National Park occupies 9.6% of the TPA, and the remaining public lands are owned by Montana FWP and the Rocky Mountain Elk Foundation. Private lands comprise 16.6% of the Upper Gallatin TPA.

Land ownership in the West Fork Gallatin TPA is primarily private (71.5%). The remaining 28.5% is administered by the USFS.

Table 2-4. Land Ownership

Owner	Acres	Square Miles	% of Total
Private	80,168	125.3	16.6%
US Forest Service	347,720	543.3	71.9%
US Park Service	46,427	72.5	9.6%
Montana FWP	8,644	13.5	1.8%
Rocky Mountain Elk Foundation	460	0.7	0.1%
Total	483,461	755.3	—

2.3.3 Land Use and Land Cover

Land cover within both the Upper Gallatin and West Fork Gallatin TPAs is dominated by evergreen forest. Information on land use is based on the USGS National Land Cover Dataset. The data are at 1:250,000 scale. Land use is illustrated in **Appendix A**, **Figure 2-17**.

Table 2-5. Land Use and Land Cover in the Upper Gallatin TPA

Land Use	Acres	Square Miles	% of Total
Evergreen Forest	319,314	498.93	66.03%
Shrub/Scrub	118,674	185.43	24.54%
Herbaceous	32,549	50.86	6.73%
Barren Land	3,305	5.17	0.68%
Emergent Herbaceous Wetlands	3,171	4.95	0.66%
Developed Open Space	1,999	3.12	0.41%
Woody Wetlands	1,673	2.61	0.35%
Deciduous Forest	1,641	2.57	0.34%
Developed Low Intensity	263	0.41	0.05%
Hay Pasture	251	0.39	0.05%
Mixed Forest	224	0.35	0.05%
Open Water	452	0.71	0.09%
Cultivated Crops	46	0.07	0.01%
Developed Moderate Intensity	9	0.01	0.00%
Evergreen Forest	319,314	498.93	66.03%
Shrub/Scrub	118,674	185.43	24.54%
Herbaceous	32,549	50.86	6.73%
Barren Land	3,305	5.17	0.68%
Emergent Herbaceous Wetlands	3,171	4.95	0.66%
Developed Open Space	1,999	3.12	0.41%
Woody Wetlands	1,673	2.61	0.35%

Table 2-6. Land Use and Land Cover in the West Fork Gallatin TPA

Land Use	Acres	Square Miles	% of Total
Evergreen Forest	26,724	41.76	52.11%
Shrub/Scrub	16,234	25.37	31.65%
Herbaceous	6,239	9.75	12.17%
Developed Open Space	1,160	1.81	2.26%
Barren Lands	241	0.38	0.47%
Emergent Herbaceous Wetlands	190	0.30	0.37%
Deciduous Forest	171	0.27	0.33%
Developed Low Intensity	130	0.20	0.25%
Woody Wetlands	119	0.19	0.23%
Mixed Forest	40	0.06	0.08%
Open Water	13	0.02	0.03%
Cultivated Crops	10	0.02	0.02%
Developed Moderate Intensity	7.8	0.01	0.02%
Hay Pasture	7.3	0.01	0.01%
Evergreen Forest	26,724	41.76	52.11%
Shrub/Scrub	16,234	25.37	31.65%
Herbaceous	6,239	9.75	12.17%
Developed Open Space	1,160	1.81	2.26%
Barren Lands	241	0.38	0.47%
Emergent Herbaceous Wetlands	190	0.30	0.37%
Deciduous Forest	171	0.27	0.33%

United States Geological Survey (2008) report that roughly 1,400 acres upstream of the Gallatin Gateway gage are irrigated with surface water diversions.

2.3.4 Transportation Networks

Transportation networks (road and railroads) are illustrated in **Appendix A**, **Figure A-18**.

Roads
The principal transportation route in the TPA is US Highway 191. Highway 191 connects West Yellowstone to Bozeman. The network of unpaved roads on public and private lands will be further characterized as part of the sediment source assessment.

Railroads
No railroads are located within the TPA.

2.3.5 Mining

Mining has been of less importance in the Upper Gallatin TPA than in other watersheds in western Montana. Abandoned and inactive mines are present (**Appendix A**, **Figure 2-19**), but at relatively low density. No active mines are present as of 2009, according to DEQ Environmental Management Bureau files.

2.3.6 Timber Harvest

According to Snyder et al., (1978) the TPA experienced tie cutting during the period 1880-1900, and then relatively little timber harvesting until 1950. After 1950, mature stands of Lodgepole pine were harvested in clearcuts on both private and USFS lands in numerous drainages within the TPA.

2.3.7 Wastewater

The Big Sky Water and Sewer District encompasses both Big Sky Mountain Village and Big Sky Meadow Village. They are connected via a sewer main that runs roughly parallel to the Middle Fork West Fork Gallatin River. Wastewater treatment is via a lagoon system located near Big Sky Meadow Village, and wastewater is land-applied during the summer months to the Big Sky Golf Course at meadow village.

Outside of the West Fork Gallatin TPA and the Big Sky area, wastewater treatment systems are largely limited to scattered residences. Wastewater treatment and disposal is via on-septic system drain fields. Gallatin County septic system records show 864 septic systems installed within the Upper Gallatin TPA. Of these, 34 are commercial systems. A total of 226 septic systems (8 commercial) are recorded in the West Fork Gallatin River watershed.

SECTION 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 streams in the Upper Gallatin TMDL Planning Area streams can be found in **Appendix B**.

3.1 Upper Gallatin TMDL Planning Area Stream Classification 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 within the Upper Gallatin watershed are classified as either A-1 or 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. While some of the Upper Gallatin 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. On the 2008 303(d) List, six waterbody in the Upper Gallatin TPA are listed as not supporting one or more beneficial uses (**Table 3-1**).

More detailed descriptions of Montana's surface water classifications and designated beneficial uses are provided in **Appendix B**.

Table 3-1. Waterbody in the Upper Gallatin TPA from the 2008 303(d) List and their Associated Level of Beneficial Use Support

Waterbody & Stream Description	Waterbody #	Use Class	Length (Miles)	Year	Aquatic Life	Coldwater Fishery	Drinking Water	Contact Recreation	Agriculture	Industry
Cache Creek from headwaters to mouth (Taylor Fork)	MT41H005_030	B-1	3.9	2008	P	P	X	F	F	F
Middle Fork, West Fork Gallatin River from headwaters to mouth (West Fork Gallatin River)	MT41H005_050	B-1	6.0	2008	P	P	F	N	F	F

Table 3-1. Waterbody in the Upper Gallatin TPA from the 2008 303(d) List and their Associated Level of Beneficial Use Support

Waterbody & Stream Description	Waterbody #	Use Class	Length (Miles)	Year	Aquatic Life	Coldwater Fishery	Drinking Water	Contact Recreation	Agriculture	Industry
South Fork, West Fork Gallatin River from headwaters to mouth (West Fork Gallatin River)	MT41H005_060	B-1	13.8	2008	P	P	F	P	F	F
Squaw Creek from headwaters to mouth (Gallatin River)	MT41H005_010	B-1	13.7	2008	P	P	X	F	F	F
Taylor Creek from Lee Metcalf Wilderness boundary to the mouth (Gallatin River)	MT41H005_020	B-1	17.4	2008	P	P	X	F	X	P
West Fork Gallatin River from confluence of Middle and North forks West Gallatin to the mouth (Gallatin River)	MT41H005_040	B-1	3.7	2008	P	N	F	N	F	F

F = Full Support, P = Partial Support, N = Not Supported, T = Threatened, X = Not Assessed (Lacking Sufficient Credible Data)

3.2 Upper Gallatin 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 B** defines each of these.

Numeric standards apply to concentrations of pollutants that are known to have adverse effects on human health or aquatic life. Pollutants for which numeric standards exist include metals, organic chemicals, and other toxic constituents. Human health standards have been set at levels to protect against long-term (lifelong) exposure as well as short-term exposure through direct contact such as swimming. Aquatic life numeric standards include chronic and acute values. *Chronic* aquatic life standards are designed to prevent effects of long-term low level exposure to pollutants, while *acute* aquatic life standards are protective of short-term exposure to pollutants. Chronic standards are more stringent than acute standards, but they can be exceeded for short periods of time, while acute standards can never be exceeded.

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 (naturally occurring 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, nutrient and pathogen water quality standards that apply to the Upper Gallatin watershed are summarized in **Appendix B**.

SECTION 4.0
DESCRIPTION OF TMDL COMPONENTS

A TMDL is basically a 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. A TMDL is also a reduction in pollutant loading resulting in attainment of water quality standards. More specifically, a TMDL is the sum of waste load allocations (WLAs) for point sources, and load allocations (LAs) for nonpoint sources and natural background sources. 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 allowable pollutant load must ensure that the waterbody will be able to attain and maintain water quality standards regardless of seasonal variations in water quality conditions, streamflows, and pollutant loading. TMDLs are expressed by the following equation:

$$\text{TMDL} = \Sigma\text{WLA} + \Sigma\text{LA} + \text{MOS}$$

Sections 5 through **Section 7** includes 303(d) pollutant listings, the source assessment process for that pollutant, relevant water quality targets, a comparison of existing conditions to targets, quantification of loading from identified sources, TMDLs, and allocations to sources. The major components that figured into TMDL development are described below.

4.1 Establishing and Evaluating Targets

Because loading capacity is evaluated in terms of meeting water quality standards, quantitative water quality targets and supplemental indicators (in some cases) 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 pollutants responsible for impairment of streams of the West Fork Gallatin River watershed. TMDL water quality targets help translate the numeric or narrative water quality standards for the pollutant of concern, and are specific to the waterbody being evaluated. For pollutants with established numeric water quality standards, the numeric values are used as TMDL water quality targets. For pollutants with only narrative standards, such as sediment, the water quality targets help to further interpret the narrative standard and provide an improved understanding of impairment conditions. Water quality targets for sediment typically include a suite of instream 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.

4.2 Quantifying Pollutant Sources

All significant pollutant sources, including natural background loading, are quantified so that the relative pollutant contributions can be determined. Because water quality impacts can vary throughout the year, often source assessments must evaluate the seasonal nature and ultimate fate of the pollutant loading. The source assessment usually helps 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 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-watershed (or tributaries) approach can be used whereby most or all sources 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.

Figure 4-1 is a schematic diagram illustrating how numerous sources contribute to the existing load and how a TMDL is determined by comparing the existing load to that which will meet standards.

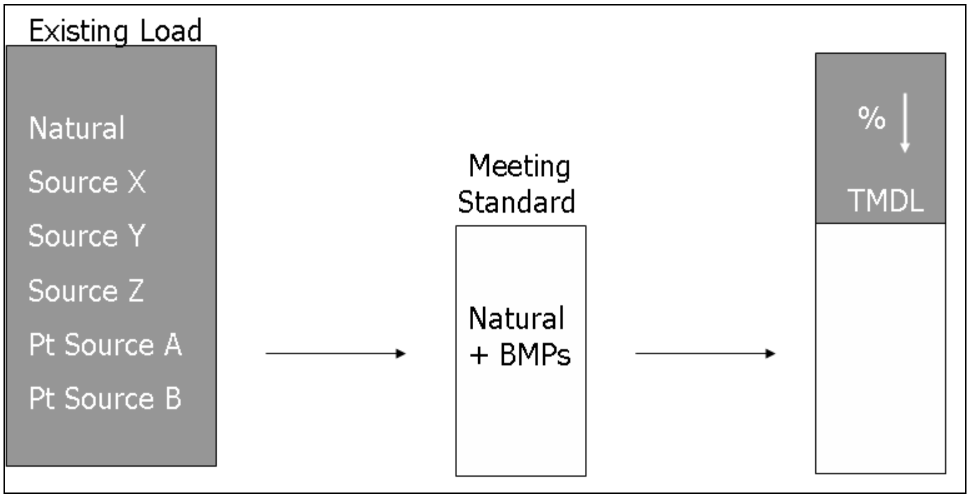

Figure 4-1. Schematic example of TMDL development.

4.3 Determining Allocations

Once the loading capacity (i.e., TMDL) is determined, that total must be divided, or allocated, among the contributing sources. Allocations are 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 BMPs, but additional conservation practices may be required to achieve compliance with water quality targets and restore beneficial uses. **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. Under the current regulatory framework for development of TMDLs, flexibility is allowed for specifying 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.

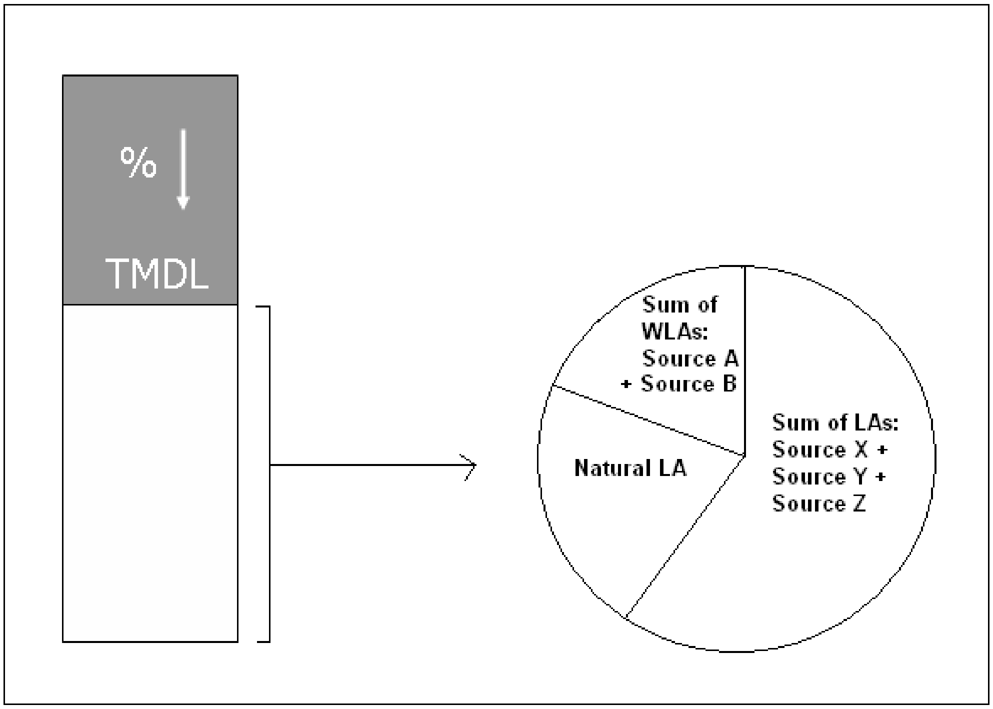

Figure 4-2. Schematic diagram of TMDL and allocations.

4.4 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. 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 (EPA, 1999).

SECTION 5.0
SEDIMENT

This portion of the document focuses on sediment as an identified cause of water quality impairments in the West Fork Gallatin River watershed. 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) the various contributing sources of sediment based on recent studies, and 5) the sediment TMDLs and allocations.

The term sediment is used in this document to refer collectively to several closely-related pollutant categories, including suspended sediment, stream channel geometry that can affect sediment delivery and transport, and sediment deposition on the stream bottom.

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 and affect fish and other aquatic life by increasing turbidity and causing excess sediment to accumulate in critical aquatic habitat areas not naturally characterized by high levels of fine sediment.

More specifically, sediment may block light and cause a decline in primary production, and it may also interfere with fish and macroinvertebrate survival and reproduction. Fine sediment deposition reduces availability of suitable spawning habitat for salmonid fishes and can smother eggs or hatchlings. Effects from excess sediment are not limited to suspended or fine sediment; an accumulation of larger sediment (e.g. cobbles) can fill pools, reduce the percentage of desirable particle sizes for fish spawning, and cause channel overwidening (which may lead to additional sediment loading and/or increased temperatures). Although fish and aquatic life are typically the most sensitive beneficial uses regarding sediment, excess sediment may also affect other uses. For instance, high concentrations of suspended sediment in streams can also cause water to appear murky and discolored, negatively impacting recreational use, and excessive sediment can increase filtration costs for water treatment facilities that provide safe drinking water.

5.2 Stream Segments of Concern

A total of three waterbody segments in the West Fork Gallatin River watershed (a.k.a West Fork) appeared on the 2008 Montana 303(d) List due to sediment impairments (**Table 5-1**); listing causes solids (suspended/bedload) and sedimentation/siltation. The listed waterbodies include the Middle Fork West Fork, South Fork West Fork and the West Fork of the Gallatin Rivers.

Although not shown in **Table 5-1** (see **Table 1-1**), the Middle Fork West Fork and South Fork West Fork are also listed for habitat alterations, which are forms of pollution frequently associated with sediment impairment. TMDLs are limited to pollutants, but implementation of land, soil, and water conservation practices to reduce sediment loading will inherently address habitat impairments for those waterbodies. No other waterbody segments in the watershed are listed for habitat alterations.

Table 5-1. Waterbody Segments in the West Fork Gallatin River Watershed with Sediment Listings on the 2008 303(d) List

Stream Segment	Waterbody #	Sediment Causes of Impairment
MIDDLE FORK OF WEST FORK GALLATIN RIVER, headwaters to mouth (West Fork Gallatin River)	MT41H005_050	**Solids (Suspended/Bedload)**
SOUTH FORK OF WEST FORK GALLATIN RIVER, headwaters to mouth (West Fork Gallatin River)	MT41H005_060	**Sedimentation/ siltation**
WEST FORK GALLATIN RIVER, Confluence Mid & N Forks West Gallatin to mouth (Gallatin River)	MT41H005_040	**Sedimentation/ siltation**

5.3 Information Sources and Assessment Methods

A sediment data compilation was performed to gather historical data from within the sediment-listed watersheds and also relevant local and regional reference data. The primary data sources are DEQ assessment files containing information used to make the existing impairment determinations and data collected and/or obtained during the TMDL development process. Most physical and habitat data in the assessment files were collected between 1970 and 2000, but numerous macroinvertebrate samples were collected in various locations between 1991 and 2008 (**Appendix A, Figure 5-1**). 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 2008 from 16 monitoring reaches on the listed waterbodies and their tributaries (**Appendix A**, **Figure 5-2**).

Initially, all streams of interest underwent an aerial assessment procedure by which reaches were characterized by four main attributes not linked to human activity: stream order, valley gradient, valley confinement, and ecoregion. These four attributes represent main factors influencing stream morphology, which in turn influences sediment transport and deposition. The next step in the aerial assessment involved identification of near-stream land uses since land management practices can have a significant influence on stream morphology and sediment characteristics. The resulting product was a stratification of streams into reaches that allow for comparisons among those reaches of the same natural morphological characteristics, while also indicating stream reaches where land management practices may further influence stream morphology. The stream stratification, along with field reconnaissance, provided the basis for selecting the above-referenced monitoring reaches. Monitoring reaches were chosen to allow for a representation of various reach characteristics and anthropogenic influence. There was a preference toward sampling those reaches where anthropogenic influences would most likely lead to impairment conditions since it is a primary goal of sediment TMDL development to further characterize sediment impairment conditions. Thus, it is not a random sampling design intended to sample stream reaches representing all potential impairment and non-impairment conditions. Instead, it is a targeted sampling design that aims to assess a representative subset of reach types while ensuring that reaches within each [sediment] 303(d) listed waterbody with potential impairment conditions are incorporated into the overall evaluation. Typically, the effects of excess sediment are most apparent in low gradient, unconfined streams larger than 1st order (i.e. having at least one tributary); therefore, this stream type was the focus of the field effort (**Table 5-2**). Although the TMDL development process necessitates this targeted sampling design, it is acknowledged that this approach results in 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.

Table 5-2. Reach Types Assessed in the West Fork Gallatin River Watershed.

Level III Ecoregion	Gradient	Strahler Stream Order	Confinement	Reach Type	Number of Monitoring Reaches	Total Number of Stratified Reaches
Middle Rockies	0-<2%	3	Unconfined	MR-0-3-U	3	12
		4	Unconfined	MR-0-4-U	1	4
	2-<4%	1	Unconfined	MR-2-1-U	1	1
		2	Unconfined	MR-2-2-U	2	6
		3	Unconfined	MR-2-3-U	5	9
	4-<10%	1	Confined	MR-4-1-C	1	10
		1	Unconfined	MR-4-1-U	3	40

The field parameters assessed in 2008 include standard measures of stream channel morphology, fine sediment, stream habitat, riparian vegetation, and streambank erosion. Although the sampling areas are frequently referred to as “sites” within this document, to help increase sample sizes and capture variability within assessed streams, they were actually sampling reaches ranging from 500 to 2000 feet (depending on the channel bankfull width) that 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 contained in **Appendix G**.

Additional data sources include GIS data layers and USFS reference data and publications regarding historical land usage, channel stability, and sediment conditions. Regional reference data was derived from the Beaverhead Deerlodge National Forest (BDNF) reference dataset and the PACFISH/INFISH Biological Opinion Effectiveness Monitoring Program (PIBO). The BDNF data were collected between 1991 and 2002 from approximately two hundred reference sites: seventy of the sites are located in the Greater Yellowstone Area, including the Gallatin River watershed, and the remaining sites are in the BDNF, which is also located in southwestern Montana (Bengeyfield n.d.). The PIBO reference dataset includes USFS and BLM sites throughout the Pacific Northwest, but to increase the comparability of the data to conditions in the West Fork Gallatin River watershed, only data collected within the Middle Rockies ecoregion were evaluated. This includes data from the 57 sites collected between 2001 and 2008.

5.4 Water Quality Targets and Comparison to Existing Conditions

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

In developing targets, natural variation throughout the river continuum must be considered. As discussed in more detail in **Section 3** and **Appendix B**, DEQ uses the reference condition to gage natural variability and assess the effects of pollutants with narrative standards, such as sediment. The preferred approach to establishing the reference condition is utilizing reference site data, but modeling, professional judgment, and literature values may also be used. The DEQ defines "reference" as the condition of a waterbody capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, 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 due to human activity.

The basis for the value for each water quality target varies depending on the availability of reference data. As discussed in **Appendix B**, there are several statistical approaches the DEQ uses for target development; they include using percentiles of reference data or of the entire sample dataset, if reference data are limited. For example, if low values are desired, the sampled streams are assumed to be severely degraded, and there is a high degree of confidence in the reference data, the 75th percentile of the reference dataset or the 25th percentile of the sample dataset (if reference data are not available) is typically used. However, percentiles may be used differently depending on whether a high or low value is desirable, the representativeness and range of variability of the data, the severity of human disturbance to streams within the watershed, and size of the dataset. Additionally, the target value for some parameters may apply to all streams in the West Fork Gallatin River watershed, 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. The MOS is discussed in additional detail in **Section 5.8.2**.

The sediment water quality targets for the West Fork Gallatin River watershed are summarized in **Table 5-3** and described in detail in the sections that follow. For sediment, a combination of measurements of instream siltation, channel form and habitat characteristics that contribute to loading, storage, and transport of sediment or that demonstrate those effects, and biological response to increased sediment are typically used to assess the current condition of a stream. Generally, water quality targets most closely linked to sediment accumulation or sediment-related effects to aquatic life habitat are given the most weight. Values are based on the current best available information but will be assessed during future TMDL reviews for their validity and may be modified if new information provides a better understanding of reference conditions.

Table 5-3. Sediment Targets for the West Fork Gallatin River watershed.

Targets	Parameter Type	Criterion
Percentage of fine surface sediment <6mm in riffles based the reach average of riffle pebble counts	Fine sediment	Comparable with reference values for the appropriate Rosgen stream type based on the BDNF channel morphology dataset (**Table 5-4**)
Percentage of fine surface sediment <2mm based on the reach average of riffle pebble counts		≤ 7% for B3 stream types ≤ 8% for all other stream types
Percentage of fine surface sediment <6mm based on the reach average of grid tosses in riffles and pool tails		≤ 5% for riffles and ≤ 7% for pools
Bankfull width/depth ratio, based on median of the channel cross-section measurements	Channel form and stability	Comparable with reference values for the appropriate Rosgen stream type based on the BDNF channel morphology dataset (**Table 5-5**)
Entrenchment ratio, based on median of the channel cross-section measurements		≥ 1.8 for B stream types ≥ 3.7 for C and E stream types
LWD/mile	Instream habitat	≥ 188 LWD/mile for reaches <2% gradient ≥ 222 LWD/mile for reaches 2-4% gradient ≥ 330 LWD/mile for reaches >4% gradient
Pools/mile		≥ 39 pools/mile for reaches <4% gradient ≥ 72 pools/mile for reaches >4% gradient
Reach average residual pool depth		≥ 1.4ft for reaches <2% gradient ≥ 0.9ft for reaches >2% gradient
Percent of streambank with understory shrub cover, expressed as the average of the greenline measurements	Riparian health	≥ 53% understory shrub cover in reaches with potential for dense shrub cover
Macroinvertebrates	Biological indices	Mountain MMI > 63
		O/E > 0.80
Mean riffle stability index (RSI)	Sediment supply & sources	>40 and <70 for B stream types
		>45 and <75 for C stream types
Anthropogenic sediment sources		No significant sources based on field/aerial surveys

5.4.1 Water Quality Targets

Sediment-related targets for the West Fork Gallatin River watershed are based on a combination of reference data from the BDNF, reference data from the Middle Rockies portion of the PIBO dataset, and sample data from the DEQ 2008 sampling effort. **Appendix G** provides a summary of the DEQ 2008 sample data and a description of associated field protocols. For all water quality targets, future surveys should document stable (if meeting criterion) or improving trends. The exceedence of one or more target values does not definitively equate to a state of impairment; the degree to which one or more targets are exceeded are taken into account (as well as the current 303(d) listing status), and the combination of target analysis, qualitative observations, and sound, scientific professional judgment is crucial when assessing stream condition. Site-specific conditions such as recent wildfires, natural conditions, and flow alterations within a watershed may warrant the selection of unique indicator values that differ slightly from those presented below, or special interpretation of the data relative to the sediment target values.

5.4.1.1 Fine Sediment

The percent of surface fines less than 6 mm and 2 mm is a measurement of the fine sediment on the surface of a streambed and is directly linked to the support of the cold water 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 Bjornn 1984; Shepard et al. 1984; Weaver and Fraley 1991; Suttle et al. 2004). Excess fine sediment can also decrease macroinvertebrate abundance and taxa richness (Mebane 2001; Zweig and Rabeni 2001). Because similar concentrations of sediment can cause different degrees of impairment to different species, and even age classes within a species, and because the particle size defined as “fine” is variable and some assessment methods measure surficial sediment while others measure also include subsurface fine sediment, literature values for harmful fine sediment thresholds are highly variable. Some studies of salmonid and macroinvertebrate survival found an inverse relationship between fine sediment and survival (Suttle et al. 2004) whereas other studies have concluded the most harmful percentage falls within 10 and 40 percent fine sediment (Bjornn and Reiser 1991; Relyea et al. 2000; Mebane 2001). Therefore, literature values are taken into consideration during fine sediment target development, but because increasing concentrations of fine sediment are known to be harmful to aquatic life, targets are developed using a conservative statistical approach consistent with **Appendix B**.

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

Less than 6mm

Surface fine sediment measured in riffles by the modified Wolman (1954) pebble count indicates the particle size distribution across the channel width and is an indicator of aquatic habitat condition that can point to excessive sediment loading.

The target for riffle substrate percent fine sediment <6mm is set at less than or equal to the median of the reference value based on the BDNF reference dataset (**Table 5-4**). The median was chosen instead of the 75th percentile because pebble counts in the BDNF reference dataset were performed using the “zigzag” method, which includes both riffles and pools, and likely results in a higher percentage of fines than a riffle pebble count, which was the method used for TMDL related data collection in the West Fork Gallatin River watershed by DEQ in 2008.

Table 5-4. BDNF Reference Dataset Median Percent Fine Sediment <6mm.

Parameter	**B3**	**B4**	**B**	**C3**	**C4**	**C**	**E3**	**E4**	**Ea**	**E**
Sample Size (n)	26	14	40	11	19	30	12	64	23	115
% Surface Fines < 6mm	7	18	9	8	22	17	17	30	28	30

Less than 2mm

No regional reference data is available for fine sediment <2mm so the target is based on the entire 2008 West Fork dataset (Appendix G). In a cursory review of <6mm fine sediment data from the West Fork watershed, the 75th percentile of the sample dataset compares favorably to the median of the BDNF reference dataset. This indicates fine sediment levels are generally very low within the West Fork watershed and that the 75th percentile of the sample data for fine sediment <2mm may be a reasonable target. The percentiles of the sample dataset are as follows: 25th = 3%, median = 5%, and 75th = 8%. Because of the comparison of the sample data relative to reference values and that the 25th percentile and median of fine sediment <2mm are well below literature values, the target for fine sediment <2mm is based on the 75th percentile of the sample dataset, unless the <6mm target is less. Therefore, the riffle pebble count target for fine sediment <2mm is equal to or less than 7% for B3 stream types and 8% for all other stream types. The target should be compared to the reach average value from pebble counts. Using this approach to target development acknowledges that fine sediment throughout assessed portions of the West Fork watershed are predominantly close to reference values, and that areas beyond the target value represent outlier conditions where excess fine sediment deposition may indicate a water quality problem.

Percent Fine Sediment <6mm in Riffle and Pool Tails via Grid Toss
Grid toss measurements in riffles and pool tails are an alternative measure to pebble counts that assess the level of fine sediment accumulation in macroinvertebrate habitat and potential fish spawning sites. A 49-point grid toss (Kramer et al. 1991) was used to estimate the percent surface fine sediment <6mm in riffles and pool tails in the West Fork watershed. The PIBO reference data for the Middle Rockies ecoregion only contains grid toss measurements for pool tails. The 75th percentile of the reference data for pool tails is 12% and the median is 6%. Because the 75th percentile of pebble count fine sediment values from the sample dataset were comparable to BDNF reference values, the 75th percentile of grid toss measurements from the sample dataset was evaluated. Of the West Fork watershed grid toss measurements, the 75th percentile is 5% for riffles and 7% for pools. Thus, the 75th percentile of the West Fork dataset is more protective of aquatic life than the 75th percentile of PIBO reference data (for pool tails) and will be used as the basis for the grid toss targets. Therefore, the grid toss target for fine sediment <6mm is ≤ 5% for riffles and ≤ 7% for pool tails. These grid toss targets are similar to the median of PIBO pool tail data from both the Middle Rockies ecoregion (n=57) and the Gallatin National Forest (n=11) (i.e. 6%). For each habitat area, the target should be assessed based on the reach average grid toss value.

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 and each provides a measure of channel stability, as well as an indication of the ability of a stream to transport and naturally sort sediment into a heterogeneous composition of fish habitat features (i.e. riffles, pools, and near bank zones). Although they are not direct measurements of instream sediment, as indicators of channel stability, they integrate alterations to streamflow and sediment supply at the reach and watershed scale and influence habitat availability. Factors that can alter channel morphology include stream channelization, dams, clearcutting, riparian vegetation removal, and over-grazing in the riparian zone.

Width/depth and entrenchment ratios are variable, but minimally disturbed streams in similar landscape settings tend to exhibit similar characteristics. Therefore, if a channel has a width/depth ratio greater than the expected range, this suggests channel overwidening and aggradation, which is frequently linked to excess sediment loading from bank erosion or other acute or chronic upstream sources, excess levels of fine and/or coarse sediment within the channel, and a reduction in habitat for fish and other aquatic life. Whereas channel overwidening is typically associated with aggradation, channel entrenchment, or incision, is typically related to channel downcutting and degradation. Streams are often incised due to detrimental land management or may be naturally incised due to landscape characteristics. As a channel becomes incised (i.e. the entrenchment ratio decreases), the stream loses its ability to dissipate energy onto the floodplain during high flow and that energy becomes concentrated within the channel, resulting in increased sediment loading to the channel from bank erosion. If the stream is not actively downcutting, the sources of human caused incisement are historic in nature and may not currently be present; however, because of the altered channel form, increased bank erosion may be continuing and limiting aquatic life habitat. To summarize, accelerated bank erosion, an increased sediment supply, and a reduction in aquatic life habitat 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). Therefore, due to the long-lasting impacts of changes to channel morphology and the large potential for sediment loading in altered channels, width/depth ratio and entrenchment ratio are important measures of channel condition as it relates to sediment loading and habitat condition.

The target values for width/depth ratio and entrenchment ratio are based on the BDNF reference dataset, which is stratified by Rosgen channel type. Bankfull widths within the BDNF dataset have a similar range to those in the sample dataset. Therefore, the width/depth ratio target for the Upper Gallatin TPA is set at less than or equal to the 75th percentile of the reference value (**Table 5-5**). As shown in **Table 5-5**, the 75th percentile of the entrenchment ratios for some of the C and E stream types are much greater than the Rosgen delineative criteria (i.e. B = 1.4-2.2, C & E >2.2) (Rosgen 1996), and additional stability (or reductions in sediment loading) will not necessarily be gained by increasing the entrenchment ratio in a channel adequately accessing its floodplain. Therefore, the target for entrenchment ratio is set at the lowest BDNF reference value per entrenchment category, which are **bolded** in **Table 5-5**: (moderately entrenched) B ≥ 1.8 and (slightly entrenched) C/E ≥ 3.7. When comparing assessment results to target values, more weight will be given to those values that fail to satisfy both the identified target and fail to meet the minimum value associated with literature values for Rosgen stream type (i.e. B > 1.4 and C/E > 2.2). Overall, the 75th percentile of BDNF reference is comparable to the median of the sample dataset, indicating a slight shift in channel morphology. During sampling in 2008, the width/depth ratio and entrenchment ratio were calculated for five riffle cross sections within each sample reach; the target value applies to the median values for each sample reach.

Table 5-5. BDNF Reference Dataset 75th Percentiles of Channel Morphology Measures.

Parameter	**B3**	**B4**	**B**	**C3**	**C4**	**C**	**E3**	**E4**	**Ea**	**E**
Sample Size (n)	26	14	40	11	19	30	12	64	23	115
Width/Depth Ratio	15	17	16	31	20	23	10	7	7	7
Entrenchment Ratio	1.8	1.9	**1.8**	5.1	14.1	10.1	14	15.9	8.7	**3.7**

5.4.2.1 Instream Habitat Measures

Reach type characteristics like gradient and bankfull width can be used to group streams that respond similarly to flow and sediment inputs (Bauer and Ralph 1999). These two characteristics were used to stratify the PIBO reference data and subsequently develop target values for instream habitat measures discussed in this section. Although streams in the West Fork dataset are typically larger than those in the PIBO dataset (i.e. 75th percentile of bankfull widths = 40 ft in the West Fork dataset vs. 27 ft in the PIBO dataset), both datasets contain streams with a similar range of bankfull widths (i.e. W Fork dataset range = 7 – 51 ft vs. 6 – 56 ft for the PIBO streams). The PIBO dataset is also similar to the sample dataset in that it has data from streams at a variety of gradients but primarily contains reaches with a gradient of less than 2% (because that is where sediment effects tend to be most prominent). The gradient classes of the West Fork dataset (i.e. <2%, 2-4%, >4%) were evaluated relative to the median bankfull width of the sample reaches and each gradient grouping tended to contain reaches with similar bankfull widths. Although there is some overlap between gradient groupings in the reference dataset and the 2008 West Fork dataset, bankfull width decreases as gradient increases. This indicates that gradient is a sufficient parameter by which to group reaches expected to function similarly for the development of instream habitat supplemental indicators.

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 over the long-term, and its frequency tends to be greater in smaller streams (Bauer and Ralph 1999).

Historic riparian harvest was noted at the majority of sampling reaches within the West Fork watershed. Due to development in certain areas, it is acknowledged that some reaches may not have the potential to meet the LWD target, but because LWD recruitment is from near-channel and upstream sources, and overall there is room for improvement to woody riparian vegetation, the LWD frequency target is based on the 25th percentile of PIBO reference data for the Middle Rockies. The 25th percentile values per reach gradient category are as follows: <2% = 188 (n=38), 2-4% = 222 (n=13), and >4% = 330 (n=6). Target criteria for large woody debris frequency is established at greater than or equal to the 25th percentile of the PIBO reference data for each gradient category. Large woody debris per mile should be calculated based the LWD number per reach and then scaled up to give a frequency per mile.

Residual Pool Depth

Residual pool depth, defined as the difference between the maximum depth and the tail crest depth, is a discharge-independent measure of pool depth and an indicator of the quality of pool habitat. Deep pools are important resting and hiding habitat for fish, and provide refugia during temperature extremes and high flow periods. Similar to channel morphology measurements, residual pool depth integrates the effects of several stressors; pool depth can be decreased as a result of filling with excess sediment, 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.

Because the bankfull width for the majority of assessed streams within the West Fork watershed is larger than that within the reference dataset, and habitat formation is also a function of stream size, streams within the West Fork watershed are expected to have deeper pools than the 25th percentile of the reference dataset. Therefore, the residual pool depth target is based on the median of the PIBO reference dataset. For reaches with a gradient of less than 2 percent, the median is 1.4 feet (n=38), and for both reaches with a gradient between 2 and 4 percent and those greater than 4 percent, the median is 0.9 feet (n=19). Therefore, the target for average residual pool depth is greater than or equal to 1.4 feet for reaches less than 2 percent and 0.9 feet for reaches greater than 2 percent. The target should be assessed based on the reach average residual pool depth value. Because residual pool depths can indicate if excess sediment is limiting pool habitat, this parameter will be particularly valuable for future trend analysis using the data collected in 2008 as a baseline. Future monitoring should document an improving trend (i.e. deeper pools) at sites which fail to meet the target criteria, while a stable trend should be documented at established monitoring sites that are currently meeting the target criteria.

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.

Because the bankfull width for the majority of assessed streams within the West Fork watershed is larger than that within the reference dataset, and habitat formation is also a function of stream size, lower gradient reaches in particular would be expected to have a pool frequency on the lower end of the PIBO reference data. However, reaches with a slope greater than 4% were more similar in bankfull width to the reference data and would be expected to have a similar potential to reference. Therefore, the pool frequency target for reaches with a slope <4% is based on the 25th percentile of PIBO reference and the target for reaches >4% is based on the median of the reference data. The pool frequency targets per mile are as follows: equal to or greater than 39 pools for reaches <4% and 72 pools for reaches >4%. Pools per mile should be calculated based the number of measured pools per reach and then scaled up to give a frequency per mile.

5.4.2.2 Riparian Health

Because greenline understory shrub cover is less sensitive to specific reach type characteristics than instream measurements, target values are not expressed per gradient class.

Greenline Understory Shrub Cover
Interactions between the stream channel and the riparian vegetation along the streambanks are a vital component in the support of the beneficial uses of cold water fish and aquatic life. Riparian vegetation provides organic material used as food by 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. The percent of understory shrub cover is of particular interest in valley bottom streams historically dominated by willows and other riparian shrubs.

During 2008 West Fork watershed sampling, understory vegetation was assessed along both streambanks (i.e. the greenline) of each sampling reach. 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. During sampling in 2008, six monitoring reaches were identified where dense understory shrub cover would be expected for them to meet their potential. The reaches were located on the Middle Fork of the West Fork, Beehive Creek (a tributary to the Middle Fork), and the West Fork (MFWF02-01-1, MFWF09-02, BEEH12-01, WFGR01-02, WFGR01-04 and WFGR02-01). Based on values within the assessment cells for each of the six reaches (there were typically 5 cells/reach), there was a median value of 53% and a 75th percentile of 60% understory shrub cover. Median values for understory shrub cover from reference reaches in the Upper Big Hole watershed ranged from 41 to 58 percent (DEQ 2008) and median values per reach in the West Fork Gallatin ranged from 25 to 63 percent. Based on the range of reach median values from the West Fork watershed, the potential for improvement observed during the field assessments, and the range of reference values from the Upper Big Hole, the target value for understory shrub cover is based on the median of the West Fork sample data. Therefore, the target for understory shrub cover is equal to or greater than 53%. This target should be assessed based on the reach average greenline understory shrub cover value and only applies to reaches with potential for a dense shrub understory (i.e. typically meadow reaches).

5.4.2.3 Biological Indices

Macroinvertebrates

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

The 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 within this document were collected according to DEQ protocols (DEQ 2006).

The MMI is organized based on different bioregions within Montana (e.g. Mountain, Low Valley, and Plains), and the West Fork Gallatin River watershed falls exclusively within the Mountain MMI region, for which the impairment threshold is an MMI score <63. This value is established as a sediment target in West Fork watershed. The O/E model compares the taxa that are expected at a site under a variety of environmental conditions with the actual taxa that were found when the site was sampled and is expressed as a ratio of the Observed/Expected taxa (O/E value). The O/E impairment threshold for all Montana streams is any O/E value <0.8. Therefore, an O/E score of >0.80 is established as a sediment target in the West Fork watershed. For both metrics, an index score greater than the threshold value is desirable, and the result of each sampling event is evaluated separately. Index values may be affected by other pollutants or forms of pollution such as habitat disturbance; therefore, macroinvertebrate scores will be evaluated in consideration of more direct indicators of excess sediment.

5.4.2.4 Sediment Supply and Sources

Riffle Stability Index
The Riffle Stability Index (RSI) provides an estimate of sediment supply in a watershed. RSI target values are established based on values calculated by Kappesser (2002), who found that RSI values between 40 and 70 in B-channels indicate that a stream's sediment transport capacity is in dynamic equilibrium with its sediment supply. Values between 70 and 85 indicate that sediment supplies are moderately high, while values greater than 85 are suggestive of excessively sediment loaded streams. The scoring concept applies to any streams with riffles and depositional bars. Additional research on RSI values in C stream 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 West Fork watershed, an RSI target value of >40 and <70 is established for B stream types, while a value of >45 and <75 is established for C stream types. The target should be compared to the mean of measurements within a sample reach.

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 identified anthropogenic sources of sediment within the watershed of a 303(d) listed steam, no TMDL will be prepared since 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 obtained using aerial imagery and GIS data layers. Source assessment analysis will be provided by 303(d) listed waterbody in **Section 5.6**, with additional information in **Appendices D**, **E** and **F**.

5.4.2 Existing Condition and Comparison to Water Quality Targets

This section includes a comparison of existing data to water quality targets and a TMDL development determination for each 303(d) listed waterbody.

5.4.2.1 Middle Fork West Fork Gallatin River

The Middle Fork West Fork Gallatin River (MT41H005_050) was listed for solids (suspended/bedload) on the 2008 303(d) List. The Middle Fork West Fork Gallatin River (a.k.a.

Middle Fork) extends 6.0 miles from its headwaters on Lone Mountain to the confluence with the North Fork West Fork Gallatin River, where they form the West Fork Gallatin River.

The Middle Fork was originally listed in 1990 because of sediment loading associated with roads lacking best management practices, residential/resort development, and extensive riparian harvest. Containing the community of Big Sky and a ski resort, the Middle Fork watershed is the most developed portion of the West Fork watershed and residential/resort development continues to be the primary land use.

Physical Condition and Sediment Sources

The sediment and habitat assessment was performed at six monitoring sites on the Middle Fork in 2008, with two monitoring sites located upstream of Lake Levinsky and the remaining four sites located downstream of Lake Levinsky (**Appendix A**, **Figure 5-3**). Both sites upstream of the lake appeared to be recovering from historical riparian timber harvest and the limited bank erosion observed was attributed to natural sources. Likely as a result of the timber harvest and a lack of slash removal, woody debris was extensive within the channel and floodplain, and was the primary formative feature of pools at the uppermost monitoring site (MFWF02-01-2). Another factor likely related to riparian vegetation removal is that the substrate was embedded in places and fine sediment accumulations were observed in pool tail-outs. Progressing downstream (MFWF02-01-1), historic channel disturbances were observed where the stream partially flows through and partially flows around a small man-made impoundment. The Middle Fork and two other tributaries draining Lone Mountain then flow into Lake Levinsky.

Downstream of Lake Levinsky, the Middle Fork is a larger stream and flows through a narrow valley that was logged historically but has very limited bank erosion (MFWF04-01). Although the accumulation of fine sediment was only noted upstream of Lake Levinsky, embedded substrate was observed at this reach and another reach downstream of the lake (MFWF09-01). The next monitoring site (MFWF08-01) was also located in an area where riparian timber harvest along the channel margin occurred historically, as well as resort area development. In addition, the dirt road/trail along the southern valley wall was observed to be a sediment source with deep gullies leading to the valley bottom, though sediment transport all the way to the channel was not observed. The most notable streambank erosion sediment source was observed in reach MFWF09-01 where the stream flows into the valley wall downstream of a crossing that is part of the cross-country ski trail system. This streambank erosion sediment source is leading to localized channel aggradation and over-widening. Additional sediment loading is also likely associated with a failing silt fence that was also observed in this reach. Downstream of this reach, the stream flows into a meadow before joining the North Fork West Fork Gallatin River. Human impacts along the lowest reach (MFWF09-02) were minimal beyond beaver dam removal and upstream watershed management.

In addition to these six monitoring sites, streambank erosion data was collected at two additional sites along the Middle Fork, as well at five sites on the tributaries of Beehive Creek and Stone Creek. At the Middle Fork sites, minor streambank erosion was observed and primarily attributed to riparian timber harvest with some influence from resort development. In Beehive Creek, extensive streambank erosion was observed and active sediment loading was observed during spring runoff in June of 2008. One of the reaches along Beehive Creek appeared to be an old lake bed, and that combined with its sedimentary geology likely contribute to higher background erosion rate. However, streambank erosion and channel downcutting along this reach of Beehive Creek may have been accelerated by a mis-aligned culvert downstream of the reach, which is near the Beehive Basin Trailhead. At the three sites on Stone Creek, one site had bank erosion associated with roads and historic logging, and bank erosion at the other sites appeared to be related to natural sources.

Existing Data and Comparison to Water Quality Targets

The existing sediment, habitat, and biological data in comparison to the targets for the Middle Fork West Fork Gallatin River are summarized in **Tables 5-6** and **5-7**. Macroinvertebrate samples were collected six times on the Middle Fork West Fork Gallatin River between 1991 and 2005; all samples were collected downstream of Lake Levinsky.

Table 5-6. Middle Fork West Fork Gallatin River Data Compared to Targets.

Monitoring Site	Potential Rosgen Stream Type/Reach Gradient	Channel Form (median)		Fine Sediment:(mean)				Instream Habitat			Riparian Health
				Riffle Pebble Count		Grid Toss %<6mm		Residual Pool Depth (mean)	Frequency (#/mile)		
		W/D Ratio	Entrenchment Ratio	% <6mm	% <2mm	Riffle	Pool Tail		Pools	LWD	% Greenline Shrubs (mean)
MFWF02-01-2*	E4a >4%	**8.1**	7.8	11	**10**	**15**	**13**	**0.5**	296	1045	N/A
MFWF02-01-1*	E4b >4%	**13.9**	4.0	13	8	5	**12**	**0.8**	132	**290**	53
MFWF04-01	B4 >4%	16.6	3.9	10	6	4	4	1.1	79	528	N/A
MFWF08-01	B3 2-4%	12.7	3.4	7	3	3	3	1.4	**32**	787	N/A
MFWF09-01	C3b 2-4%	17.3	4.4	7	4	2	1	1.3	**21**	**180**	N/A
MFWF09-02	C4 2-4%	20.4	6.7	11	5	4	4	1.9	48	**79**	59

Bold indicates target value was not met. *Indicates a site upstream of Lake Levinsky.

Table 5-7. Macroinvertebrate Metrics for Middle Fork West Fork Gallatin River.

Station ID	Site Location	Collection Date	MMI	O/E
BKK081	0.75 mi downstream of Lake Levinsky	7/30/1991	**53**	**0.65**
GLTNR02	Near confluence with N Fork W Fork	9/21/2002	72	0.92
GLTNR02		6/26/2003	67	**0.61**
GLTNR02		9/24/2003	74	1.13
GLTNR02		7/20/2004	69	1.13
MFWF01	0.1 mi d/s of Lake Levinsky	9/15/2005	**43**	1.13

Bold indicates target value was not met (MMI > 63; O/E > 0.80).

The two sites upstream of Lake Levinsky had width/depth ratios that exceeded the target criteria, and the most downstream site was borderline but likely associated with historical beaver activity. Entrenchment ratios were within expectations given the potential Rosgen stream type. Fine sediment percentages were generally low but at sites upstream of Lake Levinsky, fine sediment exceeded <2mm pebble count and riffle/pool tail grid toss targets at one site and the pool tail grid toss target at another site. Based on the channel and fine sediment data, it appears that channel overwidening has occurred upstream of Lake Levinsky and may be contributing excess sediment to the channel that is being retained within and upstream of the lake.

Both sites upstream of the lake also failed to meet the residual pool depth target values. One site upstream of Lake Levinsky had less LWD than the target value, and pool frequency and LWD frequency each failed to meet target criteria at two sites between Beehive Creek and the mouth. Although the two sites expected to have extensive riparian shrubs were meeting the target criteria of ≥ 53%, actively eroding streambanks associated with human sources were observed at three out of eight sites, indicating that streambank erosion is a source of sediment along portions of the Middle Fork West Fork Gallatin River. The RSI was only evaluated within one reach (MFWF09-02), and with a value of 88, it exceeded the target criteria of for C4 stream types (>45 and <75). However, an eroding streambank upstream of the gravel bar where the sample was collected suggests this is a localized situation.

Because the biological indices assess different aspects of the macroinvertebrate community, the values must be considered together. The MMI target value was not met in two of the samples and the O/E target value was not met in two of the samples, but the indices were only in agreement regarding impairment for one sample. This indicates impairment at the site downstream of Lake Levinsky but no consistent trend within the Middle Fork. A closer examination of the community composition (i.e. taxa that tend to burrow in the substrate) at the site near Lake Levinsky and other sites indicated that sediment is likely not the factor altering the aquatic insect communities in the collected samples.

Summary and TMDL Development Information

Excess fine sediment in riffles and pool tails and low residual pool depths upstream of Lake Levinsky indicate an increased sediment supply and probable effects to aquatic life. No macroinvertebrate samples were collected upstream of the lake, and although the biological indices suggest some impairment of the macroinvertebrate community downstream of the lake, the community composition indicates it is not related to excess sediment, which is consistent with the observation of no excess sediment accumulation was observed in riffles or pools downstream of Lake Levinsky. Based on recent data, the primary issue downstream of Lake Levinsky is associated with habitat alterations that have resulted in decreased pool and LWD frequency and are likely diminishing the Middle Fork’s ability to fully support the aquatic life and fishes beneficial uses. The primary anthropogenic sources are roads, resort development, recreation, and historic riparian vegetation removal. This information supports the 303(d) listing, particularly for the upper portion of the watershed, and a TMDL for sediment will be developed for the Middle Fork West Fork Gallatin River.

5.4.2.2. South Fork West Fork Gallatin River

The South Fork West Fork Gallatin River (MT41H005_060) was listed for sedimentation/siltation on the 2008 303(d) List. The South Fork West Fork Gallatin River (a.k.a. South Fork) extends 13.8 miles from its headwaters to its mouth at the West Fork Gallatin River.

The South Fork was originally listed in 1990 based on elevated bank erosion and turbidity, as well as siltation and substrate embeddedness, particularly near the mouth, and sources were identified as historical timber harvest, improperly maintained roads, and resort development. Large-scale land development, primarily in the upper portion of the watershed, continues to be a major land use.

Physical Condition and Sediment Sources

Sediment and habitat assessments were performed at three monitoring sites on the South Fork in 2008 (**Appendix A**, **Figure 5-4**). The uppermost site (SFWF22-01) was located upstream of Ousel Falls in an area with extensive large woody debris aggregates at meander bends. There was one long vertical eroding streambank that was largely attributed to historic logging but most bank erosion in the reach was attributed to natural sources. Progressing downstream, site SFWF28-01 was located in a naturally confined area. The majority of this reach was a continuous riffle, and although the river was cutting into a terrace in one location and a hillslope at another, bank erosion appeared almost entirely natural. Within the lowermost site (SFWF29-02), the river flowed into the hillslope at several places. The hillslopes are comprised of shale made up of clay, which partially resembles bedrock but is relatively soft and erodible. Fifteen exposed hillslopes were identified along the South Fork during a review of aerial imagery, extending from upstream of Ousel Falls down to the confluence with the West Fork Gallatin River. These hillslopes appear to be natural sources of sediment and likely contribute fine sediment loads during rain events, along with being a source of streambank erosion sediment load during high water events. Substrate size within all monitoring reaches was large and likely limits fish spawning potential.

In addition to the three monitoring sites, streambank erosion was assessed at two additional sites along the South Fork and two sites on the tributaries of Muddy Creek and First Yellow Mule Creek. Minimal bank erosion was observed on the South Fork upstream of the confluence with Muddy Creek (SFWF17-02) and was attributed to natural sources. A streambank erosion restoration project on the South Fork at the confluence with Muddy Creek was observed to be failing. Downstream of the confluence with Muddy Creek (SFWF18-01), minor bank erosion was observed and predominantly related to historic logging, though much of the monitoring site lacked defined streambanks due to channel aggradation. Excess bedload was noted in Muddy Creek and appeared to be the source of aggradation within the South Fork, but the cause of the excess bedload was unclear. Streambank erosion on Muddy Creek was observed at several sites in association with transportation infrastructure, including one failing bridge just upstream of the confluence with the South Fork West Fork Gallatin River. Streambank erosion observed on First Yellow Mule Creek was attributed to historic logging and natural sources.

Existing Data and Comparison to Water Quality Targets

The existing sediment, habitat, and biological data in comparison to the targets for the South Fork West Fork Gallatin River are summarized in **Tables 5-8** and **5-9**. Eleven macroinvertebrate samples were collected on the South Fork West Fork Gallatin River between 1995 and 2005. The macroinvertebrate sites near the mouth have relatively large cobble substrate, a factor that can limit the number of insects collected since samples were collected by the “kick” method, which involves shuffling within riffles to collect macroinvertebrates (DEQ 2006). However, only two of the samples from the whole dataset (both from June 2003) were well below the desired sample size (i.e. 300 insects), indicating that most of the samples are a good representation of the macroinvertebrate community.

Table 5-8. South Fork West Fork Gallatin River Data Compared to Targets.

Monitoring Site	Potential Rosgen Stream Type/Reach Gradient	Channel Form (median)		Fine Sediment: (mean)				Instream Habitat			Riparian Health
				Riffle Pebble Count		Grid Toss %<6			Frequency (#/mile)		
		W/D Ratio	Entrenchment Ratio	% <6mm	% <2mm	Riffle	Pool Tail	Residual Pool Depth (mean)	Pools	LWD	% Greenline Shrubs (mean)
SFWF22-01	C4 <2%	21.2	7.6	12	8	2	2	2.1	58	560	N/A
SFWF28-01	B3 2-4%	26.1	2.3	4	3	4	1	1.1	21	143	N/A
SFWF29-02	C3 <2%	39.5	3.4	7	4	2	3	2.0	21	190	N/A

Bold indicates target value was not met

Table 5-9. Macroinvertebrate Metrics for South Fork West Fork Gallatin River.

Station ID	Sampling Location	Collection Date	MMI	O/E
BKK155	S Fork downstream of 2nd Yellow Mule Cr	8/22/1995	77	0.87
BKK140	Near mouth at W Fork	8/22/1995	72	1.06
BKK140		9/10/1996	**62**	0.82
BKK156	S Fork downstream of 1st Yellow Mule Cr	9/10/1996	81	**0.73**
GLTNR34	2.5 mi upstream from mouth at W Fork	9/21/2002	83	1.14
GLTNR34		6/26/2003	66*	0.88*
GLTNR34		9/24/2003	74	1.01
GLTNR34		7/20/2004	**61**	1.01
GLTNR04	Near mouth at W Fork	9/21/2002	**44**	**0.72**
GLTNR04		6/26/2003	**62***	**0.64***
GLTNR04		9/24/2003	66	0.88
GLTNR04		7/20/2004	47	0.64
SFWF01	S Fork downstream of 1st Yellow Mule Cr	9/15/2005	67	1.23

Bold indicates target value was not met (MMI > 63; O/E > 0.80). *Indicates low sample size.

Width/depth ratios exceeded target criteria at all three monitoring sites and may indicate aggradation due to excess bedload sediment transport, however, the South Fork is a high energy system and elevated width/depth ratios may be natural. All reaches met the target for residual pool depth, indicating the large substrate is not aggrading within the pools. However, the pool frequency target was not met at two sites and the LWD frequency was below the target value at the site which was predominantly a riffle (SFWF 18-01). Actively eroding banks at three of the five South Fork sites assessed for streambank erosion had an anthropogenic component. Since the South Fork flows through a valley dominated by coniferous vegetation, dense understory shrub cover is not expected and no target was applied for greenline shrub cover. Two RSI measurements were taken (SFWF 28-01 and 29-02) and both met the target criteria.

Because the biological indices assess different aspects of the macroinvertebrate community, they must be considered together. The MMI target was not met in 5 samples and the O/E target was not met in 4 of the 13 samples. However, the indices were only in agreement regarding impairment in three samples near the mouth, indicating possible impairment near the mouth but no consistent trend within the South Fork. A closer examination of the community composition (i.e. taxa that tend to burrow in the substrate) indicated that sediment is likely not altering the aquatic insect communities in the collected samples.

Summary and TMDL Development Information

Despite heavy siltation and substrate embeddedness when the South Fork was put on the 303(d) List, recent field observations documented little fine sediment accumulation. This suggests that changes in land management practices have resulted in a flushing of fine sediment from the system; low pool and LWD frequency are likely a legacy of the historic habitat alterations along the South Fork. The biological data do indicate impairment, but based on a review of the burrowing component of the macroinvertebrate community and no evidence of fine sediment accumulation, the data do not necessarily indicate sediment is limiting aquatic life.

However, sediment and traction sand from roads as well as upland sediment from ski and residential areas are all sediment sources to the South Fork and its tributaries where loading could be reduced, and conditions observed in 2008 may not be entirely representative of sediment effects to instream habitat within the South Fork. Although the assessment sites are spatially diverse, they were all visited in 2008, which was a notable high flow year with minimal late season or summer rain events. Therefore, particularly during drought years or those with significant post-runoff rain events, it is possible that erosion related to land management practices could lead to elevated fine sediment deposition and affect fish and aquatic life. Because the South Fork is currently listed for sediment impairment, significant controllable sediment sources were identified, and there is a high potential for significant sediment loading from future growth, a TMDL for sediment will be written for the South Fork of the West Fork Gallatin River.

5.4.2.3 West Fork Gallatin River

The West Fork Gallatin River (MT41H005-040) was listed for sedimentation/siltation on the 2008 303(d) List. The West Fork Gallatin River (a.k.a. West Fork) flows 3.7 miles from the confluence of the Middle Fork and the North Fork to its mouth at the Gallatin River.

The West Fork was originally listed in 1990 because of sediment inputs associated with roads and recreational trails throughout the watershed, logging along the South Fork, and residential/resort development in the Middle and South Forks. As mentioned in the data review for the Middle and South Forks, large-scale land development for residential and recreational purposes continues to be the primary land use within the watershed. Land use along the West Fork itself is primarily residential and a golf course associated with Big Sky Meadow Village.

Physical Condition and Sediment Sources

Sediment and habitat assessments were performed at four monitoring sites along the West Fork in 2008 (**Appendix A**, **Figure 5-5**). The uppermost site (WFGR01-02) is located upstream of the golf course and is a single channel that formerly contained multiple channels and beaver complexes. Beaver complexes tend to act as sediment sinks (which trap erodible fine sediment) and active bank erosion in the reach was attributed to the removal of beavers. Some localized channel over-widening and bank erosion was observed and likely the result of a bridge upstream of the reach. The next downstream reach (WFGR01-04) is channelized and flows through the golf course. The reach was largely a continuous riffle; fine sediment was observed in riffles and the substrate was noted as embedded. The golf course encroaches within five feet of the channel in places and is regularly within ten feet of the channel. A narrow band of willows was found along most of this reach, and there was some wetland vegetation along the channel margin. The relatively straight channel is somewhat entrenched through much of this reach, though bank erosion was minimal due to the band of riparian vegetation, lack of sinuosity, and large substrate. In addition, there is an in-stream impoundment mid-way through the golf course, as well as one at the downstream end, which likely influence sediment storage and transport through this reach. Downstream of the golf course (WFGR02-01), the stream flows along the waste water treatment plant holding ponds and through a willow-dominated meadow that was likely a large beaver complex at one time. Bank erosion was occurring on both sides of the channel along a remnant beaver pond at the upper end of the reach, causing localized over-widening. The lowermost site on the West Fork (WFGR03-03) was located downstream of the confluence with the South Fork. This site was one continuous riffle and streambank erosion was limited due to a substantial portion of the banks containing large cobbles.

In addition to the four monitoring sites, streambank erosion was assessed at three additional sites. Two of the sites had actively eroding streambanks attributed to human sources (WFGR01-03 and WFGR01-05). Erosion sources included residential development, roads, the golf course, and removal of beaver damns.

Existing Data and Comparison to Water Quality Targets

The existing sediment, habitat, and biological data in comparison to the targets for the West Fork Gallatin River are summarized in **Tables 5-10** and **5-11**. Reaches with a particle size potential of “3/4” are dominated by cobble substrate, which is a key factor in channel form, but are expected to have a higher percentage of fine sediment than C3 channels (in this case because of their suitability as beaver habitat). Therefore, those reaches will be evaluated against the C3 target for width/depth ratio and the C target for percent fines <6mm.

Twelve macroinvertebrate samples were collected on the West Fork Gallatin River between 1995 and 2008. The majority of the samples were collected near Big Sky Meadow Village and the mouth, both areas with relatively large cobble substrate. Large substrate could influence the results because samples are collected by the “kick” method, which involves shuffling within riffles to collect macroinvertebrates (DEQ 2006). However, only two of the samples (both downstream of Meadow Village) were well below the desired sample size (i.e. 300 insects), indicating that the other samples are a good representation of the macroinvertebrate community.

Table 5-10. West Fork Gallatin River Data Compared to Targets

Monitoring Site	Potential Rosgen Stream Type/Reach Gradient	Channel Form (median)		Fine Sediment: (mean)				Instream Habitat			Riparian Health
		W/D Ratio	Entrenchment Ratio	Riffle Pebble Count		Grid Toss %<6		Residual Pool Depth (mean)	Frequency (#/mile)		% Greenline Shrubs (mean)
				% <6mm	% <2mm	Riffle	Pool Tail		Pools	LWD	
WFGR01-02	C3/4b 2-4%	26.8	7.2	9	6	3	0	1.4	**21**	**69**	**48**
WFGR01-04	C3/4 2-4%	25.2	3.7	13	12	**6**	no pools	no pools	**0**	0	62
WFGR02-01	C3/4 <2%	25.7	5.6	11	7	2	2	1.4	**37**	58	**51**
WFGR03-03	B3c <2%	**22.5**	**1.6**	**9**	**9**	2	3	1.2	**5**	58	N/A

Bold indicates target value was not met.

Table 5-11. Macroinvertebrate Metrics for West Fork Gallatin River.

Station ID	Sampling Location	Collection Date	MMI	O/E
BKK079	1 mi downstream of N Fork & M Fork	8/22/1995	68	0.81
WFGR01	0.4 mi downstream of N Fork & M Fork	9/15/2005	73	1.06
BKK157	Downstream of Meadow Village & upstream of S Fork	8/22/1995	70	1.14
BKK157		9/10/1996	74	0.82
GLTNR10		9/21/2002	**48**	**0.64**
GLTNR10		6/26/2003	**63***	**0.72***
GLTNR10		7/20/2004	**47***	0.88*
GLTNR36	Near mouth of W Fork	8/2/2000	**52**	0.99
GLTNR36		7/14/2001	**48**	1.28
GLTNR36		7/8/2005	**50**	0.99
GLTNR36		9/12/2008	**47**	0.85
WFGR03		9/14/2005	**50**	**0.79**

Bold indicates target value was not met (MMI > 63; O/E > 0.80). *Indicates low sample size.

The lowermost monitoring site exceeded the width/depth ratio target but entrenchment ratios were within expectations at all of the assessed sites. Riffle pebble count percent fine sediment slightly exceeded target values at the lowermost site. Site WFGR01-04, which flows through the golf course, had the highest percentage of riffle fine sediment and failed to meet the grid toss target for riffles. All pool tails had low percentages of fine sediment and met the target. Residual pool depths met target criteria at all sites with pools. All sites failed to meet the target for both pool and LWD frequency, and site WFGR01-04 had no pools or LWD. Actively eroding banks at five of the seven sites assessed for streambank erosion had an anthropogenic component. Also, two of the three sites expected to have a dense shrub understory failed to meet the 53% target value. Because of a lack of point bars, no RSI measurements were collected.

Because the biological indices assess different aspects of the macroinvertebrate community, they must be considered together. The MMI target was not met in 8 samples and the O/E target criteria was not met in 3 out of the 12 samples, which all corresponded to sampling events with low MMI values. Therefore, the macroinvertebrates indicate impairment upstream and downstream of the confluence with the South Fork. However, a closer examination of the community composition (i.e. taxa that tend to burrow in the substrate) indicated that sediment is likely not altering the aquatic insect communities in the collected samples.

Summary and TMDL Development Information

Overall, channel morphology is within the expected range. There is some accumulation of excess fine sediment near the golf course, which is likely associated with the historic removal of beavers and the in-channel impoundments, and there is also some accumulation of fine sediment near the mouth. Given current land use within the reach, restoration of beaver complexes is probably not feasible, and some excess fine sediment is expected as the system finds a new equilibrium. The predominant issues along the West Fork are associated with habitat alterations that have reduced pool quantity and quality and also reduced LWD quantity. Habitat alterations are most pronounced in the channelized section of stream that flows through the golf course. The biological data do indicate impairment, but based on a review of the burrowing component of the macroinvertebrate community, the data do not necessarily indicate sediment is limiting aquatic life. Sediment sources are streambank and upland loading associated with removal of beaver dams and residential/resort development, as well as roads and sources along the Middle, South, and North Forks. Based on the listing status, significant controllable sediment sources, and a high potential for significant sediment loading from future growth, a TMDL for sediment will be written for the West Fork Gallatin River.

5.5 TMDL Development Summary

Based on the 303(d) sediment listings and a comparison of existing conditions to water quality targets, three sediment TMDLs will be developed in the West Fork Gallatin River Watershed. **Table 5-12** summarizes the sediment TMDL development determinations and corresponds to **Table 1-1**, which contains the TMDL development status for all listed waterbody segments on the 2008 303(d) List.

TMDL development for each waterbody segment also addresses the tributary streams in the 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 influenced sediment loading is occurring. This results in a comprehensive watershed protection approach versus sorting out individual tributaries for additional sediment TMDL development work in a piece-meal fashion that uses resources that could be focused on implementation.

Table 5-12. Summary of TMDL development determinations

Stream Segment	Waterbody #	TMDL Development Determination (Y/N)
MIDDLE FORK OF WEST FORK GALLATIN RIVER, headwaters to mouth (West Fork Gallatin River)	MT41H005_050	Y
SOUTH FORK OF WEST FORK GALLATIN RIVER, headwaters to mouth (West Fork Gallatin River)	MT41H005_060	Y
WEST FORK GALLATIN RIVER, Confluence Mid & N Forks West Gallatin to mouth (Gallatin River)	MT41H005_040	Y

5.6 Source Assessment and Quantification

This section summarizes the assessment approach, current sediment load estimates, and rationale for load reductions from anthropogenic sources within the four main source categories: streambank erosion, upland erosion, roads, and storm water 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 within each source category, and, as no calibration has been conducted, should not be considered as actual loading values. Rather, relative estimates provide the basis for percent reductions in loads that can be accomplished via improved land management practices for each source category. 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

Streambank erosion was assessed in 2008 at the 16 full assessment reaches discussed in **Section 5.3**, but because the results of the field assessment are extrapolated to the listed-segment watershed scale, an additional 14 reaches were assessed for bank erosion to help obtain a representative dataset of existing loading conditions, causes, and the potential for loading reductions associated with improvements in land management practices. Sediment loading from eroding streambanks was assessed by performing Bank Erosion Hazard Index (BEHI) measurements and evaluating the Near Bank Stress (NBS) (Rosgen 1996, 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
- silviculture
- natural sources
- other (e.g. resort/residential/commercial development, ski runs, golf courses)

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 2008 monitoring site was used to extrapolate to the reach scale. Then, the average value for each unique reach category was applied to unmonitored reaches within 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 assessed 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 it is acknowledged that a moderate risk of erosion may not be achievable in all areas, greater reductions will likely be achievable in some areas, and reference data (Bengeyfield, 2004) indicate a moderate BEHI score is a reasonable goal.

For bank erosion, some sources are the result of historical land management activities that are not easily mitigated through changes in current management, and 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., residential and ski areas), the allocation is presented as a percent reduction expected collectively from human sources.

Assessment Summary

Based on the source assessment, streambank erosion contributes 1,821 tons of sediment per year to the West Fork Gallatin River watershed. Of the total load, 11 percent is from the West Fork, 27 percent is from the Middle Fork, 58 percent is from the South Fork, and the remaining 4 percent is from the North Fork (which is not on the 303(d) List). For the entire West Fork Gallatin River Watershed, 67% of the sediment load due to streambank erosion was attributed to natural sources, with the remaining 33% being attributable to human sources. The estimated annual contribution of natural versus anthropogenic loads for each 303(d) listed watershed is shown in **Figure 5-6**. Significant anthropogenic sources of streambank erosion include historic logging (particularly in the riparian zone), roads, and residential/resort development. Appendix D contains additional information about the streambank erosion source assessment and associated load estimates for the 303(d) listed streams within the West Fork Gallatin River watershed, including a breakdown by particle size class (i.e. coarse gravel, fine gravel, and sand/silt).

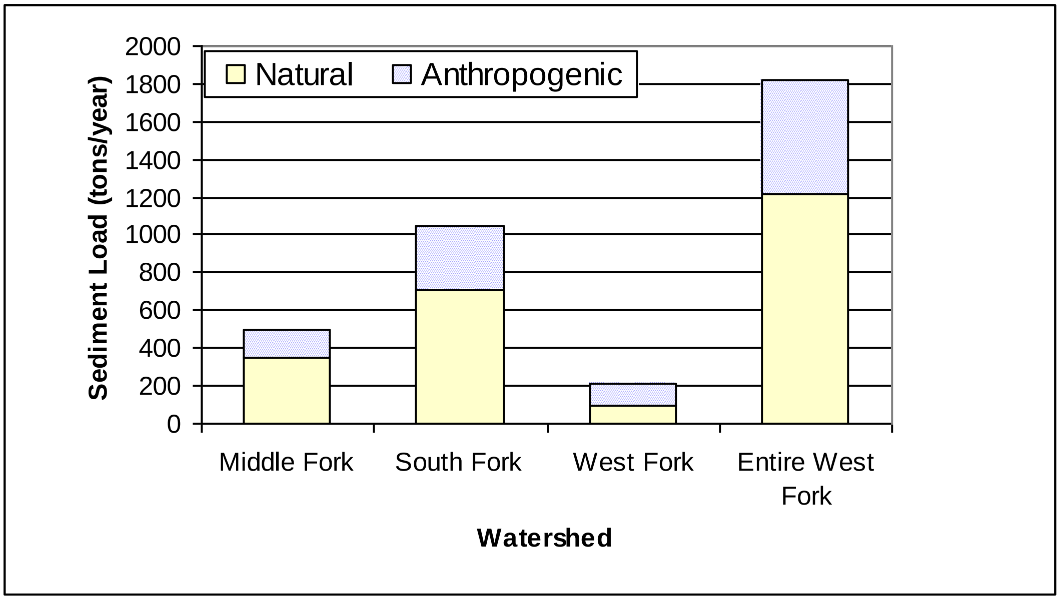

Figure 5-6. Existing annual sediment load from streambank erosion by 303(d) listed watershed within the West Fork Gallatin River watershed.

5.6.2 Upland Erosion and Riparian Buffering Capacity

Upland sediment loading due to hillslope erosion was assessed using a model based on a modified version of the USLE (Universal Soil Loss Equation) referred to as USPED (Unit Stream Power - based Erosion Deposition). The model incorporated rainfall erosivity, soil erodibility, vegetative cover, land management practices, and slope to estimate areas of erosion and deposition and calculate sediment loading from varying land uses within each 303(d) listed watershed. LIDAR elevation data and a detailed land use land cover (LULC) dataset developed by researchers at Montana State University (Campos et al 2008) were used. The major land use categories were residential, ski area, and naturally occurring, and each category is composed of different combinations of land cover (e.g. grass, rock, soil/sparse vegetation, forest, urban).

The model provided an estimate of existing sediment loading from upland sources and an estimate of potential sediment loading reductions that could be achieved by applying best management practices (BMPs). Existing conditions were estimated by approximating the current level of ground cover and BMP implementation associated with different land uses, and the potential reductions were estimated by determining the level of improvement in ground cover associated with implementing additional BMPs. Ground cover values and BMP implementation for both scenarios were based on literature values, stakeholder input, and field observations. It is acknowledged that ground cover values and BMP implementation are variable within land use categories throughout the watershed and over time, but due to the scale of the model, values for ground cover were assumed to be consistent throughout each land use category and throughout the year. Because riparian vegetation can greatly influence sediment loading to streams, model results were then adjusted downward to reflect the sediment removal capacity associated with the existing condition of 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** and the improved condition with BMPs in place was represented as 75 percent of the riparian habitat in good condition and 25 percent in fair condition.

Therefore, allocations for upland sediment sources were derived based on a combination of reductions in sediment loads that will occur by increasing ground cover through the implementation of upland BMPs and improving the condition (i.e. sediment-trapping efficiency) of near-channel vegetation via riparian BMPs. The allocation to these sources includes both present and past influences and is not meant to represent only current management practices; many of the restoration practices that address current land use will reduce pollutant loads that are influenced from historic land uses.

Assessment Summary

Based on the source assessment, hillslope erosion contributes approximately 29,054 tons per year to the West Fork Gallatin River watershed. Based on the assessment, 58% of the annual load is from natural sources and the remaining 42% is from anthropogenic sources. The estimated annual upland sediment contribution associated with natural and anthropogenic sources for each 303(d) listed watershed is shown in **Figure 5-7**. The primary anthropogenic sources are residential/resort development and the ski areas. A more detailed description of the model setup and results, and the riparian adjustment factor can be found in **Appendix E**. During model construction, each 303(d) listed watershed was subdivided into additional watersheds (e.g. Beehive Creek, Muddy Creek, etc); although the allocation to upland erosion for each TMDL in this document will address the major land use categories at the 303(d) listed watershed scale, loads are also expressed for each subwatershed within **Appendix E**, which may be helpful during TMDL implementation.

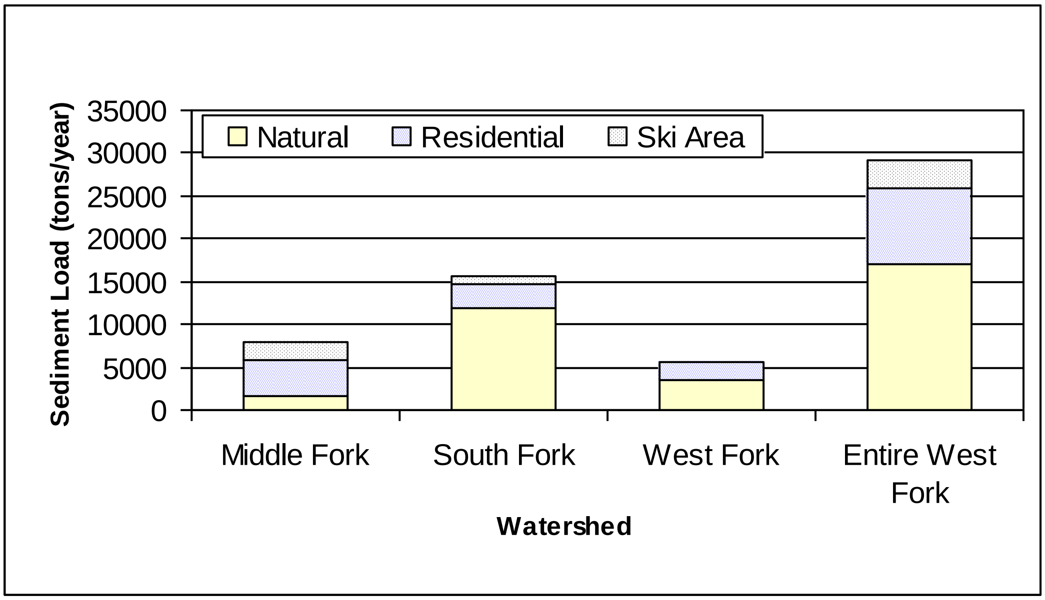

Figure 5-7. Existing annual sediment load from upland erosion by 303(d) listed watershed within the West Fork Gallatin River watershed.

5.6.3 Roads and Traction Sand

Sediment loading from roads was assessed within the West Fork Gallatin River watershed in 2008. The roads assessment evaluated three sources of sediment loading from roads. These are:

- Unpaved and paved road/stream crossings
- Traction sand on paved roads
- Potential culvert failure

Roads

The roads assessment utilized a combination of GIS analysis, field data collection, the Water Erosion Prediction Project (WEPP) model, and data analysis and extrapolation to estimate sediment loading to streams at or near road crossings. In some cases, parallel road segments are also sources of sediment; based on a review of the road network and field reconnaissance, however, parallel segments were determined to be an insignificant source in the West Fork watershed and not included in the source assessment. All 98 road/stream crossings within the watershed are on private land and 71 percent of the crossings are paved. Field assessments were conducted at 25 crossings; the field effort aimed to assess a representative sampling of the road surface types (i.e. paved, gravel, native/dirt) and existing level of BMP implementation. 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 was extrapolated to the remaining roads in the watershed. The model was used to approximate the sediment load associated with existing road crossings (and current BMP usage) and the achievable sediment loading reductions associated with additional BMP implementation. The reductions associated with additional BMP implementation are equivalent to an 85 percent sediment removal efficiency, which is based on literature values for vegetative buffers (Asmussen et al. 1977; Hall et al. 1983; Mickelson et al. 2003; Han et al. 2005), the primary BMP observed. Although the effectiveness of vegetative buffers was used to estimate potential reductions associated with additional BMP implementation, the reduction could be achieved by a variety of BMPs that reduce sediment delivery to streams such as improving ditch relief at crossings, adding water bars, improving maintenance, and using rolling dips and cross slopes. Additional details regarding the roads assessment are provided in **Appendix F**.

Traction Sand

Traction sand applied to paved roads in the winter can be a significant source of sediment loading to streams, and is a particularly important road-related source to consider in the West Fork watershed because 71 percent of the road crossings are paved. A study by the Montana Department of Transportation (MDT) (Staples et al. 2004) found that traction sand predominantly contains particles less than 6mm and 2mm, which are size fractions that can be detrimental to fish and other aquatic life as in-stream concentrations increase (Irving and Bjornn 1984; Shepard et al. 1984; Weaver and Fraley 1991; Mebane 2001; Zweig and Rabeni 2001; Suttle et al. 2004).

Sediment loading associated with traction sanding was estimated based on application rates provided by the MDT (for Highway 64) and the Big Sky Homeowners Association (for other roads). Areas of traction sand usage were identified during the field effort for the road crossing assessment; contributing road lengths for the assessed paved crossings and the application rate per road type were used to estimate the applied traction sand load per crossing. The delivered load was estimated based on the presence of roadside vegetative buffers and literature values for buffer effectiveness. Crossings were generally well buffered and assumed to have an 85 percent efficiency (Asmussen et al. 1977; Hall et al. 1983; Mickelson et al. 2003; Han et al. 2005); however, as shown in **Figure 5-8**, traction sand from numerous years is accumulating and increasing the available traction sand sediment load during runoff and storm events. Therefore, it was estimated that each year a fraction of the sand applied over the previous five years is retained within the “berm” and available for transport, resulting in a 56 percent delivery rate of the annual amount applied. This was assumed to represent the annual delivery rate for all paved crossings. The loading reduction potential was estimated by assuming that BMPs could reduce the annual delivery rate to 15 percent. This is effectively equivalent to preventing roadside accumulation from year to year but the reduction could be achieved by a combination of BMPs, which may include a lower application rate, street sweeping, improving maintenance of existing BMPs, altering plowing speed at crossings, and structural control measures. It is acknowledged that public safety is a primary factor in the usage of traction sand, and the reduction in loading from traction sand is anticipated to be achieved by improving BMPs without sacrificing public safety. Additional details regarding the traction sand assessment are provided in **Appendix F**.

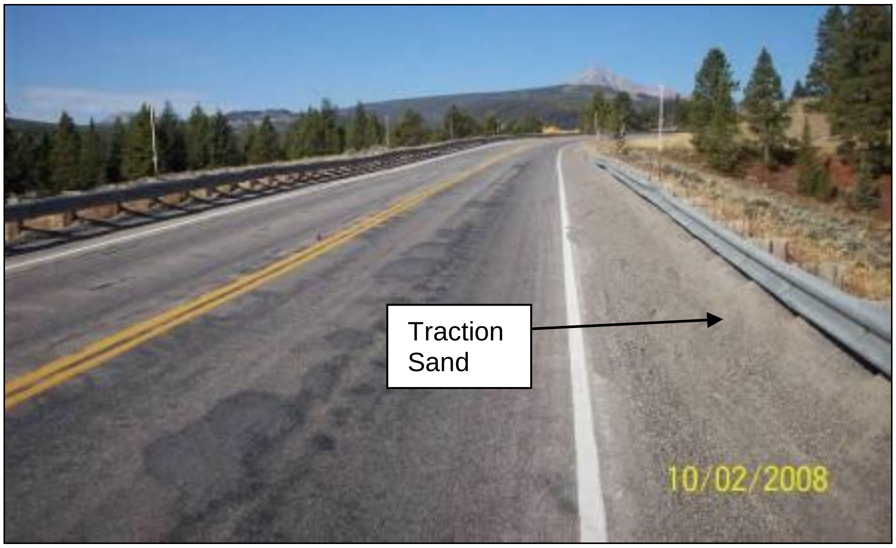

Figure 5-8. Assessment crossing C12 (North Fork West Fork Gallatin River) showing typical build up of traction sand adjacent to a guardrail along Highway 64.

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. Bridges in the study area appeared adequate to pass large flows and since bridges are not covered in large quantities of fill (like culverts), bridges were excluded from the culvert assessment. The culvert analysis was performed during the roads assessment and utilized bankfull width measurements taken upstream of each culvert to determine the stream discharge associated with different flood frequencies (e.g. 2, 5, 10, 25, 50, and 100 year) and measurements for each culvert to estimate its capacity and amount of fill material. It is assumed that fill above an undersized culvert will periodically erode into the channel but the culvert will not completely fail; therefore, the annual amount of sediment at risk was set at a 25 percent probability.

A common BMP for culverts is designing them to accommodate the 25-year storm event; this capacity is specified as a minimum in both the International Building Code Standards for 2006 (ICC 2006) and Water Quality BMPs for Montana Forests (MSU 2001), and it is typically the minimum used by the USFS. Therefore, fill was only assumed to be at-risk in culverts that cannot convey a 25-year event. However, other considerations such as fish passage, the potential for large debris loads, and the level of development and road density upstream of the culvert should also be taken into consideration during culvert installation and replacement, and may necessitate the need for a larger culvert. For instance, the USFS typically designs culverts to pass the 100-year event and be suitable for fish and aquatic organism passage on fish bearing streams (USDA 1995).

Fish passage assessments were based on methodology in A Summary of Technical Considerations to Minimize the Blockage of Fish at Culverts on the National Forests of Alaska (USFS 2002), which is geared toward assessing passage for juvenile salmonids. Considerations for the assessment include stream flow, the culvert slope, culvert perch/outlet drop, culvert blockage, and constriction ratio (i.e. culvert width to bankfull width). The assessment is intended to be a coarse level evaluation of fish passage that quickly identifies culverts that are likely fish passage barriers and those that need a more in-depth analysis.

Though culvert failure represents a potential load of sediment to streams, due to its sporadic nature and particularly uncertainty regarding estimating the timing of such failures, this source is addressed within the roads allocation but not included within the estimate of existing loads. Loads were calculated to provide an estimate of the magnitude of potential loading associated with undersized culverts. The allocation strategy for culverts is no loading from culverts as a result of being undersized, improperly installed, or inadequately maintained. At a minimum, culverts should meet the 25-year event, but for fish-bearing streams or those with a high level of road and impervious surface development upstream, meeting the 100-year event is recommended. Additional details regarding the culvert assessments are provided in **Appendix F**.

Assessment Summary

Based on the source assessment, roads are estimated to contribute 8.1 tons of sediment per year to the West Fork Gallatin River watershed and traction sand is estimated to contribute 155 tons of sediment per year. Largely as a result of the application rate, most of the traction sand (89%) is associated with Highway 64. The estimated annual sediment contribution associated with roads and traction sand for each 303(d) listed watershed is shown in **Figure 5-9**. Factors influencing sediment loads from roads at the watershed scale include the overall road density and the configuration of the road network, along with factors related to road construction and maintenance. **Appendix F** contains additional information about sediment loads from unpaved roads in the West Fork Gallatin River watershed by subwatershed, including all that were assessed.

Out of 17 assessed culverts, 16 were evaluated to pass events up to the 5 year event, but only 9 were estimated to be capable of accommodating a 25 year event. Assuming a 25 percent probability of failure annually, it was estimated that 323 tons of sediment are at-risk. Additionally, of the culverts assessed, 13 (76 percent) were determined to pose a significant fish passage risk to juvenile fish at all flows and 2 were determined to need additional analysis. Additional details regarding these results are included within **Appendix F**.

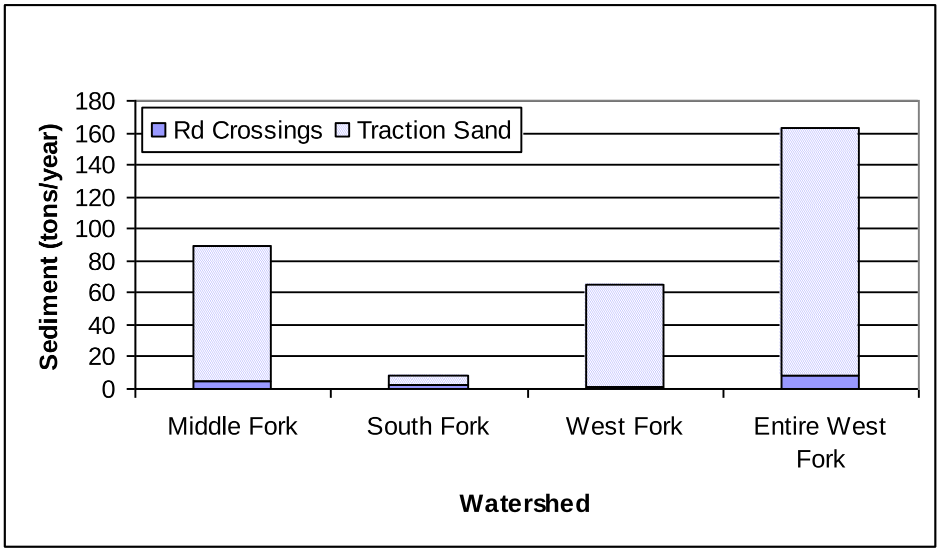

Figure 5-9. Existing annual sediment load from roads and traction sand by 303(d) listed watershed within the West Fork Gallatin River watershed.

5.6.4 Point Sources

There are no municipal or individual permitted point sources of sediment that discharge to streams listed for sediment impairment (**Table 5-1**). However, as of January 28, 2010, there were 58 general permits for construction storm water within the West Fork Gallatin River watershed. They are all authorized under General Permit MTR100000. Twenty two of the permits are in the Middle Fork watershed and 29 are in the South Fork watershed, and approximately 60 percent of the permits are for disturbances greater than 5 acres (**Table 5-13** and **Appendix A**, **Figure 5-10**). It is acknowledged that these permits represent a snapshot in time, but it is assumed that the existing level of large-scale development will continue in the West Fork Gallatin River watershed. 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 construction activities within the West Fork watershed are related to inadequate BMP usage and improper maintenance.

Table 5-13. Number of Storm Water Permits by Subwatershed

Subwatershed	1-5 acres		> 5 acres		Pending	Total Acreage
	Number	Acreage	Number	Acreage	Number	
North Fork	5	14	1	40	0	54
Middle Fork	13	41	9	399	1	440
South Fork	4	10	25	1,029	0	1,039
West Fork*	22	65	35	1,467	1	1,532

*The values for the West Fork are the sum of all storm water permits within the watershed

To assess the disturbed acreage associated with construction storm water permits, each permit file was evaluated. Each file contains the number of anticipated acres to be disturbed. Permits are valid for several years and are typically completed in phases. Therefore, the total number of disturbed acres within the permit files for large projects is likely not representative of disturbed soils on an annual basis, which is the timeframe for the sediment TMDLs and allocations. Based on a review of permits for several large (i.e. >5 acres) projects within the West Fork watershed, 2 years was a typical timeframe for ground disturbance activities. Therefore, for all permits with a disturbance area greater than 5 acres, the acreage was divided by two to approximate the amount of soil disturbed annually. For permits involving projects smaller than 5 acres, which typically have a shorter lifespan than large projects, the acreage expressed in the permit was assumed to be the area disturbed in a one year period.

Each permittee is required to develop a Storm Water 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, and although Montana storm water regulations provide the authority to require storm water monitoring, water quality sampling is typically not required (Personal Communications, Brian Heckenberger, May 2009). Existing loading and potential reductions associated with construction storm water permits are incorporated into soil/sparse vegetation component of the upland erosion assessment, which was reviewed in **Section 5.6.2** and is discussed in additional detail in **Appendix E**. As discussed in **Appendix E**, 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, as with the upland model, 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. Therefore, loading and allocations are addressed collectively for all construction storm water permits within each impaired watershed based on the acreage with soil/sparse vegetation land cover within both residential and ski area land use categories.

Assessment Summary

Based on the source assessment for point sources, almost all of the disturbed soil within the South Fork watershed is associated with permitted point sources but permitted point sources account for a much smaller portion of the disturbed soil within the Middle Fork watershed and lower portion of the West Fork watershed. The estimated relative percentage of disturbed soils due to construction storm water permits and the associated existing annual sediment load (based on the Upland Erosion model) are shown in **Table 5-14**.

Table 5-14. Estimated existing sediment load associated with point sources in the West Fork Gallatin River watershed.

Subwatershed	Permitted Total Acreage	Adjusted Annualized Disturbed Acres for Permits	Total Acres Disturbed/ Sparsely Vegetated Soil from Upland Model	Percent of Annualized Permitted Acres to Modeled Disturbed Acres	Estimated Existing Sediment Load (tons/yr)
Middle Fork	440	214	613	35%	360
South Fork	1,039	449	489	92%	202
West Fork	54	34	150	23%	6
Entire West Fork*	1,532	697	1,252	56%	568

*The values for the West Fork are the sum of all storm water permits within the watershed

5.6.5 Source Assessment Summary

The estimated annual sediment load from all identified sources within the West Fork Gallatin River watershed is 31,201 tons. 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 5.8.3**. However, the modeling results for each source category, and the ability to proportionally reduce loading with the application of improved management practices (**Appendices D**, **E**, and **F**), 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 West Fork Gallatin River watershed 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 discussed for each waterbody segment and then the TMDL will be provided.

Based on the evaluation of existing conditions relative to water quality targets (**Section 5.4.2**), the TMDL expression differs slightly between the Middle Fork and the South and West Forks. The Middle Fork was the only sediment-listed segment that exhibited instream effects of excess sediment, which indicates current sediment loading is above the TMDL. Therefore, the Middle Fork 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. Conversely, conditions in the South Fork and West Fork indicate current loading is not exceeding the TMDL; however, both watersheds are experiencing high levels of growth and the source assessments indicated existing sources are not following all reasonable land, soil, and water conservation practices. Therefore, allocations within those TMDLs will also be expressed as percent reductions but the TMDLs will be based on the existing load. Because of the uncertainty between the source assessments and the instream condition (including very high flows during the 2008 assessments), 5 percent of the remaining load will be allocated to an explicit margin of safety and the remainder will be allocated to future sources. **Figure 5-11** contains a schematic diagram of the two differing sediment TMDL approaches within the West Fork Gallatin River watershed.

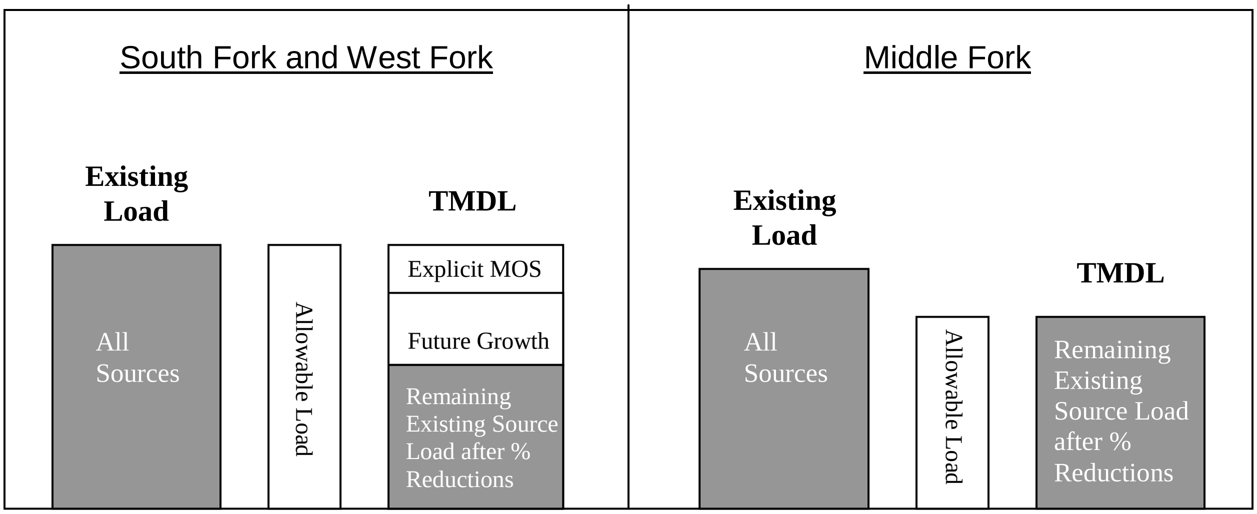

Figure 5-11. Schematic diagram of TMDL and allocation approach for the West Fork Gallatin River watershed

Because sediment generally has a cumulative effect on beneficial uses, and all sources in the West Fork watershed (including construction storm water 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 G**.

Allocation Approach and Assumptions

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. Sediment load reductions at the watershed scale 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.

Because of the scale of the source assessments, reductions are estimated by making assumptions at the watershed scale about the level of existing BMP implementation and level of additional BMP implementation and associated effectiveness that will meet the intent of the relevant water quality standards. 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.

5.7.1 Middle Fork West Fork Gallatin River (MT41H005_050)

The current annual sediment load is estimated at 8,611 tons/year, with 23% attributed to natural sources and the remaining 77% due to human influenced sources (**Table 5-15**). By applying BMPs, the sediment load to the Middle Fork watershed could be reduced to 6,125 tons/year. To achieve this reduction, a 72% sediment load reduction is allocated to roads sources, which include road crossings and traction sand. The allocation to culverts is no loading due to undersized, improperly installed, or inadequately maintained culverts. At a minimum, culverts should meet the 25-year event, but for fish-bearing streams or those with a high level of road and impervious surface development upstream, meeting the 100-year event is recommended. Additionally, a 41% reduction is allocated to human caused streambank erosion, while upland sediment sources associated with residential uses and ski areas are allocated a 37% reduction. The reductions associated with streambank and upland erosion are anticipated to primarily be achieved through the application of riparian BMPs. A WLA of 299 tons/year is collectively allocated to construction storm water permits. 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 (MTR100000), which include a Storm Water Pollution Prevention Plan (SWPPP) with numerous BMPs and site stabilization before a permit can be terminated. The total maximum daily sediment load for the Middle Fork West Fork Gallatin River is expressed as a 29% reduction in the total average annual sediment load.

Table 5-15. Sediment TMDL and Allocations for Middle Fork West Fork Gallatin River (MT41H005_050)

Sediment Sources		Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Sediment Load Allocation (% reduction)
Roads	Culverts	Not quantified	No loading from undersized, improperly installed, or inadequately maintained culverts[1]	
	Road Crossings	4.8	1.7	65%
	Traction Sand	84	23	73%
	Total	**89**	**25**	**72%**
Streambank Erosion	Human Caused	145	86	41%
	Natural	349	349	N/A
	Total	**494**	**435**	**12%**
Upland Erosion	Natural	1,661	1,661	N/A
	Residential	3,915	2,623	37%
	Ski Area	2,092	1,152	
	Total	**7,668**	**5,436**	**29%**
Point Sources	Construction Storm Water Permits[2]	360	229	36%
Total Sediment Load		**8,611**	**6,125**	**TMDL = 29%**

[1] For culverts, passing the 25-year event is a minimum, but passing the 100-year event is recommended for fish-bearing streams or those with a high level of existing or anticipated development upstream. [2] The loads for construction storm water permits are a portion of the human loads from the upland erosion source assessment.

5.7.2 South Fork West Fork Gallatin River (MT41H005_060)

The current annual sediment load for the South Fork is estimated at 16,583 tons/year, with 76% of the load attributed to natural sources and the remaining 24% due to human influenced sources (**Table 5-16**). As discussed in **Section 5.7**, the South Fork West Fork Gallatin River sediment TMDL is equal to the current average yearly load for existing sources, but based on reductions achievable through additional BMP implementation, existing sources will be allocated an 8% reduction (i.e. 1,287 tons/year). The source assessment methods incorporate an implicit MOS (see **Section 5.8.2**), but because of the uncertainty between source assessments and the instream condition, and because the TMDL is being set at the current load, an explicit 5% MOS is also a component of the TMDL. The remaining 3% of the load reduction (i.e. 8% reduction – 5% MOS = 3%) is allocated to future sources. The explicit MOS is 829 tons/year and future sources are allocated 458 tons/year. All future sources should adhere to the same level of BMP implementation as allocated to existing sources.

To achieve the 8% reduction, a 67% sediment load reduction is allocated to roads sources, which include road crossings and traction sand. The allocation to culverts is no loading due to undersized, improperly installed, or inadequately maintained culverts. At a minimum, culverts should meet the 25-year event, but for fish-bearing streams or those with a high level of road and impervious surface development upstream, meeting the 100-year event is recommended. Additionally, a 21% reduction is allocated to human caused streambank erosion, while upland sediment sources associated with residential uses and ski areas are allocated a 33% reduction. The reductions associated with streambank and upland erosion are anticipated to primarily be achieved through the application of riparian BMPs. A WLA of 131 tons/year is collectively allocated to construction storm water permits. 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 (MTR100000), which include a Storm Water Pollution Prevention Plan (SWPPP) with numerous BMPs and site stabilization before a permit can be terminated. The total maximum daily sediment load for the Middle Fork West Fork Gallatin River is expressed as a 0% reduction in the total average annual sediment load but an 8% reduction from existing sources.

Table 5-16. Sediment TMDL and Allocations for South Fork West Fork Gallatin River (MT41H005_060)

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Total Allowable Load (Tons/Year)**	**Sediment Load Allocation (% reduction)**
Roads	Culverts	Not quantified	No loading from undersized, improperly installed, or inadequately maintained culverts[1]	
	Road Crossings	2.1	0.7	67%
	Traction Sand	6.5	1.8	72%
	Total	**9**	**3**	**67%**
Streambank Erosion	Human Caused	338	266	21%
	Natural	711	711	N/A
	Total	**1,049**	**977**	**7%**
Upland Erosion	Natural	11,832	11,832	N/A
	Residential	2,668	1,661	33%
	Ski Area	823	692	
	Total	**15,323**	**14,185**	**7%**
Point Sources	Construction Storm Water Permits[2]	202	**131**	**35%**
Future Growth	All Sources	N/A	**458**	**N/A**
5% Explicit Margin of Safety			**829**	**N/A**
Total Sediment Load		**16,583**	**16,583**	**0%**

[1] For culverts, passing the 25-year event is a minimum, but passing the 100-year event is recommended for fish-bearing streams or those with a high level of existing or anticipated development upstream. [2] The loads for construction storm water permits are a portion of the human loads from the upland erosion source assessment.

5.7.3 West Fork Gallatin River (MT41H005_040)

The current estimated annual sediment load in the West Fork Gallatin River watershed is estimated at 31,038 tons/year, with 59% attributed to natural sources and the remaining 41% due to human influenced sources (**Table 5-17**). As discussed in **Section 5.7**, the West Fork Gallatin River sediment TMDL is equal to the current average yearly load for existing sources, but based on reductions achievable through additional BMP implementation, existing sources will be allocated a 15% reduction (i.e. 4,595 tons/year). The source assessment methods incorporate an implicit MOS (see **Section 5.8.2**), but because of the uncertainty between source assessments and the instream condition, and because the TMDL is being set at the current load, an explicit 5% MOS is also a component of the TMDL. The remaining 10% of the load reduction (i.e. 15% reduction – 5% MOS = 15%) is allocated to future sources. The explicit MOS is 1,552 tons/year and future sources are allocated 3,043 tons/year. All future sources should adhere to the same level of BMP implementation as allocated to existing sources.

To achieve the 15% reduction, a 72% sediment load reduction is allocated to roads sources, which include road crossings and traction sand. The allocation to culverts is no loading due to undersized, improperly installed, or inadequately maintained culverts. At a minimum, culverts should meet the 25-year event, but for fish-bearing streams or those with a high level of road and impervious surface development upstream, meeting the 100-year event is recommended. Additionally, a 21% reduction is allocated to human caused streambank erosion, while upland sediment sources associated with residential uses and ski areas are allocated a 36% reduction. The reductions associated with streambank and upland erosion are anticipated to primarily be achieved through the application of riparian BMPs. A WLA of 364 tons/year is collectively allocated to construction storm water permits. 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 (MTR100000), which include a Storm Water Pollution Prevention Plan (SWPPP) with numerous BMPs and site stabilization before a permit can be terminated.

The total maximum daily sediment load for the West Fork Gallatin River is expressed as a 0% reduction in the total average annual sediment load but a 15% reduction from existing sources. Note that the TMDL incorporates sources from the entire watershed, including the Middle Fork and South Fork. If those respective TMDLs are considered, 20% of the West Fork TMDL is composed of allocations to sources in the Middle Fork watershed, 53% is composed of allocations to sources within the South Fork watershed, and the remaining 27% of the load is allocated to sources in the remainder of the watershed, including the North Fork.

Table 5-17. Sediment TMDL and Allocations for West Fork Gallatin River (MT41H005_040)

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Total Allowable Load (Tons/Year)**	**Sediment Load Allocation (% reduction)**
Roads	Culverts	Not quantified	No loading from undersized, improperly installed, or inadequately maintained culverts[1]	
	Road Crossings	8.1	2.9	64%
	Traction Sand	155	42	73%
	Total	**163**	**45**	**72%**
Streambank Erosion	Human Caused	604	418	31%
	Natural	1,217	1,217	N/A
	Total	**1,821**	**1,635**	**10%**
Upland Erosion	Natural	16,991	16,991	N/A
	Residential	8,580	5,565	36%
	Ski Area	2,915	1,843	
	Total	**28,486**	**24,399**	**14%**
Point Sources	Construction Storm Water Permits[2]	**568**	**364**	**36%**
Future Growth	All Sources	N/A	**3,043**	**N/A**
5% Explicit Margin of Safety			**1,552**	**N/A**
Total Sediment Load		**31,038**	**31,038**	**0%**

[1] For culverts, passing the 25-year event is a minimum, but passing the 100-year event is recommended for fish-bearing streams or those with a high level of existing or anticipated development upstream. [2] The loads for construction storm water permits are a portion of the human loads from the upland erosion source assessment.

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 West Fork Gallatin River Watershed 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 West Fork Gallatin River Watershed, 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 G**.

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). Although the TMDLs for the South Fork and West Fork include an explicit MOS, all sediment TMDLs in this document also 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 D**, **E**, and **F**).

- 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) (see **Appendix B**) 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.

Based on the evaluation of existing conditions discussed in **Section 5.4.2**, the TMDL for the Middle Fork is expressed as a percent reduction from the existing load and the TMDLs for the South Fork and West Fork are based on the existing load. The data used to assess the "existing condition" were collected during a year with substantial runoff, which may have flushed fine sediment from the system, and although each TMDL expression is associated with some uncertainty, the goal of the margin of safety (both implicit and explicit) is to mitigate as much uncertainty as possible to ensure that the TMDLs result in attainment of water quality standards. Another component to TMDL development that addresses uncertainty is an adaptive management plan to account for uncertainties in the field methods and water quality targets.

For the purpose of this document, adaptive management relies on continued monitoring of water quality and stream habitat conditions, continued assessment of impacts from human activities and natural conditions, and continued assessment of how aquatic life and coldwater fish respond to changes in water quality and stream habitat conditions. 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 and also incorporates large flow events via the method used to identify bank area and retreat rates. Therefore, a significant portion of the bank erosion load is based on large flow events versus typical yearly loading. Additionally, bank erosion rates are based on measured retreat rates from the Lamar River in Yellowstone National Park, which may have a greater annual retreat rate than streambanks in the West Fork Gallatin River watershed. However, both watersheds have sedimentary geology, and in the absence of local retreat rates, rates from the Lamar River are assumed to provide a good approximation of retreat rates in the West Fork watershed. 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 E**), 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 C**, **D**, and **E**.

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.

SECTION 6.0
NUTRIENTS

This portion of the document focuses on nutrients (nitrogen and phosphorus forms) as a cause of water quality impairments in the West Fork Gallatin River watershed. It addresses:

- Beneficial use impacts
- Stream segments of concern
- Water quality data sources
- Water quality targets and comparison to existing conditions
- Nutrient source assessment
- Nutrient total maximum daily loads
- Nutrient source load allocations
- Seasonality and margin of safety

6.1 Nutrient Impacts to Beneficial Uses

Nutrients (nitrogen and phosphorus forms) are needed for primary production to occur and produce food for aquatic insects and eventually the fishery. However, excessive concentrations of nutrients can affect a waterbody's ability to support its aquatic life, coldwater fisheries, drinking water, and recreation beneficial uses. Excess nutrients typically impair beneficial uses by leading to a proliferation of undesirable algae growth in streams, thereby impairing a stream's recreational and aquatic life uses.

6.2 Stream Segments of Concern

Stream segments of concern in the West Fork Gallatin River watershed are those streams listed as impaired for phosphorus and/or nitrogen on the 2008 303(d) List and include:

Table 6-1. Stream Segments of Concern for Nutrients: 2008 303(d) List

Stream Segment	Segment ID	2008 303(d) Nutrient Impairments
Middle Fork West Fork Gallatin River	MT41H005_050	Nitrate+Nitrite
West Fork Gallatin River	MT41H005_040	Total Nitrogen, Total Phosphorus
South Fork West Fork Gallatin River	MT41H005_060	Nitrate+Nitrite, Total Phosphorus

6.3 Water Quality Data Sources

Primary data sources used to evaluate existing in-stream nutrient concentrations in the West Fork Gallatin River watershed include:

1) DEQ conducted water quality sampling from 2006 through 2008 in support of nutrient Total Maximum Daily Load development. Water samples were collected and analyzed for nutrients at 16 sites throughout the West Fork Gallatin River watershed in 2006 and 2007 and at 24 sites in 2008 (**Figure 6-1**). In 2006 and 2007, sampling was conducted during August, November, February/March and May/June on the Middle Fork West Fork Gallatin River. Two additional monitoring events were conducted during the summer of 2008 to provide supporting information regarding summer nutrient concentrations and

potential sources. In addition to water quality samples, algal samples were collected in 2005 and 2008 and analyzed for chlorophyll-*a* density.
2) Montana State University researchers conducted extensive water quality sampling from 2005 through 2007 at over 50 sites in the West Fork watershed (**Figure 6-1**) in support of soluble nitrogen export model development. Nutrient parameters were primarily soluble forms, with over 900 nitrate/nitrite results within the watershed.
3) The Blue Water Task Force and the DEQ sampled macroinvertebrates at several locations in the West Fork Gallatin Watershed from 2000 through 2008.

As these sampling events represent the most recent and the most exhaustive water quality characterization of nutrients to date, data from these events is used as the primary source of data for the evaluation of water quality targets and assessment of nutrient sources. Raw data from these sources is extensive and is not included herein, but is publicly available through EPA's STORET water quality database and the DEQ's EQuIS water quality database, and is also available through the DEQ upon request. The following section provides an evaluation of water quality conditions with respect to nutrients for stream segments of concern in the West Fork Gallatin River watershed.

6.4 Nutrient Water Quality Targets and Comparison to Existing Conditions

TMDL water quality targets are numeric indicator values used to evaluate attainment of water quality standards, and are discussed conceptually in **Section 4.0**. The following section presents nutrient water quality targets, and compares those target values to recently collected nutrient data in the West Fork Gallatin watershed following DEQ's draft Assessment Methodology for Determining Wadeable Stream Impairment Due to Excess Nutrients: Nitrogen and Phosphorus (DEQ, 2010).

6.4.1 Nutrient Water Quality Targets

Montana's water quality standards for nutrients (nitrogen and phosphorous forms) are narrative and are addressed via narrative criteria. These narrative criteria require, *"State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will create conditions which produce undesirable aquatic life"* [ARM 17.30.637(1)(e)]. Numeric nutrient criteria are presently under development by the Montana DEQ, and are established at levels believed to protect against the growth of 'undesirable aquatic life' (i.e algae). Nutrient water quality targets include nutrient concentrations in surface waters and measures of benthic algae chlorophyll-*a* concentrations. It must be noted that targets are established specifically for Nutrient TMDL development in the West Fork Gallatin River watershed and may or may not be applicable to streams in other TMDL planning areas. See **Section 6.5.4.3** for the adaptive management strategy as it related to nutrient water quality targets.

6.4.2 Nutrient Concentrations and Chlorophyll a

Numeric nutrient targets for nitrogen and phosphorus are established at levels believed to prevent the growth and proliferation of excess or undesirable algae. Since 2002, Montana has conducted a number of technical studies in pursuit of numeric criteria development for nutrients (N and P forms) and has developed draft nutrient criteria for nitrate+nitrite nitrogen (NO_3+NO_2), total nitrogen (TN), total phosphorus (TP), and chlorophyll-*a* concentration based on 1) the results of public perception surveys (Suplee, 2009) regarding what level of algae was perceived as 'undesirable', and 2) the outcomes of nutrient stressor-response studies that determine nutrient concentrations that will maintain algal growth below undesirable levels (Suplee, 2008).

Nutrient targets for nitrate+nitrite (NO_3+NO_2), total nitrogen (TN), total phosphorus (TP), and chlorophyll-*a* are based on the draft nutrient criteria development process and are presented in **Table 6-2**. As numeric nutrient chemistry targets are established to maintain algal levels below target chlorophyll-a concentrations, target attainment applies and is evaluated during the summer months (July 1st through Sept 30th) when algal growth has the highest potential to affect beneficial uses.

Table 6-2. Nutrient Targets* in the Upper Gallatin TPA

Parameter	Target Value
Nitrate+Nitrite (NO_3+NO_2)	≤ 0.100 mg/L
Total Nitrogen (TN)	≤ 0.320 mg/L
Total Phosphorus (TP)	≤ 0.030 mg/L
Chlorophyll-*a*	≤ 129 mg/m²

*see **Section 6.5.4.3** for the adaptive management strategy for nutrient targets

The following section provides a data summary and evaluation of nutrient target attainment for streams in the West Fork Gallatin River watershed following the DEQ's nutrient impairment assessment methodology (Suplee, M., and R. Sada de Suplee. 2010).

6.4.3 Existing Conditions and Comparison to Water Quality Targets

Attainment of nutrient water quality targets was evaluated for several discrete stream reaches (**Figure 6-2**) within each stream segment of concern (**Table 6-3**). For each assessment reach, only summertime (July 1st – Sept 30th) nutrient data from 2005-2008 collected within the listed waterbody segment was evaluated for target attainment.

Evaluation of nutrient target attainment is conducted by comparing exiting water quality conditions to established water quality targets (in this case, the nitrogen, phosphorus and chlorophyll-*a* values provided in **Table 6-2**), following the methodology in the DEQ draft guidance document, *Assessment Methodology for Determining Wadeable Stream Impairment due to Excess Nutrients (Nitrogen and Phosphorus)*. The assessment methodology utilizes two statistical tests (Exact Binomial Test and the One-Sample Student's T-test for the Mean) to evaluate water quality data for compliance with established target values. In general, compliance with water quality targets is <u>not</u> attained when nutrient chemistry data demonstrates a target exceedence rate of >20% (Exact Binomial Test), when mean water quality nutrient chemistry results exceed target values (Student T-test), or when chlorophyll-*a* results exceed benthic algal target concentrations. Where water chemistry and algae data do not provide a clear determination of impairment status, or other limitations exist, macroinvertebrate biometrics (HIBI >4.0) are considered in further evaluating compliance with nutrient targets, as directed by the assessment methodology. Lastly, inherent to any impairment determination is the existence of human sources of pollutant loading anthropogenic sources of nutrients must be present for a stream to be considered impaired.

Table 6-3. Nutrient Assessment Reaches

Stream Segment	Segment ID	Assessment Reaches
Middle Fork West Fork Gallatin River	MT41H005_050	Upper Middle Fork WFGR
		Lower Middle Fork WFGR
West Fork Gallatin River (WFGR)	MT41H005_040	West Fork Gallatin River
South Fork West Fork Gallatin River	MT41H005_060	Upper South Fork WFGR
		Lower South Fork WFGR

6.4.3.1 Middle Fork West Fork Gallatin River (MT41H005_050)

The Middle Fork West Fork Gallatin River is listed on the 2008 303(d) List as impaired due to nitrate/nitrite. That determination is based primarily on data collected in 1995 and 1996, and employed assessment methods and target values that have since been modified and updated with target development and evaluation processes discussed in **Section 6.4**. And, as land uses and land cover have changed rapidly in the West Fork Gallatin River watershed since the mid 1990's, this segment is re-evaluated herein for nutrient impairments using data recently collected, and employing DEQ's recently adopted nutrient impairment assessment methodology (Suplee, M., and R. Sada de Suplee. 2010).

Due to differences in land use and pollutant sources above and below Lake Levinsky, the Middle Fork West Fork Gallatin River was broken into two assessment reaches: upstream of Lake Levinsky and downstream of Lake Levinsky (**Figure 6-2**). Upstream of Lake Levinsky, land uses consist primarily of active ski resort and residential development, while downstream of Lake Levinsky land use is primarily lower level development and relatively unimpacted natural vegetation.

Upper Middle Fork West Fork Gallatin River

Land use in the Middle Fork West Fork Gallatin River watershed upstream of Lake Levinsky (**Figure 6-3**) is dominated by recreational resort development associated with Big Sky Ski Resort and Moonlight Basin Ski Resort. No permitted point sources (individual MPDES permits) of nutrients exist in the upper watershed and nitrogen sources are believed to consist of a variety of variable and diffuse sources that include:

- natural background sources of nitrogen
- nitrogen derived from residential and resort land and vegetation clearing
- nitrogen derived from residential and commercial landscape maintenance and management
- sewer or service line failures or leaks

Figure 6-3. Upper Middle Fork West Fork Gallatin River: Nutrient Sampling Sites

Summary nutrient data statistics and compliance determinations for the upper Middle Fork West Fork Gallatin River are provided in **Table 6-4** and **6-5**, respectively. There were 10 independent nitrate+nitrite nitrogen samples collected between 2005 and 2008. Of these 10 values, seven exceeded nutrient targets for nitrate+nitrite nitrogen, thus failing the Exact Binomial Test. This sub-segment also failed the Student's T-test for nitrate+nitrite nitrogen. There were only two total nitrogen and two total phosphorus samples collected in the upper sub-segment of the Middle Fork West Fork Gallatin River, precluding target compliance evaluations for those nutrient parameters. Likewise, there were no chlorophyll a samples or macroinvertebrate samples collected within the upper sub-segment of the Middle Fork West Fork Gallatin River.

Table 6-4. Nutrient Summary Statistics for the Upper Middle Fork West Fork Gallatin River

Nutrient Parameter	n	min	max	mean	25th percentile	median	75th percentile
Nitrate+Nitrite	10	0.029	0.258	0.148	0.107	0.165	0.177
TN	2	0.160	0.260	0.210	NA	NA	NA
TP	2	0.029	0.260	0.161	NA	NA	NA
Chlorophyll-*a*	0	NA	NA	NA	NA	NA	NA

Table 6-5. Nutrient Compliance Results for the Upper Middle Fork West Fork Gallatin River

Nutrient Parameter	n	Target Value (mg/l)	No. Exceedences	Binomial Test Result	T-test Result	Chl-a Test Result	Compliance Determination
Nitrate+Nitrite	10	0.100	7	Fail	Fail	NA	Fail
TN	2	0.320	0	NA	NA	NA	NA
TP	2	0.030	0	NA	NA	NA	NA
Chlorophyll-*a*	0	129 mg/m2	NA	NA	NA	NA	NA

Binomial and Student T-test failures for nitrate+nitrite nitrogen result in a compliance failure determination for this nutrient parameter, meaning that the upper Middle Fork West Fork Gallatin River is not meeting water quality targets for nitrate+nitrite. While limited sample size did not allow target compliance evaluation for total nitrogen (TN) nor total phosphorus (TP), the waterbody segment is not presently listed as impaired for these parameters and in-stream values were below target concentrations.

Lower Middle Fork West Fork Gallatin River

The Middle Fork West Fork Gallatin River watershed downstream of Lake Levinsky (**Figure 6-4**) consist primarily of a relatively less-impacted stream corridor than the upper reaches; however some lower level residential and resort development exists in the within the segment. The types of nutrient sources in this reach are similar to those above Lake Levinsky, but are considerably less prevalent throughout the reach. Potential nutrient sources include:

- natural background sources of nitrogen
- nitrogen derived from residential and resort land and vegetation clearing
- nitrogen derived from residential and commercial landscape maintenance and management
- sewer or service line failures or leaks
- those aforementioned nutrient sources derived from the Middle Fork West Fork Gallatin River segment upstream from Lake Levinsky

Figure 6-4. Lower Middle Fork West Fork Gallatin River: Nutrient Sampling Sites

Summary nutrient data statistics and compliance determinations for the lower segment of the Middle Fork West Fork Gallatin River are provided in **Table 6-6** and **6-7**, respectively. There were 36 independent nitrate+nitrite nitrogen samples collected between 2005 and 2008. Of these 36 values, four exceeded nutrient targets for nitrate+nitrite nitrogen. Nitrate+nitrite results for this reach passed both the Exact Binomial and Student T-tests. There were eight TN and ten TP samples collected in the lower segment of the Middle Fork West Fork Gallatin River in 2007 & 2008. All 18 TN and TP samples were below target values, and passed both the Exact Binomial and Student T-tests.

Chlorophyll-*a* values, however, did not pass compliance tests. Of seven samples collected from this reach in 2005 and 2008, two exceeded target values, suggesting that soluble nutrients exist at levels that promote nuisance algal growth during certain periods. Macroinvertebrate samples collected from 2002-2004 (**Table 6-7A**) exhibited low HIBI values, suggesting that nutrient concentrations were below thresholds believed to adversely influence macroinvertebrate communities during the 2002-2004 sampling timeframe.

Table 6-6. Nutrient Summary Statistics for the Lower Middle Fork West Fork Gallatin River

Nutrient Parameter	n	min	max	mean	25th percentile	median	75th percentile
Nitrate+Nitrite	36	0.001	0.120	0.039	0.005	0.031	0.065
TN	8	0.050	0.180	0.101	0.073	0.090	0.123
TP	10	0.005	0.009	0.007	0.006	0.007	0.008
Chlorophyll-*a*	7	23	170	81	49	58	111

Table 6-7. Nutrient Compliance Results for the Lower Middle Fork West Fork Gallatin River

Nutrient Parameter	n	Target Value (mg/l)	No. Exceedences	Binomial Test Result	T-test Result	Chl-a Test Result	Compliance Determination
Nitrate+Nitrite	36	0.100	4	Pass	Pass	NA	Pass
TN	8	0.320	0	Pass	Pass	NA	Pass
TP	10	0.030	0	Pass	Pass	NA	Pass
Chlorophyll-*a*	7	129 mg/m2	2	NA	NA	Fail	Fail

Table 6-7a. Macroinvertebrate HIBI Values: Lower Middle Fork West Fork Gallatin River

Site	Site Description	Data	HIBI value
MFWF02	Middle Fork West Fork Gallatin River u/s of North Fork Confluence	9/21/2002	2.4
		9/24/2003	2.3
		7/20/2004	2.9

While nutrient parameters passed the Exact Binomial and Student T-tests, chlorophyll-*a* concentrations were above target criteria in 2 of 7 samples, suggesting biological assimilation of nutrients to algal biomass within the reach. While water chemistry samples for this reach do not violate target criteria at levels believed to cause impairment, soluble nitrogen (nitrate+nitrite) exceedences in the upper segment, in conjunction with algal density target exceedences in the lower segment are sufficient to demonstrate water quality target exceedences for the entire waterbody segment (upper and lower), and subsequently verify nitrate+nitrite impairment for the Middle Fork West Fork Gallatin River.

6.4.3.2 West Fork Gallatin River (MT41H005_040)

The West Fork Gallatin River begins where the North Fork West Fork Gallatin River flows into the Middle Fork West Fork Gallatin River (**Figure 6-5**). The West Fork Gallatin River is listed on the 2008 303(d) List as impaired due to nutrient-related causes, total nitrogen, total phosphorus and chlorophyll-*a*. That determination is based primarily on data collected in 1995 and 1996, and employed assessment methods and target values that have since been modified and updated with target development and evaluation processes discussed in **Section 6.4**. And, as land uses and land cover have changed rapidly in the West Fork Gallatin River watershed since the mid 1990’s, this segment is re-evaluated herein for nutrient impairments using data recently collected, and employing DEQ’s recently adopted nutrient impairment assessment methodology (Suplee, M., and R. Sada de Suplee. 2010).

Land use along the West Fork Gallatin River consists primarily of recreational, residential and commercial development, and includes seasonal and year-long residences, commercial shopping areas, a golf course, water treatment facility and lagoons, and recreational parks and pavilions. No permitted point sources (individual MPDES permits) of nutrients exist, although wastewater effluent from the Big Sky Water and Sewer District (BSWSD) treatment lagoons is applied to the Big Sky Golf Course.

Anthropogenic nutrient sources within this reach are believed to consist of a variety of variable sources and include nutrients derived from:

- sewer or service line failures or leaks
- golf course fertilizer and amendments
- improper management of land-applied effluent
- residential lawn and landscape management
- those aforementioned upstream nutrient sources derived from the Middle Fork West Fork Gallatin and from the South Fork West Fork Gallatin River

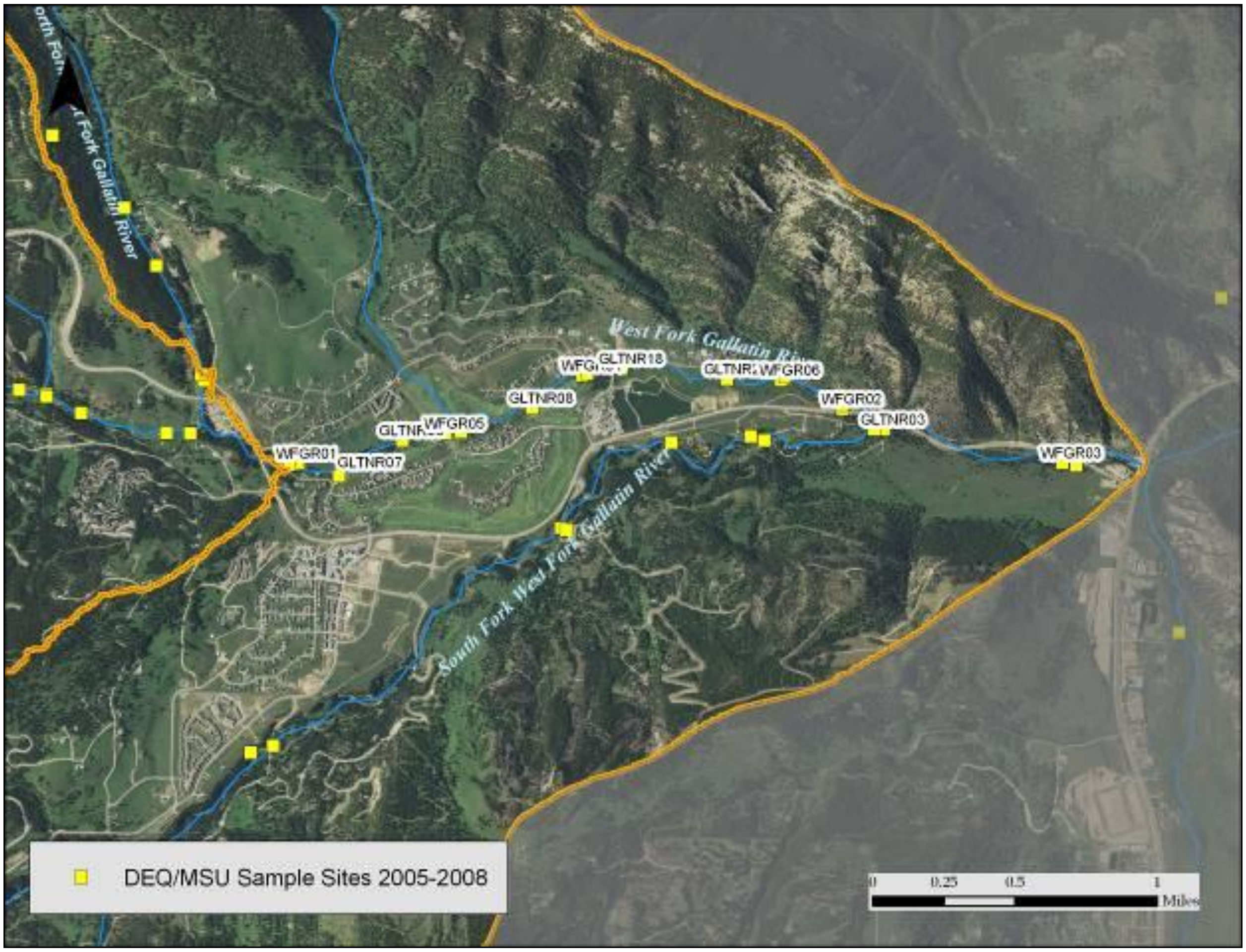

Figure 6-5. West Fork Gallatin River: Nutrient Sampling Sites

Summary nutrient data statistics and compliance determinations for the West Fork Gallatin River are provided in **Table 6-8** and **6-9**, respectively. There were 61 independent nitrate+nitrite nitrogen samples collected between 2005 and 2008. Of these 61 values, 17 (28%) exceeded nutrient targets for nitrate+nitrite nitrogen, thus failing the Exact Binomial Test. Mean summertime nitrate+nitrite concentrations were 0.081 mg/l, below the target concentration of 0.100 mg/l, thus passing the student T-test. Of twelve TN samples collected, 3 (25%) exceeded target concentration, thereby failing the Exact Binomial test. Mean TN concentrations were below the TN target value, thereby passing the Student T-test. Of sixteen TP samples collected, none exceeded target values. TP mean and maximum values were low, and passed both the Exact Binomial and Student T-tests.

Twelve algae samples were collected from six sites in 2005 and 2008. Of twelve samples, five exceeded target values with the highest values (200-500 mg/m2) observed at the two most downstream sites, WFGR02 and WFGR03. Likewise, eight macroinvertebrate samples taken at these same locations from 2000-2008 exhibited high HIBI values (**Table 6-10**).

Table 6-8. Nutrient Summary Statistics for the West Fork Gallatin River

Nutrient Parameter	n	min	Max	mean	25th percentile	median	75th percentile
Nitrate+Nitrite	61	0.001	0.574	0.081	0.020	0.046	0.105
TN	12	0.025	0.520	0.201	0.057	0.140	0.320
TP	16	0.004	0.016	0.008	0.006	0.008	0.010
Chlorophyll-*a*	12	16	443	147	38	109	220

Table 6-9. Nutrient Compliance Results for the West Fork Gallatin River

Nutrient Parameter	n	Target Value (mg/l)	No. Exceedences	Binomial Test Result	T-test Result	Chl-a Test Result	Compliance Determination
Nitrate+Nitrite	61	0.100	17	Fail	Pass	NA	Fail
TN	12	0.320	3	Fail	Pass	NA	Fail
TP	16	0.030	0	Pass	Pass	NA	Pass
Chlorophyll-a	12	129 mg/m2	5	NA	NA	Fail	Fail

Table 6-10. Macroinvertebrate HIBI Values: West Fork Gallatin River

Site	Site Description	Data	HIBI Value
WFGR03	Gallatin River West Fork near mouth	8/2/2000	4.6
WFGR03	Gallatin River West Fork near mouth	7/14/2001	4.9
WFGR03	Gallatin River West Fork near mouth	7/8/2005	3.8
WFGR03	Gallatin River West Fork near mouth	9/12/2008	5.8
WFGR03	Gallatin River West Fork near mouth	9/12/2008	5.8
WFGR02	Gallatin River West Fork upstream South Fork confluence	9/21/2002	4.7
WFGR02	Gallatin River West Fork upstream South Fork confluence	9/24/2003	4.4
WFGR02	Gallatin River West Fork upstream South Fork confluence	7/20/2004	4.4

Nutrient parameters TN and nitrate+nitrite both failed the Exact Binomial Test and passed the Student T-tests. Total phosphorus values were all below targets and passed all tests. Chlorophyll-*a* concentrations were above target values in 5of 12 samples, and show increases in biomass that correlated spatially with corresponding in-stream increases in nitrogen, specifically nitrate+nitrite, through the reach. TN and nitrate+nitrite target exceedences (Exact Binomial test failure), when considered in conjunction with chlorophyll-*a* target exceedences and macroinvertebrate HIBI indicators, provide verification of TN as a cause of impairment and implicate nitrate+nitrite as a primary component contributing to TN impairment.

While listed for TP on the 2008 303(d) List, recent data did not exceed TP target values. Likewise, soluble phosphorus (PO4) data collected in 2005 through 2007 on the West Fork watershed showed that soluble phosphorus concentrations in the West Fork Gallatin River were very low during all seasons (**Table 6-11**), and were not likely to contribute to nutrient enrichment conditions in the segment. Consequently, high chlorophyll-*a* levels witnessed during this time period appear to be the result of elevated soluble nitrate+nitrite concentrations within the assessment reach.

Table 6-11. Soluble Phosphorus (PO4) Summary Statistics for the West Fork Gallatin River

Season		n	min	max	mean	25th	median	75th
Low Flow	Oct-April	100	0.001	2.008	0.036	0.001	0.001	0.001
High Flow	May-June	48	0.001	0.007	0.001	0.001	0.001	0.001
Low Flow	July-Sept	37	0.001	0.004	0.001	0.001	0.001	0.001

6.4.3.3 South Fork West Fork Gallatin River (MT41H005_060)

The South Fork of the West Gallatin River flows into the West Fork Gallatin River below the Big Sky Meadow Village area (**Figure 6-6**). The South Fork West Gallatin River is listed on the 2008 303(d) List as impaired due to nutrient-related causes: nitrate+nitrite, total phosphorus and chlorophyll-*a*. That determination is based primarily on data collected in 1995 and 1996, and employed assessment methods and target values that have since been modified and updated with target development and evaluation processes discussed in **Section 6.4**. This segment is re-evaluated herein for nutrient impairments using data recently collected, and employing DEQ's recently adopted nutrient impairment assessment methodology (Suplee, M., and R. Sada de Suplee. 2010).

Land use along the South Fork West Fork Gallatin River consists primarily of recreational and resort development in the upper watershed (the Yellowstone Club) on forested lands, and light residential and commercial development in the lower reaches. No permitted point sources of nutrients exist. Anthropogenic nutrient sources within this reach are believed to consist of a variety of variable sources and include nutrients derived from:

- septic systems close to stream
- residential lawn and landscape management
- resort land clearing and development

Summary nutrient data statistics and compliance determinations for the South Fork West Fork Gallatin River are provided in **Table 6-12** and **6-13**, respectively. No exceedences of target parameters, TN, TP or nitrate+nitrite, were observed in any samples collected from 2005 through 2008. Chlorophyll-*a* levels, however, did exceed target concentrations at two sites in the lower South Fork in 2005, and algal biomass (as measured in g/m2 ash-free dry weight) was very high. Additionally, high HIBI values were observed from macroinvertebrate samples collected in the lower South Fork West Fork Gallatin River (**Table 6-14**).

Table 6-12. Nutrient Summary Statistics for the South Fork West Fork Gallatin River

Nutrient Parameter	n	min	max	mean	25th percentile	Median	75th percentile
Nitrate+Nitrite	36	0.001	0.060	0.018	0.005	0.015	0.024
TN	8	0.020	0.120	0.065	0.035	0.065	0.093
TP	12	0.002	0.017	0.006	0.002	0.004	0.007
Chlorophyll-*a*	8	12	468	91	19	24	54

Table 6-13. Nutrient Compliance Results for the South Fork West Fork Gallatin River

Nutrient Parameter	n	Target Value (mg/l)	No. Exceedences	Binomial Test Result	T-test Result	Chl-a Test Result	Compliance Determination
Nitrate+Nitrite	36	0.100	0	Pass	Pass	NA	Pass
TN	8	0.320	0	Pass	Pass	NA	Pass
TP	12	0.030	0	Pass	Pass	NA	Pass
Chlorophyll-*a*	8	129 mg/m2	2	NA	NA	Fail	Fail

Table 6-14. Macroinvertebrate HIBI Values: South Fork West Fork Gallatin River

Site	Site Description	Data	HIBI Value
SFWF02	Gallatin River South Fork of West Fork at Streamside Way bridge	9/21/2002	1.6
SFWF02	Gallatin River South Fork of West Fork at Streamside Way bridge	9/24/2003	2.3
SFWF02	Gallatin River South Fork of West Fork at Streamside Way bridge	7/20/2004	3.0
SFWF03	Gallatin River South Fork near Two Rivers Road	9/21/2002	4.6
SFWF03	Gallatin River South Fork near Two Rivers Road	9/24/2003	2.6
SFWF03	Gallatin River South Fork near Two Rivers Road	7/20/2004	5.7

Nutrient parameters TN, TP and nitrate+nitrite passed the Exact Binomial Test and passed the Student T-tests. Chlorophyll-*a* concentrations were above target values in 2of 8 samples and macroinvertebrate HIBI values showed evidence of nutrient enrichment at the lower-most sites on the South Fork West Fork Gallatin River. While biological response to nutrients was evidenced, in-stream nutrient concentrations were low suggesting that during some summer periods, nutrient inputs are significant enough to create undesirable conditions but not consistently high enough to result in elevated water column nutrient concentrations after algal uptake.

While listed for TP on the 2008 303(d) List, recent data did not exceed TP target values. Likewise, soluble phosphorus (PO4) data collected in 2005 through 2007 on the South Fork West Fork Gallatin River showed that soluble phosphorus concentrations were very low during all seasons (**Table 6-15**), and were not likely to contribute to nutrient enrichment conditions in the segment. Consequently, high chlorophyll-*a* levels witnessed during this time period appear to be the result of elevated soluble nitrate+nitrite concentrations within the assessment reach.

In the absence of in-stream water quality target exceedences, certainty as to the type of nutrients contributing to algal growth would seem low based on South Fork information alone. However, given that nutrient sources throughout the watershed are similar from stream to stream, and that nitrogen (nitrate+nitrite)has been implicated as causes of impairment in other streams in the watershed, it is expected that controlling soluble anthropogenic sources of nitrogen (nitrate+nitrite) in the South Fork West Fork watershed will maintain algal levels below target concentrations.

Table 6-15. Soluble Phosphorus (PO4) Summary Statistics for the South Fork West Fork Gallatin River

Season		n	min	max	mean	25th	median	75th
Low Flow	Oct-April	58	0.001	0.042	0.005	0.001	0.001	0.008
High Flow	May-June	44	0.001	0.017	0.003	0.001	0.001	0.003
Low Flow	July-Sept	30	0.001	0.011	0.002	0.001	0.001	0.001

6.4.3.4 Nutrient Target Compliance Summary

Compliance with nutrient water quality targets was evaluated for nutrient-impaired streams in the Upper Gallatin TMDL Planning Area: West Fork Gallatin River, Middle Fork West Fork Gallatin River and the South Fork West Fork Gallatin River. Recent data collected from 2005 through 2008 was compared to established water quality targets using DEQ’s impairment assessment methodology. Based on this analysis, it is determined that nitrate+nitrite is exceeding targets in the West Fork Gallatin River and the Middle Fork West Fork Gallatin River, and while sampling data does not confirm nitrate+nitrite exceedences in the South Fork West Fork Gallatin River, biological response data (chl-a & HIBI values) suggests that nutrient enrichment (likely nitrate+nitrite) is contributing to impairment of the South Fork West Fork Gallatin River as well, consistent with the existing nitrate impairment cause listing. Consequently, nitrate+nitrite TMDLs are prepared for these three segments and are presented in **Section 6.5**.

Total Nitrogen (TN) target exceedences were observed in only the West Fork Gallatin River, and are influenced by elevated nitrate+nitrite concentrations. Consequently, a total nitrogen TMDL is prepared for the West Fork Gallatin River. No TP exceedences were observed in any data from 2005 through 2008, and soluble forms of TP were low during all seasons, suggesting that TP source loading from anthropogenic activity is not significant. Consequently, TP does not appear to be a cause of impairment for streams in the West Fork Gallatin River watershed and no TP TMDLs are prepared. **Table 6-16** provides a summary of waterbody segments, 2008 303(d) listings, and TMDLs prepared based on the outcome of nutrient impairment evaluations provided in Section 6.

Table 6-16. Stream Segments of Concern for Nutrients: 2008 303(d) List

Stream Segment	Segment ID	2008 303(d) Nutrient Impairments	TMDLs Prepared
West Fork Gallatin River	MT41H005_040	TN, TP	TN, NO_3+NO_2
Middle Fork West Fork Gallatin River	MT41H005_050	NO_3+NO_2	NO_3+NO_2
South Fork West Fork Gallatin River	MT41H005_060	NO_3+NO_2, TP	NO_3+NO_2

6.5 Nutrient Source Characterization, TMDLs and Allocations

As described in **Section 6.4**, water quality target exceedences in the West Fork Gallatin River watershed include nitrogen fractions, total nitrogen (TN) and nitrate+nitrite (NO_3+NO_2). Data results show TN target exceedences on the West Fork Gallatin River, and NO_3+NO_2 target exceedences in the West Fork Gallatin River and the Middle Fork West Fork Gallatin River. Algal density targets (chlorophyll-*a*) were exceeded in all three segments, the West Fork Gallatin River, the Middle Fork West Fork Gallatin River, and the South Fork West Fork Gallatin River.

Assessment of existing nitrogen sources is necessary in order to develop load allocations to specific source categories. Water quality sampling conducted from 2005 through 2008 provides the most recent data for characterization of existing nitrogen water quality conditions in the West Fork Gallatin watershed. Over 1300 samples were collected by DEQ and Montana State University researchers from over 50 sampling sites over a four year period with the objectives of 1) evaluating attainment of water quality targets, and 2) assessing load contributions from nitrogen sources within the West Fork Gallatin River watershed. Data from these investigations form the primary dataset from which existing water quality conditions were evaluated and from which nitrogen loading estimates are derived. Data used to conduct analyses and loading estimations is publicly available through DEQ databases (see http://deq.mt.gov/wqinfo/datamgmt/MTEWQX.mcpx) and upon request.

The following section characterizes the type, magnitude and distribution of sources contributing to nitrogen loading to impaired streams, provides loading estimates for significant source types, and establishes TMDLs and allocations to specific source categories. Source types include natural and anthropogenic sources and are described in further detail below. Source characterization provides linkages between nitrogen sources, nitrogen loading to streams and water quality response, and supports the formulation of the load allocation portion of the TMDL. As described in **Section 6.4**, TN and NO_3+NO_2 water quality targets are applicable during the summer 'growing season' (July 1st – Sept 30th). Consequently, source characterizations are focused mainly on characterizing sources and mechanisms that influence nitrogen conditions during this period. Similarly, loading estimates and subsequent load allocations are established for this 'growing season' time period and are based on observed water quality data and typical flow conditions.

Source characterization and assessment was conducted primarily by utilizing extensive monitoring data collected in the watershed from 2005 through 2008 to characterize the temporal and spatial patterns in nitrogen concentrations, loads, and biological response. Where appropriate, empirical water quality data was supplemented with nitrogen isotope data, watershed nutrient-export modeling results, field investigations, and local knowledge. Local organizations, *Blue Water Task Force, Big Sky Sewer and Water and Sewer District*, and *Big Sky Resort and Golf Course*, were instrumental in assisting with source characterization by allowing access to sampling locations and providing key information on potential sources, their magnitude and distribution.

Land uses in the West Fork Gallatin River watershed are primarily residential and recreational, stemming from rapid growth of summer and winter resort developments and associated infrastructure. The West Fork Gallatin watershed has no agricultural sources of significance, and there are no MPDES-permitted sources of wastewater discharged to streams in the West Fork Gallatin watershed. MPDES Construction Storm Water general permits are believed to be a negligible source of nitrogen and are evaluated for sediment load contribution in **Section 5.7**. Nutrient sources therefore consist primarily of 1) natural sources derived from airborne deposition, vegetation, soils, and geologic weathering, and 2) anthropogenic sources associated with residential and resort development and infrastructure. These anthropogenic sources may include a variety of discrete and diffuse pollutant inputs related to land clearing and landscaping, residential and urban runoff, septic and wastewater infiltration, and other sources inherent in developed residential areas.

The following section describes these natural and anthropogenic sources in more detail, provides nitrogen loading estimates for natural and anthropogenic source categories to nitrogen-impaired stream segments, and establishes TMDLs and load allocations to specific source categories for the following streams:

- Middle Fork West Fork Gallatin River
- West Fork Gallatin River
- South Fork West Fork Gallatin River

6.5.1 Middle Fork West Fork Gallatin River (MT41H005_050)

As described in **Section 6.4.3.1**, the Middle Fork West Fork Gallatin River consist of two assessment segments, the segment upstream of Lake Levinsky and the segment downstream of Lake Levinsky. Both segments exceeded nutrient water quality targets, and are listed as impaired for NO_3+NO_2 and chlorophyll-*a*. As determined in **Section 6.4**, an NO_3+NO_2 TMDL is provided for this waterbody segment. Source characterizations for this segment therefore focus on assessing soluble nitrogen (NO_3+NO_2) sources and estimating NO_3+NO_2 loads from natural and anthropogenic sources.

6.5.1.1 Upper Middle Fork West Fork Gallatin River

Upstream of Lake Levinsky (**Figure 6-3**), streams are small first and second order headwaters streams with measured flows at 1.0 cfs or less during the summer months. Streams drain lands dominated by recreational resort development associated with Big Sky Ski Resort and Moonlight Basin Ski Resort (**Appendix A**, **Figures 6-7**, **6-8**) and eventually flow into Lake Levinsky at the base of the Big Sky Ski Resort. The Lake Levinsky outlet is a surface-draw that may be adjusted vertically to manage water levels.

Summertime soluble nitrogen concentrations from sampling sites in the upper Middle Fork (Figure 6-3) were elevated above target concentrations in most samples (**Table 6-17**). In contrast, mean soluble nitrogen concentration (n=5) in nearby reference stream, Beehive Creek, was 0.015 mg/L during the same summer sampling timeframe.

Table 6-17. Summertime NO_3+NO_2 Summary Statistics for Streams in the upper Middle Fork West Fork Gallatin River Watershed (units in mg/L)

Parameter	n	min	max	mean	25th percentile	median	75th percentile
NO_3+NO_2	26	0.010	0.258	0.149	0.100	0.173	0.180

NO_3+NO_2 concentrations were spatially consistent throughout the developed resort area, with nitrogen concentrations in the range of 0.15 to 0.26 mg/L NO_3+NO_2 observed at multiple sites in the upper watershed. The lowest NO_3+NO_2 concentrations were observed at sites GLTNT02/MFTR01 and GLTNT07, which are sites with the least amount of adjacent developed lands.

6.5.1.1.1 Natural Nitrogen Sources: Upper Middle Fork West Fork Gallatin River

Natural background sources of nitrogen include a variety of natural sources and processes and may include: soils & local geology, natural vegetative decay, wet and dry airborne deposition, wild animal waste, and other biochemical processes that contribute nitrogen to nearby waterbodies. Estimates of natural summertime (July 1st-Sept 30th) background concentrations for nitrogen (NO_3+NO_2) in the West Fork Gallatin River watershed were derived from recent (2005-2008) data collected on nearby reference streams: North Fork West Fork Gallatin River, Beehive Creek, Yellow Mule Creek & Dudley Creek. Sampling data from these internal reference streams represented water quality conditions resultant from very little to no development or anthropogenic influences. Summary statistics for this data set are provided in **Table 6-18**.

Table 6-18. Summertime NO_3+NO_2 Summary Statistics for Reference Streams in the West Fork Gallatin River Watershed (units in mg/l)

Parameter	n	min	max	mean	25th percentile	median	75th percentile	90th percentile
NO_3+NO_2	44	0.002	0.059	0.020	0.006	0.018	0.030	0.037

In addition to recent reference data collection, data collected in the 1970's also informs the establishment of natural background conditions in the West Fork Gallatin River watershed. Nitrate data (n>400) was collected by Stuart from 1970 through 1974 at several sites in the West Fork Gallatin River watershed. Results were reported as annual average values per sampling station, and ranged from 0.020 to 0.030 mg/L NO3. Data reported by Stuart describes general nitrate conditions throughout the West Fork Gallatin River watershed prior to large-scale development, and may be considered an approximation of reference nitrogen concentrations as well. Because nitrite (NO2) fractions are typically not detected in surface water samples, reference mean and 75th percentile NO_3+NO_2 values from **Table 6-18** correlate closely with nitrate (NO3) data collected in the early 1970's (Stuart, et al, 1976).

For purposes of estimating natural background nitrate concentrations and calculating natural background loading for TMDL development, the 90th percentile reference value of <0.037 mg/l is adopted as an estimate of summertime natural background NO_3+NO_2 concentration and is used to calculate estimated natural background loads for streams in the West Fork Gallatin River watershed. At a typical summertime baseflow of 1.0 cfs at site MFWF04 (mean NO_3+NO_2 concentration =0.149 mg/L) this calculates to a NO_3+NO_2 load of ~0.200 lbs/day NO_3+NO_2, 24.8 percent of the existing NO_3+NO_2 load for the upper segment.

6.5.1.1.2 Anthropogenic Nitrogen Sources: Upper Middle Fork West Fork Gallatin River

Anthropogenic nitrogen sources contributing to nitrogen loading in the upper Middle Fork West Fork Gallatin River were assessed using water quality data collected from 2005 through 2008. Water quality data collection was conducted during summertime low flows and represents a base-flow condition that is dominated by low-flow groundwater inputs that are connected hydrologically to the stream. Sources contributing nitrogen loads during these time periods are those sources derived from resort and residential development (septic systems, landscape management, organic detritus) that would contribute nitrogen loads primarily through groundwater pathways, and do not include storm water runoff loads.

Nitrogen sources are believed to consist of a variety of variable and diffuse nonpoint sources related to residential and resort development. There are no agricultural sources of nitrogen of significance, and no individual MPDES discharge permits. A substantial portion of the upper Middle Fork West Fork Gallatin River watershed is served by a central sewer system (**Appendix A**, **Figure 6-9a**, **6-9b**) that delivers wastewater to the water treatment facility in the Meadow Village area.

Potentially significant anthropogenic nitrogen source categories include:

- on-site septic systems
- residential and resort landscape management and maintenance
- sewer or service line failure

On-site Septic Systems

On-site septic systems process household wastewater through the septic system's tank and drainfield. Nitrogen in household wastewater is typically in ammonia form, which converts to nitrite and then quickly to nitrate (NO3), and reaches groundwater by infiltration through the on-site septic system's drainfield. Septic tank and drainfield treatment provides a low level of nitrogen removal: properly installed and maintained, conventional septic systems typically remove from 10 to 30 percent (USEPA, 2002) of the nitrogen in the wastewater. After entering groundwater, nitrate may go through varying amounts of denitrification or removal, depending on a variety of environmental factors, on its subsurface pathway to surface waters.

Most commercial and residential properties with the Middle Fork watershed upstream of Lake Levinsky are within the boundaries of the Big Sky Water and Sewer District (BSWSD), and are served by a central waste collection system that delivers wastewater to the treatment facility in the Meadow Village area. Potential septic system impacts to surface waters are confined primarily to an area adjacent to the headwaters of the Middle Fork to the northwest of the BSWSD boundary (**Appendix A**, **Figure 6-9a**, **6-9b**).

Nitrate loads from on-site septic systems were assessed by MSU researchers using a nutrient export model algorithm designed to estimate soluble nitrogen (NO3) loading to streams from on-site septic systems. Researchers estimated the number of on-site septic systems in the upper Middle Fork watershed, calibrated septic nitrogen export from the range of standard nitrogen export of septic systems (USEPA, 2002), and modeled soluble nitrogen export to streams for the summertime season using nitrogen decay and travel-time retention calculations (Gardner et al., in review). Results estimate that nitrogen export from individual septic systems range from 7.5 to 28 g/day, which corresponds to ~ 0.0012 kg/ha/yr soluble nitrogen (NO_3+NO_2) reaching the Middle Fork West Fork Gallatin River during the low-flow summer months. At a typical summertime baseflow, this is equivalent to a NO_3+NO_2 load of ~1.9% of the total NO_3+NO_2 load entering the segment. Load estimates assume that septic systems are functioning according to septic design specifications, and does not assume septic failure or malfunction.

Residential and Resort Landscape Management and Maintenance

The landscape in the Middle Fork watershed upstream of Lake Levinsky consists of ski-runs and mountain resort operations in the upper elevations and commercial and residential resort development (condos, vacation rentals, merchants, parking lots) in the lower elevations. Significant land clearing, construction, and road building has occurred over the last two decades, transforming previously undeveloped lands to residential and resort/commercial landscapes. These residential and resort landscape management and maintenance activities can release NO_3+NO_2 to the groundwater through surface infiltration. Once NO_3+NO_2 infiltrates into the groundwater, shallow soils and poor soil development in the alpine environment of the upper Middle Fork West Fork Gallatin River provide less relative denitrification/removal of NO_3+NO_2 in the subsurface, and nitrogen is exported to nearby streams resulting in elevated nitrogen concentrations in surface waters.

Residential and resort landscape management and maintenance sources include those NO_3+NO_2 sources that are ubiquitous across a developed landscape and include a variety of variable and diffuse sources associated with widespread land clearing and development and may include:

- vegetative decay from detritus derived from land clearing or land maintenance activities
- landscape fertilizer application
- hydroseeding of disturbed lands
- general refuse inherent in residential resort development (pets, garbage, etc)

Due to the diffuse nature of nonpoint groundwater sources derived from landscape-scale development, the variety of nitrogen sources associated with residential and resort landscape management and maintenance are assessed as a single composite nitrogen source, and include the sum of anthropogenic NO_3+NO_2 sources not accounted for by on-site septic systems . The estimated NO_3+NO_2 load from residential and resort landscape management and maintenance sources is therefore calculated as the difference between the measured instream load and the sum of the estimated on-site septic system load and the natural background load. At a typical summertime baseflow of 1.0 cfs at site MFWF04 (mean NO_3+NO_2 concentration =0.149 mg/L) this calculates to a NO_3+NO_2 load of 0.589 lbs/day NO_3+NO_2 (**Table 6-18a**), 73.3 percent of the existing NO_3+NO_2 load for the upper segment.

Sewer or Service Line Failure

Compromised underground sewer and service lines are not uncommon to sewer systems, and have the potential to contribute nitrogen loads to nearby waterbodies. Maintenance of sewer lines is conducted routinely by the Big Sky Water and Sewer District and water quality data did not show any apparent evidence that would link in-stream nitrogen concentrations with discrete sewer or service line failures. However, the proximity of sewer mainlines and residential service connections to the West Fork and Middle Fork West Fork of the Gallatin River (**Appendix A**, **Figure 6-9b**) does not rule out the potential for sewer or service line failure to impact surface waters. Assuming that there are no discrete leaks or failures contributing to surface waters impacts, NO_3+NO_2 loads from sewer or service line failures are not significant and no load estimate is provided herein.

6.5.1.1.3 Nitrogen (NO_3+NO_2) Load Estimation Summary: Upper Middle Fork West Fork Gallatin River

Table 6-19 summarizes existing loading conditions for the Upper Middle Fork West Fork Gallatin River (above Lake Levinsky) based on typical summertime low-flow conditions observed in the watershed from 2005 through 2008.

Table 6-19. Existing NO_3+NO_2 loading conditions* for the Upper Middle Fork West Fork Gallatin River

Source Category	Load (lbs/day)	Percent of Total Load
Natural Background	0.200	24.8 %
On-site Septic Systems	0.015	1.9 %
Residential and Resort Landscape Management and Maintenance	0.589	73.3 %
Cumulative	0.804	100%

*loads are based on summertime baseflow conditions observed at sampling site MFWF04

6.5.1.2 Lower Middle Fork West Fork Gallatin River

The lower Middle Fork West Fork Gallatin River assessment segment begins at the outlet of Lake Levinsky and continues to the confluence with the North Fork West Fork Gallatin River, below which it becomes the West Fork Gallatin River (**Figure 6-4**). Flows exiting Lake Levinsky at the upstream end of the segment (MFWF01) average 2.5 cfs during the low-flow summer months and reach 5.0 to 6.0 cfs at the lower end of the segment (MFWF02). Land uses within the segment consist primarily of a relatively unimpacted riparian corridor, however some residential and resort development is present within the corridor (Lone Moose Meadows), and entering tributaries drain recently developed areas (Spanish Peaks Resort, Antler Ridge subdivision).

Table 6-20 and **Figure 6-10** present NO_3+NO_2 statistical summaries and box plots of summertime low flow data collected at sampling sites from the Middle Fork West Fork Gallatin River (2005-2008).

Table 6-20. NO_3+NO_2 summary statistics for selected sites on the Middle Fork West Fork Gallatin River (units in mg/L NO_3+NO_2)

Upper Middle Fork West Fork – Composite Data (above Lake Levinsky)						
n	**min**	**max**	**mean**	**25th**	**median**	**75th**
26	0.010	0.258	0.149	0.100	0.173	0.180
Lower Middle Fork West Fork (below Lake Levinsky)						
Site MFWF01 (upper portion, just downstream of Lake Levinsky)						
n	**min**	**max**	**mean**	**25th**	**median**	**75th**
9	0.035	0.120	0.078	0.068	0.086	0.094
Site MFWF05 (middle portion)						
n	**min**	**max**	**mean**	**25th**	**median**	**75th**
9	0.005	0.111	0.057	0.030	0.067	0.078
Site MFWF02 (lower portion)						
n	**min**	**max**	**mean**	**25th**	**median**	**75th**
33	0.001	0.105	0.024	0.005	0.021	0.032

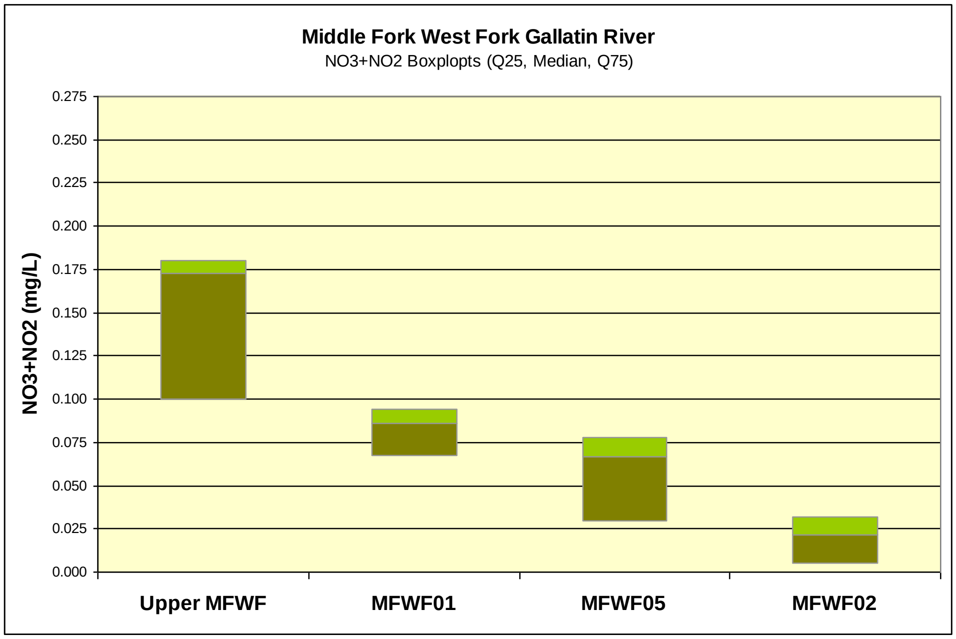

Figure 6-10. NO_3+NO_2 Boxplots: Middle Fork West Fork Gallatin River

Nitrate-nitrogen (NO_3+NO_2) concentrations are highest at the outlet of Lake Levinsky (MFWF01) and attenuate downstream. Algal concentrations (chlorophyll-*a*) from samples collected in 2008 show a corresponding trend (**Figure 6-11**), decreasing from site MFWF01 at the upper end of the reach to MFWF02 at the lower end, and mimic NO_3+NO_2 trends as nitrogen is assimilated by in-stream algae.

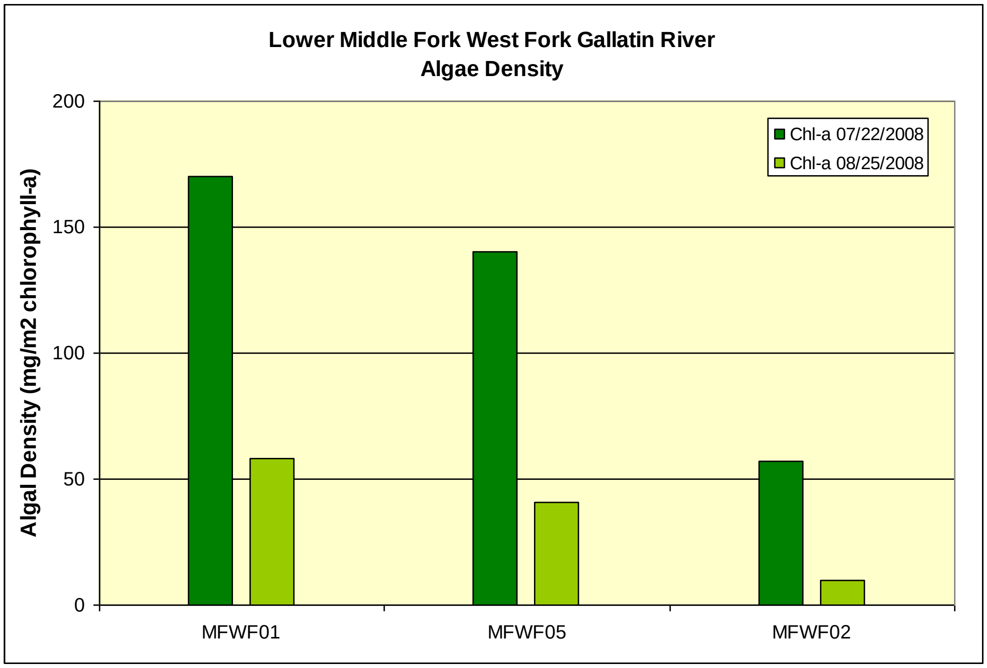

Figure 6-11. Chlorophyll-*a* Concentrations: Lower Middle Fork West Fork Gallatin River

Nitrogen concentrations in the lower segment are meeting water quality targets for NO_3+NO_2, however exceedences of chlorophyll-*a* targets were recorded in 2008. It appears that elevated NO_3+NO_2 levels (average = 0.149 mg/m2) entering Lake Levinsky in the upper Middle Fork reach are resulting in elevated NO_3+NO_2 export at the lake outlet, and while some NO_3+NO_2 is being retained or assimilated within Lake Levinsky, attenuating algal densities and NO_3+NO_2 concentrations witnessed downstream from Lake Levinsky suggests that NO_3+NO_2 is present in the lower Middle Fork West Fork Gallatin River at levels that contribute to the proliferation of nuisance algal growth. Algal densities in July 2008 exceeded target values downstream of Lake Levinsky, and while samples collected in August 2008 did not exceed chlorophyll-*a* target values, algal biomass density (measured as g/m2 ash-free dry weight) was high, as senescent algae was a large contributor to algal biomass.

Natural and anthropogenic sources contributing to NO_3+NO_2 loads entering the reach are described below. Confounding estimation of NO_3+NO_2 loads entering the Middle Fork is in-stream assimilation and retention of NO_3+NO_2 loads by algae. Average streamflow increases from 2.5 cfs to 5.4 cfs through the reach, while average NO_3+NO_2 loads drop from 1.05 lbs/day at MFWF01 to 0.70 lbs/day at site MFWF02. Algal assimilation of NO_3+NO_2 loads entering the Middle Fork from tributaries and groundwater sources throughout the reach is variable and depends on the time of season and magnitude of loading. In general, when NO_3+NO_2 concentrations are elevated significantly above natural background conditions, NO_3+NO_2 loads are assimilated throughout the reach with a net decrease in NO_3+NO_2 load measured at downstream-most site MFWF02. **Figures 6-12** and **6-13** illustrates instantaneous concentrations and loading conditions observed during 2006 and 2008 sampling events, and shows load increases and decreases, explained by a combination of flow volume inputs and algal assimilation. The highest concentrations and loads were witnessed in July, and dropped through the month of August: the highest algal concentrations were also witnessed in July.

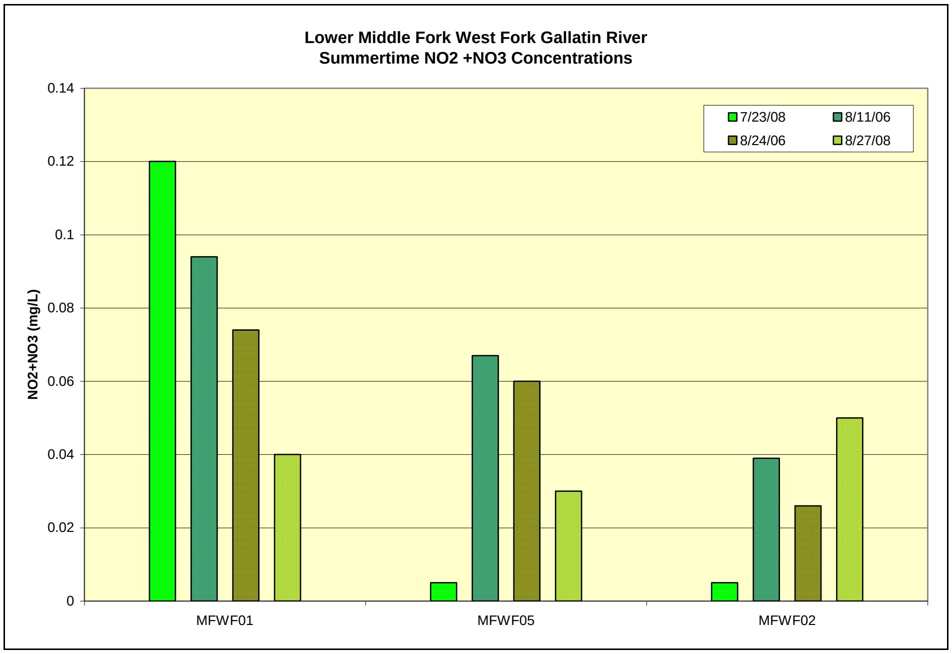

Figure 6-12. Measured NO_3+NO_2 Summer Concentrations, Middle Fork West Fork Gallatin River 2006-2008

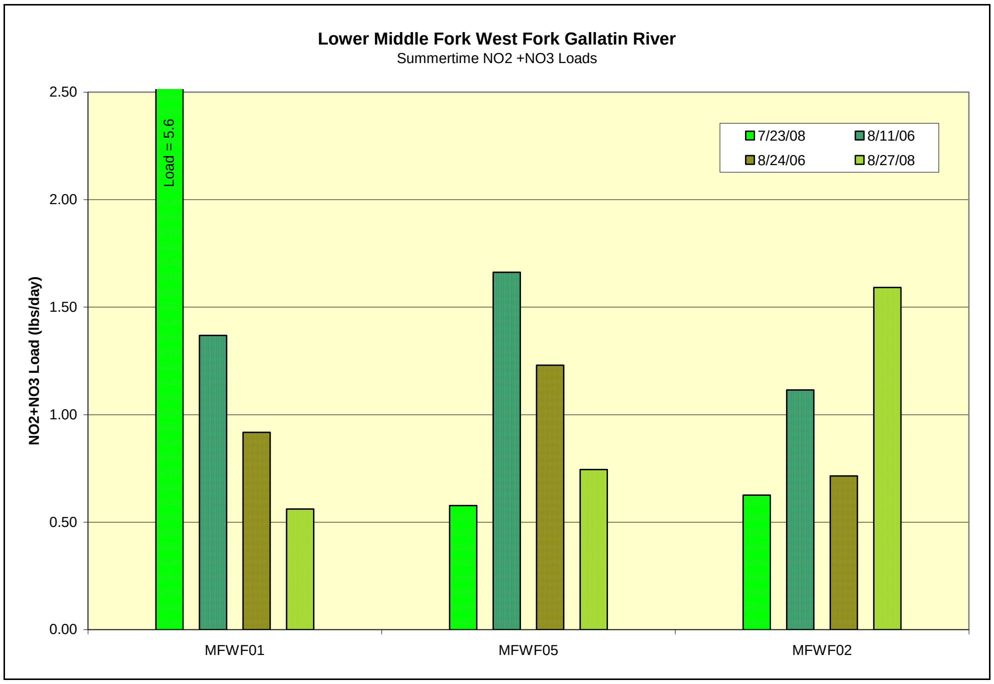

Figure 6-13. Measured NO_3+NO_2 Summer Loads, Middle Fork West Fork Gallatin River 2006-2008

Where data and analysis permit, load estimates are provide for specific source categories. Load estimations are based on a typical summer-season low-flow conditions using data collected from July through September, 2005-2008, and represent average estimated loading conditions during this timeframe.

Natural Nitrogen Sources: Lower Middle Fork West Fork Gallatin River

Natural background sources of nitrogen include a variety of natural processes and sources and may include: soils & local geology, natural vegetative decay, wet and dry airborne deposition, wild animal waste, and other biochemical processes that contribute nitrogen to nearby waterbodies. Natural background concentrations have been estimated at <0.037 mg/l NO_3+NO_2 (see **Section 6.5.1.1**) based on local reference data. Assuming a natural background concentration of <0.037 mg/L NO_3+NO_2 and a typical summertime baseflow of 5.4 cfs at site MFWF02 the average natural background NO_3+NO_2 load entering the segment is calculated by adding the estimated natural back ground load exiting Lake Levinsky at the head of the segment to the natural background load entering the segment downstream of Lake Levinsky.

The NO_3+NO_2 load exiting Lake Levinsky is calculated by using data from site MFWF01, ~150 yards downstream of Lake Levinsky: MFWF01 is assumed to represent water quality conditions as they exit Lake Levinsky. At a summertime average flow, the average summertime NO_3+NO_2 load at site MFWF01 is estimated at 1.05 lbs/day (flow=2.5cfs, 0.078 mg/L NO_3+NO_2). Appling estimated source load percentages given in Table 6-19, this corresponds to 0.26 lbs/day NO_3+NO_2 exiting from natural background sources. Between site MFWF01 and MFWF02, and the downstream end of the reach, average summer flows increase to 5.4 cfs, a 2.9 cfs addition from site MFWF01. At an estimated natural background concentration of 0.037 mg/L NO_3+NO_2, this corresponds to an average increase in natural background load of 0.58 lbs/day for a total natural background load of 0.84 lbs/day NO_3+NO_2 for the reach.

Anthropogenic Nitrogen Sources: Lower Middle Fork West Fork Gallatin River

Anthropogenic nutrient sources contributing to nitrogen concentrations in the lower Middle Fork West Fork Gallatin River are similar in type to those contributing to nitrogen loads in the upper segment; however they are of far less significance. Elevated NO_3+NO_2 concentrations coming from the Lake Levinsky outlet comprise the majority of the anthropogenic NO_3+NO_2 load entering this segment. Assessed NO_3+NO_2 source loads include:

- Lake Levinsky outlet
- residential and resort landscape management and maintenance
- on-site septic systems
- sewer or service line failure

Lake Levinsky Outlet

Nitrogen loads exiting Lake Levinsky were assessed by evaluating data from sampling site MFWF01, ~150 yards downstream from the Lake Levinksy outlet. The average NO_3+NO_2 concentration at sampling site MFWF01 is 0.078 mg/L (**Table 6-20**). Actual export concentration from the Lake Levinsky outlet may be higher, as algal growth was observed at and upstream from site MFWF01. At a summertime average flow, the average summertime NO_3+NO_2 load at site MFWF01 is estimated at 1.05 lbs/day (flow=2.5cfs, 0.078 mg/L NO_3+NO_2). Applying estimated source load percentages given in **Table 6-19** to Lake Levinsky outlet flows, this corresponds to 0.26 lbs/day NO_3+NO_2 (24.8%) from natural background sources, 0.02 lbs/day NO_3+NO_2 (1.9%) from septic sources and 0.77 lbs/day NO_3+NO_2 (73%) from residential and resort sources.

Residential and Resort Landscape Management and Maintenance

Residential and resort landscape management and maintenance NO_3+NO_2 sources in the lower Middle Fork West Fork Gallatin River are far less significant as a nitrogen source when compared to the Middle Fork upstream from Lake Levinsky. Riparian zones are largely intact and the stream corridor maintains much of its natural character. The Lone Moose Meadow subdivision above site MFWF05 is the only area developed into residential and resort land uses along the reach, however tributaries drain lands of the Spanish Peaks Resort which includes residential and golf-course development.

As water quality results throughout this reach showed, flows increase from 2.5 to 5.0 cfs while NO_3+NO_2 concentrations decrease from 0.078 to 0.024 due to both assimilation of nutrients and addition of nitrogen-poor water via tributary and groundwater inputs. While assimilation of nutrients within the reach makes it difficult to discern or measure additional nitrogen inputs from sampling data, given the low prevalence of developed land, NO_3+NO_2 loads from residential and resort landscape development activity do not appear to be significantly affecting reach-scale water quality. However, local nitrogen inputs associated with recent land clearing or maintenance activities may be present, and may influence local algal growth. Due to the low prevalence of developed lands and declining NO_3+NO_2 concentrations within the reach, NO_3+NO_2 loads from residential and resort development are believed to be of low significance throughout the reach and are not distinguished from natural background loads. Nitrogen loads derived from residential and resort development are accounted for within naturally occurring background load estimates.

On-site Septic Systems

With the exception of Lone Moose Meadows subdivision, most on-site septic systems in the lower Middle Fork West Fork Gallatin River are located away from stream corridors, and have low potential to significantly impact surface waters. Nitrate loads from on-site septic systems were assessed by MSU researchers using a nutrient export model algorithm designed to estimate soluble nitrogen (NO3) loading to streams from on-site septic systems (see description **Section 6.5.1.1.2**). Results estimate that nitrogen export from individual septic systems range from 7.5 to 28 g/day, which corresponds to ~ 0.0008 kg/ha/yr soluble nitrogen (NO_3+NO_2) reaching the lower Middle Fork West Fork Gallatin River during the low-flow summer months, an estimated 1.30% of the existing NO_3+NO_2 load for the segment. This load estimate assumes that septic systems are functioning according to septic design specifications and does not assume septic failure or malfunction.

Sewer or Service Line Failure

Compromised underground sewer and service lines are not uncommon to sewer systems, and have the potential to contribute e. coli loads to nearby waterbodies. Maintenance of sewer lines is conducted routinely by the Big Sky Water and Sewer District and water quality data did not show any apparent evidence that would link in-stream nitrogen concentrations with discrete sewer or service line failures. However, the proximity of sewer mainlines and residential service connections to the West Fork and Middle Fork West Fork of the Gallatin River (**Appendix A**, **Figure 6-9b**) does not rule out the potential for sewer or service line failure to impact surface waters. As in the upper segment, assuming that there are no discrete leaks or failures contributing to surface waters impacts, NO_3+NO_2 loads from sewer or service line failures are not significant and no load estimate is provided herein.

6.5.1.3 Nitrogen (NO_3+NO_2) Load Estimation Summary: Middle Fork West Fork Gallatin River

Table 6-21 summarizes existing loading conditions for the Middle Fork West Fork Gallatin River (below Lake Levinsky). Nitrogen (NO_3+NO_2) loading conditions were evaluated for the low-flow summertime (July-Sept) timeframe using water quality data and assessments conducted from 2005 through 2008, and represent NO_3+NO_2 loads at the downstream-most end of the segment (MFWF02). Load estimates are based on conditions sampled during this time frame and represent average observed conditions.

Table 6-21. Average summertime NO_3+NO_2 loading estimates for the Middle Fork West Fork Gallatin River

Source Category		Avg Load (lbs/day)	Total Load (%)
Lake Levinsky Outlet	*Natural*	0.26	15.7 %
	Residential/Resort	0.77	46.5 %
	Septic	0.020	1.2 %
Natural Background & Residential/Resort Landscape Management		0.58	35.0 %
On-site Septic Systems		0.027	1.3%
Cumulative		1.66 lbs/day	100%

6.5.1.4 Nitrite +Nitrate (NO_3+NO_2) Total Maximum Daily Loads: Middle Fork West Fork Gallatin River

As established in **Section 6.4**, NO_3+NO_2 Total Maximum Daily Loads are presented herein for the Middle Fork West Fork Gallatin River (MT41H005_050). A Total Maximum Daily Load (TMDL) is a calculation of the maximum pollutant load a waterbody can receive while maintaining water quality standards. The total maximum daily load (lbs/day) of NO_3+NO_2 is calculated using water quality target value established in **Section 6.4**. The total maximum daily NO_3+NO_2 load applies during the summer season (July 1st through Sept 30th) is based on an instream target value of 0.100 mg/L NO_3+NO_2 and the stream flow (**Figure 6-14**). TMDL calculations are based on the following formula:

TMDL = (X) (Y) (5.393)

TMDL= Total Maximum Daily Load NO_3+NO_2 *in lbs/day*
X= NO_3+NO_2 *water quality target in mg/L (0.100 mg/L)*
Y= streamflow in cubic feet per second
5.393 = conversion factor

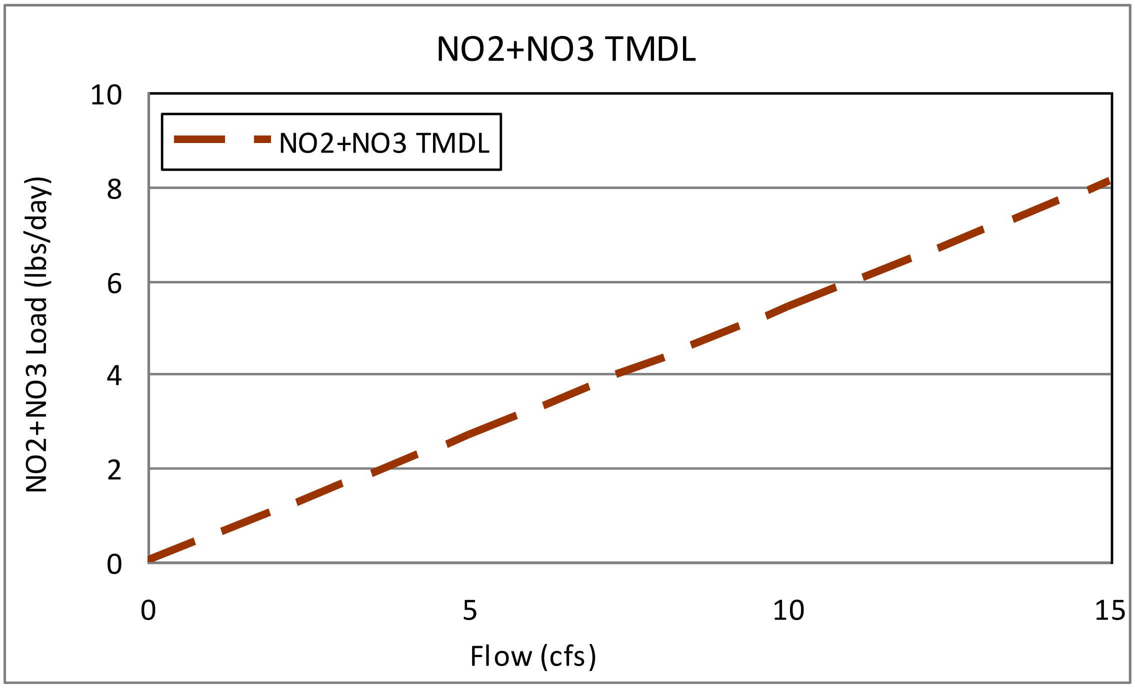

Figure 6-14. NO_3+NO_2 TMDL as a function of flow: Middle Fork West Fork Gallatin River

TMDL are allocated to point (wasteload) and nonpoint (load) NO_3+NO_2 sources. The TMDL is comprised of the sum of all point sources and nonpoint sources (natural and anthropogenic), plus a margin of safety that accounts for uncertainties in loading and receiving water analyses. In addition to pollutant load allocations, the TMDL must also take into account the seasonal variability of pollutant loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

These elements are combined in the following equation:

$$\mathbf{TMDL = \sum WLA + \sum LA + MOS}$$

Where:

- WLA = Waste Load Allocation or the portion of the TMDL allocated to point sources. Since there are no individual permitted point sources in the West Fork Gallatin watershed, the WLA=0.
- LA = Load Allocation or the portion of the TMDL allocated to nonpoint recreational/residential sources and natural background
- MOS = Margin of Safety or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. Where the MOS is implicit an additional numeric MOS is unnecessary; therefore the “explicit” MOS is set equal to 0 here.

6.5.1.5 Nitrite +Nitrate (NO_3+NO_2) Load Allocations: Middle Fork West Fork Gallatin River

For the Middle Fork West Fork Gallatin River (MT41H005_050) the NO_3+NO_2 TMDL is comprised of the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations and relevant NO_3+NO_2 nonpoint sources include natural background sources, septic sources, and a variety of diffuse sources associated with residential and resort development in the watershed. Due to the low significance of existing septic as a NO_3+NO_2 source, and septic's association with residential development sources, septic load allocations are included within the load allocation for residential and resort land use sources. Load allocations are therefore provided for 1) natural background sources and 2) cumulative septic and residential/recreational land use sources. In the absence of individual WLAs and an explicit MOS, NO_3+NO_2 TMDLs in the watershed are equal to the sum of the individual load allocations:

TMDL = LA_{NB} + $LAR_{ES+Septic}$

LA_{NB} = Load Allocation to natural background sources

$LAR_{ES+Septic}$ = Load Allocation to the combination of residential/recreational land use sources and septic sources

6.5.1.5.1 Natural Background Source Load Allocation

Load allocations for natural background sources are based on a natural background NO_3+NO_2 concentration of 0.037 mg/L (see **Section 6.5**), and are calculated using the equation:

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

LA_{NB}= NO_3+NO_2 *load allocated to natural background sources*

X= 0.037 mg/L natural background concentration

Y= streamflow in cubic feet per second

5.393 = conversion factor

6.5.1.5.2 Residential/Recreational Land Use and Septic Source Load Allocation

The load allocation to the combination of residential/recreational sources and septic sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

LARES+Septic = TMDL - LANB

6.5.1.6 NO_3+NO_2 Load Allocation Summary: Middle Fork West Fork Gallatin River

NO_3+NO_2 load allocations are provided for the Middle Fork West Fork Gallatin River (MT41H005_050) and include allocations to the following source categories: 1) natural background, and 2) the combination of residential/recreational land use and septic sources (**Table 6-2**2). **Figure 6-15** presents TMDLs and cumulative NO_3+NO_2 load allocations as a function of streamflow.

Table 6-22. NO_3+NO_2 load allocation descriptions, Middle Fork West Fork Gallatin River

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils & local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	$LA_{NB} = (X)(Y)(5.393)$ X= 0.037 mg/L natural background concentration Y= streamflow in cubic feet/second 5.393 = conversion factor
Combination of Residential and Recreational Land Use and Septic Systems	• vegetative decay from detritus derived from land clearing or land maintenance activities • landscape nutrient (fertilizer) application • general refuse inherent in residential resort development (pet waste, garbage, etc) • On-site septic systems	$LAR_{ES}+Septic = TMDL - LA_{NB}$

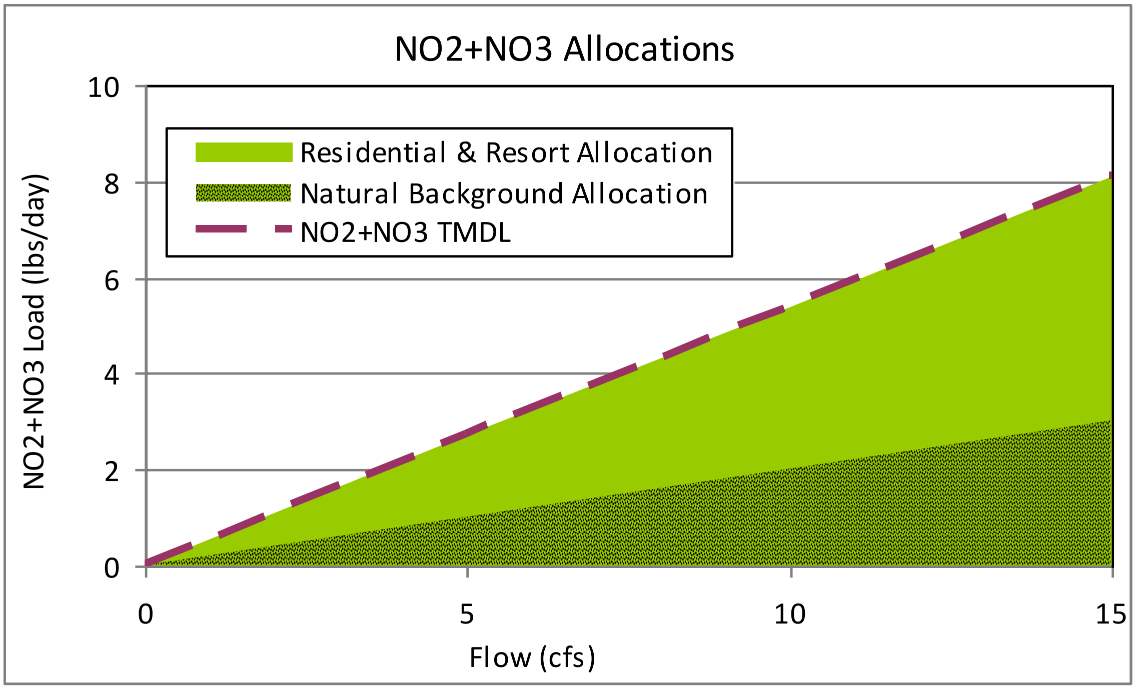

Figure 6-15. NO_3+NO_2 TMDL and Load Allocations, Middle Fork West Fork Gallatin River

Presently, NO_3+NO_2 cumulative load allocations (TMDLs) in the lower Middle Fork West Fork Gallatin River are being met at the downstream end of the segment (MFWF02), however loads entering the Middle Fork West Fork Gallatin River above Lake Levinsky are exceeding allowable NO_3+NO_2 loads. It appears that elevated NO_3+NO_2 concentrations entering the upper Middle Fork West Fork Gallatin River and Lake Levinsky are resulting in NO_3+NO_2 concentrations at the Lake Levinsky outlet that are manifesting as impacts to water quality (as evidenced by algal-growth) downstream from the lake outlet. Consequently, controlling and limiting NO_3+NO_2 loading from lands in the developed residential and resort areas above Lake

Levinsky are the focus of load reductions and should result in downstream waters meeting water quality targets for nitrogen and chlorophyll-*a*.

To illustrate, **Table 6-23** and **6-24** provide numeric loading estimates, TMDLs, allocations and NO_3+NO_2 reductions necessary to meet water quality targets for the upper and lower Middle Fork West Fork Gallatin River.

Table 6-23. Upper Middle Fork West Fork Gallatin River NO_3+NO_2 load allocations and TMDL*

Source Category	**Existing Load (lbs/day)**	**Allocation & TMDL (lbs/day)**	**Percent Reduction**
Natural Background	0.200 (25%)	0.20 (37%)	0%
Residential and Resort Landscape Management and Maintenance	0.589 (73%)	0.34 (63%)	44%
On-site Septic Systems	0.015 (2%)		
Total NO_3+NO_2 Load	**0.804 lbs/day**	**0.54 lbs/day (TMDL)**	**33%**

*based on average summertime flows (1.0 cfs) at site MFWF04

Table 6-24. Lower Middle Fork West Fork Gallatin River NO_3+NO_2 load allocations and TMDL

Source Category	**Existing Load (lbs/day)**	**Allocation & TMDL (lbs/day)**	**Percent Reduction**
Lake Levinsky Outlet	1.05	0.70 (24%)	33% (44% reduction in res/resort)
Natural Background	0.579	0.579 (20%)	0%
Residential/Resort Landscape Management		1.63 (56%)	
On-site Septic Systems	0.027		
Total NO_3+NO_2 Load	**1.66 lbs/day**	**2.91 lbs/day (TMDL)**	**0%**

*based on average summertime flows (5.4 cfs) at site MFWF02

The total maximum daily load of NO_3+NO_2 in the upper Middle Fork West Fork Gallatin River is calculated to be 0.54 lbs/day. Existing NO_3+NO_2 loading to the upper Middle Fork is estimated at 0.804 lbs/day (**Section 6.5.1.1**), requiring a total load reduction of 33% in order to meet the NO_3+NO_2 TMDL (see **Table 6-23**) for the upper segment. Load allocations and load reductions are specifically designated to the combination of 1) residential and resort landscape management and maintenance loads and 2) septic loads, which make up an estimated 75% of the NO_3+NO_2 load entering the upper segment. As septic loads associated with the allocation category are rather small (<2%), load reductions should focus on limiting and controlling NO_3+NO_2 loads from the variety of sources associated with residential and resort development.

It is believed that reducing loads from these sources in the upper Middle Fork segment, as well as other tributaries entering Lake Levinsky, will result in lower NO_3+NO_2 concentrations at the outlet of Lake Levinsky and will mitigate algal growth impacts in the lower segment. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions, and is addressed in **Section 8.0**.

6.5.2 West Fork Gallatin River (MT41H005_040)

The West Fork Gallatin River begins where the North Fork West Fork Gallatin River flows into the Middle Fork West Fork Gallatin River downstream of sampling site MFWF02 (**Figure 6-5**), and flows ~3.7 miles to its confluence with the Gallatin River. The South Fork West Fork Gallatin River flows into the West Fork Gallatin River about one mile upstream from the mouth, and more than doubles the flow of the West Fork Gallatin during summer base-flow conditions. Land use along the West Fork Gallatin River consists primarily of recreational, residential and commercial development, and includes seasonal and year-long residences, commercial shopping areas, a golf course, water treatment facility and lagoons, and recreational parks and pavilions. No permitted point sources (individual MPDES permits) of nutrients exist, although wastewater effluent from the Big Sky Water and Sewer District (BSWSD) treatment lagoons is applied to the Big Sky Golf Course, under land application guidelines issued by the DEQ (MDEQ, 1999).

The segment exceeded nutrient water quality targets for total nitrogen (TN), Nitrate+Nitrite (NO_3+NO_2) and chlorophyll-*a*: TMDLs are therefore presented herein for pollutants TN and NO_3+NO_2. Because TN exceedences are primarily the result of elevated NO_3+NO_2 concentrations, source characterizations for this segment focus on assessing soluble nitrogen (NO_3+NO_2) sources and estimating NO_3+NO_2 loads from natural and anthropogenic nitrogen sources. **While soluble nitrogen (NO_3+NO_2) is the primary constituent causing impairment conditions, TMDLs are prepared for both nitrogen fractions, NO_3+NO_2 and TN, with the understanding that reductions in NO_3+NO_2 loading will result in both NO_3+NO_2 and TN TMDLs being met.**

Summertime flows at the mouth of the West Fork Gallatin River reach an average peak of ~ 500 cfs in early July and attenuate to baseflows of <20cfs in late August through September (PBS&J, 2009). **Table 6-25** presents average monthly measured flows above and below the South Fork Gallatin River confluence from 2006-2008. Daily stream flows through the segment are rather constant from the head of the reach (WFGR01) to the South Fork West Fork Gallatin River confluence, where flows from the South Fork provide significant flow augmentation to the lower West Fork Gallatin River.

Table 6-25. Average monthly measured stream flows: West Fork Gallatin River 2006-2008

	Upper West Fork Gallatin River Flow	South Fork West Fork Gallatin River Flow	Lower West Fork Gallatin River Flow
July	66	123	173
August	15	20	33
September	8	9	18

NO_3+NO_2 concentrations were within natural background concentrations at the head of the reach (WFGR01) and increase through the golf course (WFGR05, WFGR04). Concentrations decrease slightly downstream from the BSWSD wastewater treatment lagoons (WFGR02). NO_3+NO_2 concentrations at the mouth of the West Fork Gallatin River (WFGR03) decrease further as flows from the South Fork West Fork Gallatin River provide dilution of NO_3+NO_2 concentrations. **Table 6-26** and **Figure 6-16** present summary statistics of NO_3+NO_2 concentrations at sampling sites on the West Fork Gallatin River.

Table 6-26. Summertime NO_3+NO_2 Summary Statistics for sampling sites on the West Fork Gallatin River (units in mg/L)

Site	n	min	max	mean	25th Percentile	median	75th Percentile
WFGR01	7	0.001	0.046	0.020	0.012	0.020	0.024
WFGR05	4	0.004	0.060	0.033	0.008	0.034	0.058
WFGR04	5	0.019	0.260	0.131	0.040	0.136	0.200
WFGR02	29	0.005	0.574	0.116	0.033	0.094	0.150
WFGR03	21	0.002	0.160	0.043	0.010	0.036	0.064

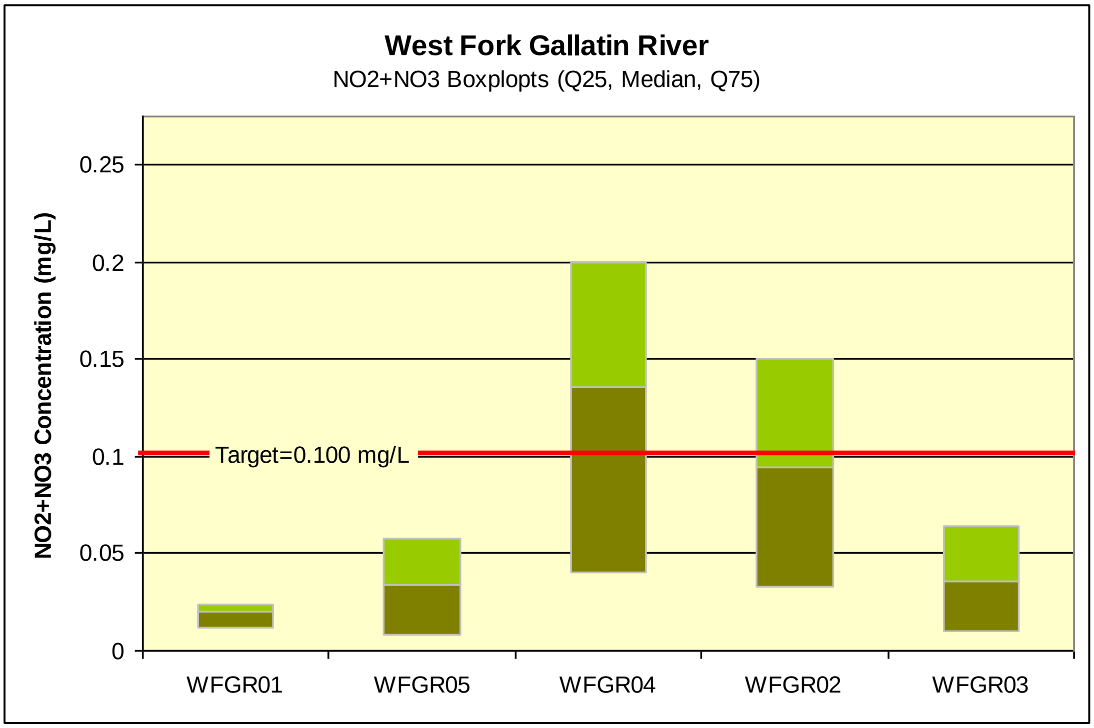

Figure 6-16. NO_3+NO_2 Boxplots: West Fork Gallatin River

Algal concentrations (chlorophyll-*a*) from samples collected in 2005 and 2008 show a corresponding trend (**Figure 6-17**), with low algal densities at the head of the segment (WFGR01) and increasing algal densities through the segment as nitrogen entering the segment is assimilated through algal growth.

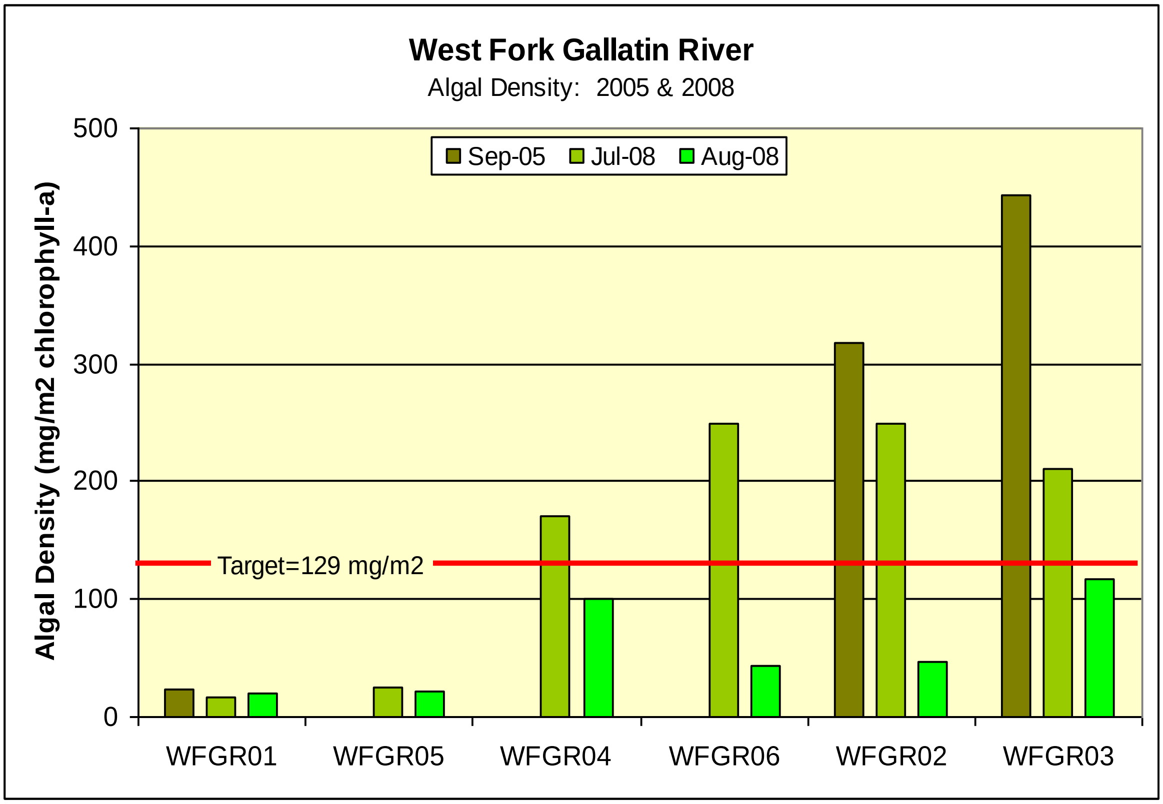

Figure 6-17. Chlorophyll-*a* Concentrations: West Fork Gallatin River

Nitrogen and algal concentrations at the head of the segment are meeting water quality targets for NO_3+NO_2 and chlorophyll-*a*. As the stream flows through the golf course at Meadow Village, average NO_3+NO_2 concentrations increase six-fold from WFGR01 to WFGR04. Consequently, algal densities from WFGR01 to the mouth increase substantially (**Figure 6-17**) as nitrogen loads entering the stream are assimilated by in-stream algae. While algal densities observed in August of 2008 appear low based on chlorophyll-*a* concentrations, algal biomass was very high (>500g/m2 AFDW), indicating that late summer senescent algal communities contributed to excessive biomass through the reach. **Figures 6-17a through 6-17h** show algal conditions observed in August of 2008 and show that while chlorophyll-*a* concentrations were low, algal biomass during late August 2008 was within 'nuisance' levels.

Figure 6-18 illustrates August average NO_3+NO_2 loading conditions and flows observed in the West Fork Gallatin River from 2005 through 2008.

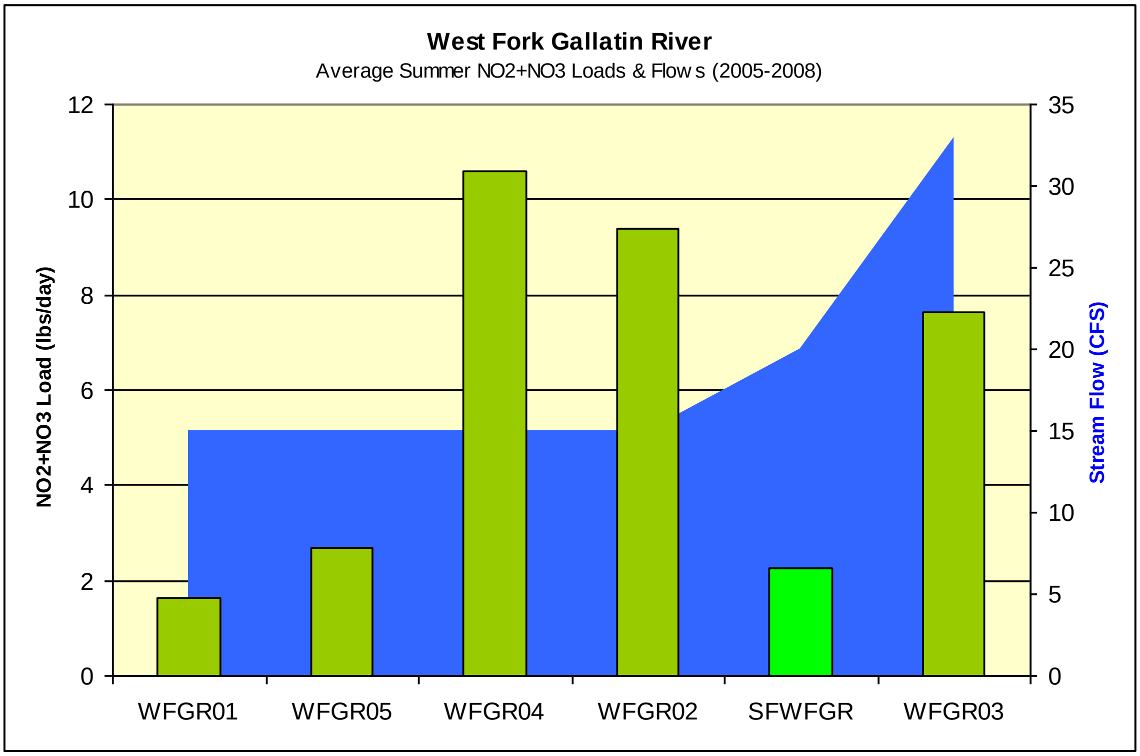

Figure 6-18. Average August NO_3+NO_2 Loads, West Fork Gallatin River 2005-2008.

Average August NO_3+NO_2loads increase from 1.6 lbs/day at site WFGR01 to 10.6 lbs/day at site WFGR04, an average increase of 9.0 lbs/day, during August. Individual August synoptic sampling events are presented in **Appendix A**, **Figures 6-19 through Figure 6-21** and show loading increases through the segment upstream of the South Fork range from 5.5 lbs/day to over 20 lbs/day NO_3+NO_2. Stream flows through the segment upstream of the South Fork (SFWFGR) confluence are relatively constant (~15cfs), indicating a significant hi-concentration NO_3+NO_2 ground-water load entering the reach through the area of the golf course. Complicating estimation of NO_3+NO_2 loads entering the West Fork Gallatin River is in-stream assimilation and retention of NO_3+NO_2 loads by algae. High algal densities through the reach indicate that some NO_3+NO_2 load is being taken up by algal growth and converted to biomass, suggesting that actual NO_3+NO_2 loads entering the reach are greater than loads measured from in-stream nitrogen measurements.

Natural and anthropogenic sources contributing to NO_3+NO_2 loads entering the reach are described below. Numeric load estimates to specific source categories are provided and form the basis for nitrogen load allocations given in **Section 6.5.2.5**.

6.5.2.1 Naturally-occurring Nitrogen Sources: West Fork Gallatin River

Naturally-occurring background sources of nitrogen include a variety of natural processes and sources and may include: soils & local geology, natural vegetative decay, wet and dry airborne deposition, wild animal waste, and other biochemical processes that contribute nitrogen to nearby water bodies. Background concentrations have been estimated at <0.037 mg/l NO_3+NO_2

(see **Section 6.5.1.1**) based on local reference data. Assuming a naturally-occurring background concentration of <0.037 mg/L NO_3+NO_2 and a typical August baseflow of 33 cfs at the mouth of the West Fork Gallatin River (WFGR03) the average background NO_3+NO_2 load to the segment is calculated to be 6.6 lbs/day. This load includes the NO_3+NO_2 load entering the segment from the South Fork West Fork Gallatin River as NO_3+NO_2 concentrations at the mouth of the South Fork are within natural background concentrations (75th percentile = 0.020 mg/L).

6.5.2.2 Anthropogenic Nitrogen Sources: West Fork Gallatin River

Anthropogenic nitrogen sources contributing to nitrogen loading in the West Fork Gallatin River were assessed using water quality data collected from 2005 through 2008. Water quality data collection was conducted during summertime low flows and represents a base-flow condition that is dominated by low-flow groundwater inputs that are connected hydrologically to the stream. Sources contributing nitrogen loads during these time periods are those sources derived from sources that would contribute nitrogen loads primarily through groundwater pathways, and do not include storm water runoff loads.

Anthropogenic nutrient sources within this reach are believed to consist of a variety of variable sources and include nitrogen derived from:

- upstream sources, the Middle Fork West Fork Gallatin River and the North Fork West Fork Gallatin River
- residential & commercial lawn and landscape management
- wastewater from wastewater effluent land-applied to the Big Sky Golf Course
- wastewater from sewer or service line failures or leaks

Upstream Sources
The West Fork Gallatin River segment begins at the confluence of the Middle Fork West Fork Gallatin River and the North Fork West Fork Gallatin River. Water volume at the head of the West Fork is comprised of the cumulative flows of these two segments. Water quality at the head of the segment is evaluated by using water quality data collected at site WFGR01. Statistical summaries of NO_3+NO_2 data collected at this site are provided in **Table 6-26,** and show median and 75th percentile values to be within naturally occurring background concentrations. Accordingly, NO_3+NO_2 loads entering the segment are included within the natural background load calculated at the mouth (**Section 6.5.2.1**).

Residential & Resort Landscape Management Sources
General residential and resort landscape management nitrogen sources in the West Fork Gallatin River include a variety of variable and diffuse NO_3+NO_2 sources associated with widespread land clearing and development and may include nitrogen derived from:

- vegetative decay of detritus derived from land clearing or land maintenance activities
- residential landscape fertilizer application
- general refuse inherent in residential resort development (animal waste, garbage, etc)

Residential and resort landscape management activities within the segment that have the greatest potential as nitrogen sources include those associated with the Big Sky Golf Course and residential properties adjacent to the West Fork Gallatin River. Turf management activities at the Big Sky Golf Course include summertime application of treated wastewater effluent from the Big Sky Water & Sewer District's wastewater lagoons, located just downstream of the golf course. Water quality sampling data and modeling analysis of effluent loads applied to the golf course provides strong evidence that load increases observed through the segment (**Figures 6-16 through 6-18**) are primarily the result of wastewater effluent, and are evaluated below as a wastewater source and not included as a component of landscape management nitrogen sources for the purpose of TMDL source assessment and load allocations.

Potential for additional baseflow inputs from residential NO_3+NO_2 sources through the segment exist, however it is believed that these additional inputs are of low significance in comparison to wastewater-derived NO_3+NO_2 loads measured in the segment and do not pose immediate threats to water quality. Non-wastewater residential NO_3+NO_2 loads fall within the range of naturally-occurring NO_3+NO_2 concentrations (<0.037 mg/L) and are therefore included within the NO_3+NO_2 load estimate provided for naturally-occurring NO_3+NO_2 sources.

Wastewater Sources

A variety of methods were used to evaluate the magnitude and spatial distribution of wastewater sources within the segment, including water quality modeling, isotope data, and seasonal synoptic water quality sampling. Wastewater NO_3+NO_2 sources assessed within the segment include 1) on-site septic systems, 2) wastewater effluent land-applied to the Big Sky Golf Course and 3) sewer infrastructure failure. Sources and assessment methods are described in more detail below.

On-site Septic Systems

Most residential and commercial properties within the West Fork Gallatin River watershed are served by a central sewer system (**Appendix A**, **Figure 6-9b**) The number of on-site septic systems are few and located mainly in the lower third of the segment.

Nitrogen loads from on-site septic systems were assessed by MSU researchers (Gardner et al., in review) using a nutrient export model algorithm designed to estimate soluble nitrogen (NO_3) loading to streams from on-site septic systems (see description **Section 6.5.1.1.2**). Results estimate that nitrogen export from individual septic systems range from 7.5 to 28 g/day, which corresponds to ~ 0.0006 kg/ha/yr soluble nitrogen (NO_3+NO_2) reaching the West Fork Gallatin River during the low-flow summer months, an estimated 0.4% of the existing NO_3+NO_2 load for the segment. This load estimate assumes that septic systems are functioning according to septic design specifications and does not assume septic failure or malfunction. Due to the non-significance of on-site septic systems as a nitrogen source, no numeric load estimate is provided.

Wastewater from Land Application and Sewer Infrastructure

The Big Sky Golf Course irrigates its grounds using treated wastewater supplied by the Big Sky Water & Sewer District. Spray-irrigated effluent is designed to have zero discharge to both ground and surface water. Spray irrigation systems are designed and approved by the DEQ to 1) apply wastewater at agronomic uptake rates for nitrogen assimilation into turf grass and 2) limit application to rates that will be wholly taken up and used by turf within the root zone by evapotranspiration or plant growth. Proper design, maintenance, and continued operation prevent wastewater from percolating to ground water or flowing overland or through subsurface soil to nearby streams or water bodies. The design and operation of the wastewater irrigation system is based on design principles specified in the *Environmental Protection Agency (EPA) Process Design Manual: Land Treatment of Municipal Wastewater, and incorporated into Circular DEQ2: Design Standards for Wastewater Facilities* (DEQ, 1999).

While wastewater treatment facilities that utilize effluent for spray irrigation disposal are approved/permitted by meeting design standards specified in DEQ2, if it is determined that effluent is reaching state waters (either ground water or surface water), a discharge permit may be required by the DEQ. It is incumbent on the Biog Sky Water & Sewer District and land-application managers to ensure that design specifications are adhered to in daily and seasonal management and application plans so that nitrogen from wastewater effluent does not reach state waters. Land-applied effluent guidelines include (DEQ, 1999 – **Appendix B**):

- establishment of spray-irrigation buffer zones to nearby streams (as determined on a case-by-case basis)
- establishment of maximum-allowable wind velocities during operation to ensure that spray-irrigation is applied directly to approved zones
- effluent and groundwater monitoring
- development of a spray-irrigation operation and management plan
- records management of application rates & volumes, effluent concentrations, and timing of spray-irrigation.

Application of wastewater to the Big Sky Golf Course is typically conducted from early summer (May-June) through October. NO_3+NO_2 load increases and high algal densities observed in the West Fork Gallatin River through the reach adjacent to the Big Sky Golf Course led DEQ to investigate wastewater from spray irrigation as a potential source of nitrogen contributing to in-stream conditions. Spray irrigation contributions were evaluated both qualitatively through site visits and on-site investigations, and quantitatively through land- application and groundwater export modeling, and through collection and analysis of isotope samples and water quality measurements.

During field visits and sampling activity conducted by DEQ personnel, deficiencies in the design and implementation of the wastewater spray irrigation system were evident and contributed to direct discharge of wastewater to the adjacent West Fork Gallatin River through cross drains (**Appendix A**, **Figures 6-24** and **6-25**) and direct sprinkler discharge. Observations indicate that wastewater derived nitrogen load increases in the segment may be partially influenced at times by direct surface discharge through cross drains and improperly managed sprinkler heads, or by inadequately buffered or located sprinkler systems, and should be used to inform future management and implementation of spray-irrigation procedures.

To evaluate the potential groundwater nitrogen load to the West Fork Gallatin River from the application of wastewater effluent on the Big Sky Golf Course, MSU researchers used land-application data (volumes and concentrations of wastewater applied to the golf course) supplied by the BSWSD to model soluble nitrogen (NO_3) loading to the subsurface and subsequently to the nearby West Fork Gallatin River (Gardner, et al, in review). Results estimate that nitrogen export from wastewater effluent sources accounts for 61% of the instream NO3 load in the West Fork Gallatin River upstream of the South Fork West Fork Gallatin River confluence.

In conjunction with nitrogen export modeling, MSU researchers utilized isotopic analysis of water quality samples to further evaluate wastewater loading to the stream. Isotopic analysis of $\delta^{15}N$ and $\delta^{18}O$ of the nitrate (NO_3) fraction in water quality samples has shown to be successful in identifying wastewater N sources, and to distinguish wastewater N sources from other isotopically distinct source signatures (Campbell et al, 2002; Kendall and McDonnell, 1998). Because wastewater is enriched in $\delta^{15}N$ in comparison to other sources of nitrogen, δ15N can be used to distinguish wastewater-derived N loads from other distinct N sources (mineral weathering, fertilizer application, or atmospheric deposition.)

Results of isotopic analysis from water samples collected through the Big Sky Golf Course at Meadow Village exhibited an isotopically distinct $\delta^{15}N$ signature (enriched δ15N) commonly associated with wastewater. Based on isotopic data collected, calculated wastewater NO_3 load contribution to the West Fork Gallatin River upstream of its confluence with the South Fork were 85% of the total instream load in the summer and 68% of the total load in the winter (Gardner et al, in preparation).

Additionally, synoptic sampling events conducted by DEQ confirm an average increase of 9.0 lbs/day (**Figure 6-18**) NO_3+NO_2 through the golf course during the summer months (July-Sept). This corresponds to 85% of the total NO_3+NO_2 load for the segment and correlates well with both the results of isotope analysis (85% wastewater contribution) and modeling results (61% wastewater contribution).

While it can be confidently concluded that wastewater is the source of nitrogen load increases through the Meadow Village reach, several unknowns complicate precise determination of nitrogen sourcing through the reach. Land application of wastewater effluent occurs during the summer months, however wastewater contributions during non-irrigation seasons (late fall and winter) are substantial, as observed by δ15N isotope data, and by synoptic sampling events conducted in November and March (**Appendix A**, **Figures 6-22** and **6-23**). It is possible that sewer or service line failure or leaks may be contributing substantially to nitrogen loads through the segment, or that groundwater loading from spray-irrigation is affecting the stream during non-irrigation periods.

Wastewater-nitrogen load estimates are calculated using empirical data, rather than modeled results. The average August NO_3+NO_2 load increase from the head of the segment (WFGR01) derived from water quality data is 9.0 lbs/day (**Figure 6-18**), which is 85% of the total NO_3+NO_2 load for the reach. Independent isotope data analysis also showed that 85% of the total NO_3 load for the reach was wastewater-sourced. The average NO_3+NO_2 load from wastewater sources is therefore estimated at 9.0 lbs/day.

6.5.2.3 NO_3+NO_2 Load Estimation Summary: West Fork Gallatin River

Table 6-27 summarizes existing loading conditions for the West Fork Gallatin River. Nitrogen (NO_3+NO_2) loading conditions were evaluated for the low-flow summertime (August) timeframe using water quality data and assessments conducted from 2005 through 2008, and represent NO_3+NO_2 loads at the downstream-most end of the segment (WFGR3). Load estimates are based on conditions sampled during this time frame and represent average observed conditions.

Table 6-27. Average summertime NO_3+NO_2 loading estimates for the West Fork Gallatin River

Source Category	Avg Load* (lbs/day)	Total Load (%)
Naturally-occurring Background & Residential/Resort Landscape Management	6.6	42%
Wastewater	9.0	58%
Cumulative	15.6 lbs/day	100%

*based on average August flow of 33 cfs at site WFGR03

6.5.2.4 Total Nitrogen and Nitrite +Nitrate (NO_3+NO_2) Total Maximum Daily Loads: West Fork Gallatin River

As established in **Section 6.4**, Total Maximum Daily Loads are presented herein for the West Fork Gallatin River (MT41H005_040). A Total Maximum Daily Load (TMDL) is a calculation of the maximum pollutant load a water body can receive while maintaining water quality standards. Total maximum daily loads (lbs/day) are calculated using water quality target value established in **Section 6.4**. Nitrogen TMDLs apply during the summer season (July 1st through Sept 30th) and are based on an instream target values of 0.100 mg/L NO_3+NO_2 and 0.320 mg/L TN. **Figure 6-26** shows TMDLs as a function of flow for TN and NO_3+NO_2. TMDL calculations are based on the following formula:

TMDL = (X) (Y) (5.393)

TMDL= Total Maximum Daily Load NO_3+NO_2 in lbs/day
X= TN or NO_3+NO_2 water quality target in mg/L
Y= streamflow in cubic feet per second
5.393 = conversion factor

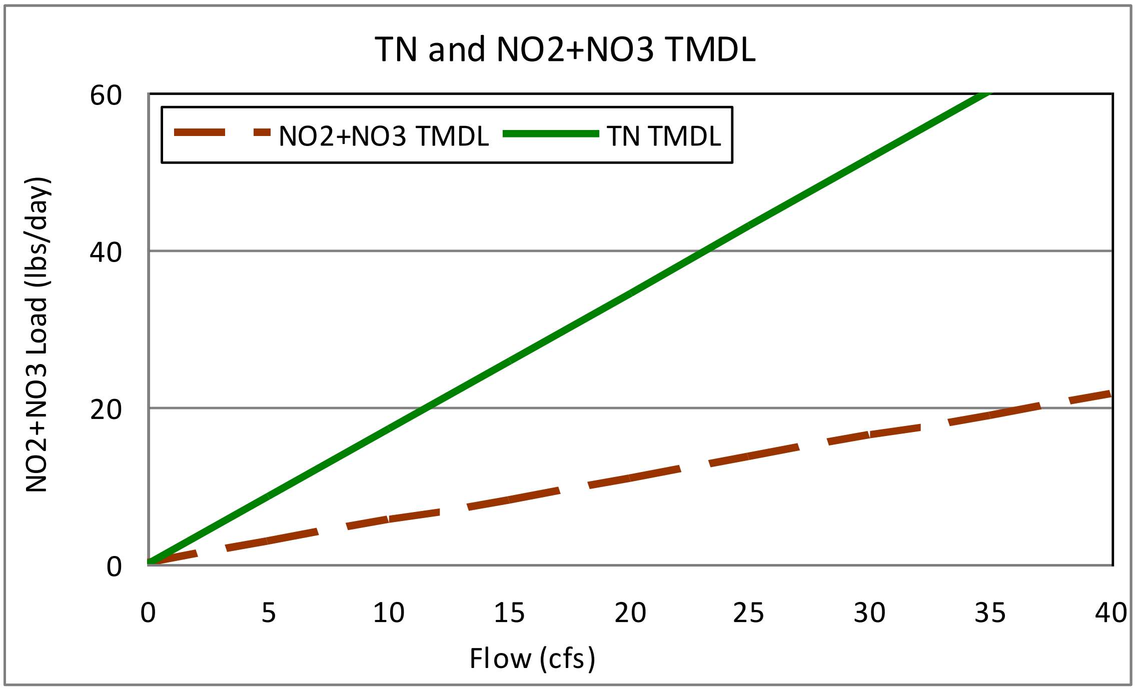

Figure 6-26. TN and NO_3+NO_2 TMDLs as a function of flow

TMDL are allocated to point (wasteload) and nonpoint (load) NO3+NO2 sources. The TMDL is comprised of the sum of all point sources and nonpoint sources (natural and anthropogenic), plus a margin of safety that accounts for uncertainties in loading and receiving water analyses. In addition to pollutant load allocations, the TMDL must also take into account the seasonal variability of pollutant loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

These elements are combined in the following equation:

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

Where:

- WLA = Waste Load Allocation or the portion of the TMDL allocated to point sources. Since there are no individual permitted point sources in the West Fork Gallatin watershed, the WLA=0.
- LA = Load Allocation or the portion of the TMDL allocated to nonpoint recreational/residential sources and natural background
- MOS = Margin of Safety or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. Where the MOS is implicit an additional numeric MOS is unnecessary; therefore the “explicit” MOS is set equal to 0 here.

6.5.2.5 NO_3+NO_2 Load Allocations: West Fork Gallatin River

For the West Fork Gallatin River (MT41H005_040) the NO_3+NO_2 TMDL is comprised of the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations and relevant NO_3+NO_2 sources include natural background sources, wastewater sources, and a variety of diffuse sources associated with residential and resort development. Due to the low significance of existing septic as a NO_3+NO_2 source and septic's association with residential development sources, septic load allocations are not significant and are included within the cumulative load allocation for residential and resort land use sources. Load allocations are therefore provided for 1) natural background sources 2) wastewater and 3) cumulative septic and residential/recreational land use sources. In the absence of individual WLAs and an explicit MOS, NO_3+NO_2 TMDLs in the watershed are equal to the sum of the individual load allocations as follows:

$TMDL = LA_{NB} + LA_{WW} + LAR_{ES+Septic}$

LA_{NB} = *Load Allocation to natural background sources*
LA_{WW} = *Load Allocation to wastewater sources*
$LAR_{ES+Septic}$ = *Load Allocation to the combination of residential/recreational land use sources and septic sources*

6.5.2.5.1 Natural Background Source Load Allocation

Load allocations for natural background sources are based on a natural background NO3+NO2 concentration of 0.037 mg/L (see **Section 6.5**) and are dependent on streamflow. Load allocations to natural background sources are calculated as follows:

$LA^{NB} = (X)(Y)(5.393)$

LA^{NB}= NO^3+NO^2 *load allocated to natural background sources in pounds per day*
X= 0.037 mg/L natural background concentration
Y= streamflow in cubic feet per second
5.393 = conversion factor

6.5.2.5.2 Wastewater Source Load Allocation

Wastewater sources include both spray-irrigated wastewater applied to the Big Sky Golf Course and potential sewer or service line disruptions. Spray-irrigated wastewater systems must adhere to design standards and not allow discharge to either surface waters or ground water. Likewise, wastewater discharges from leaking or failing sewer system infrastructure are not allowed. The NO_3+NO_2 load allocation to these sources is therefore zero pounds/day at all flows.

$LA_{ww} = 0$ **lbs/day**

6.5.2.5.3 Residential/Recreational Land Use and Septic Source Load Allocation

The load allocation to the combination of residential/recreational sources and septic sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load as follows:

$LA_{RES+Septic} = TMDL - LA_{NB}$

6.5.2.5.4 NO_3+NO_2 Load Allocation Summary

NO_3+NO_2 load allocations are provided for the West Fork Gallatin River (MT41H005_040) and include allocations to the following source categories: 1) natural background, 2) wastewater and 3) the combination of residential/recreational land use and septic sources (**Table 6-28**). Because allowable loads are a function of stream flow, load allocations are provided as equations. **Figure 6-27a** presents TMDLs and NO_3+NO_2 load allocations as a function of streamflow.

Table 6-28. NO_3+NO_2 load allocation descriptions, West Fork Gallatin River

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils & local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby water bodies.	**LA_{NB} = (X) (Y) (5.393)**
Wastewater	• Wastewater from spray-irrigated effluent applied to the Big Sky Golf Course • Wastewater from failing sewer or service line infrastructure	**LA_{WW} = 0 lbs/day**
Combination of Residential and Recreational Land Use and Septic Systems	• vegetative decay from detritus derived from land clearing or land maintenance activities • landscape nutrient (fertilizer) application • general refuse inherent in residential resort development (pet waste, garbage, etc) • On-site septic systems	**$LA_{RES+Septic}$ = TMDL - LA_{NB}**

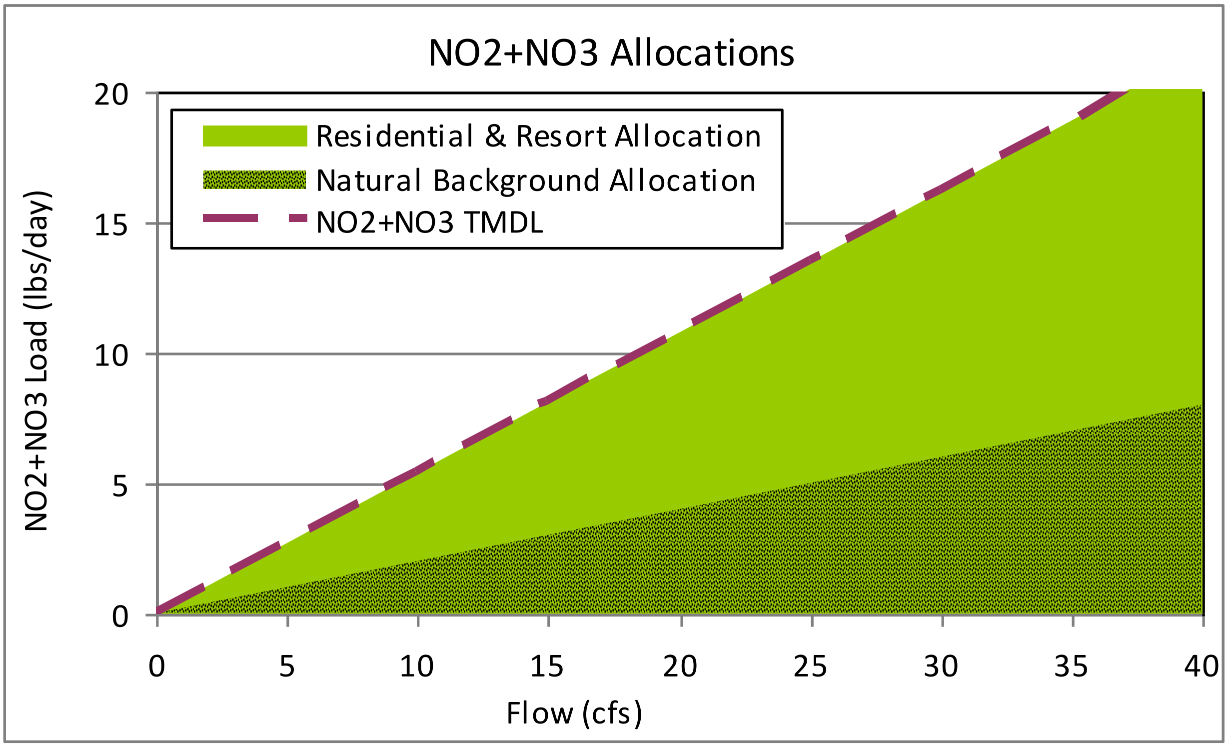

Figure 6-27a. NO_3+NO_2 TMDL and Load Allocations, West Fork Gallatin River

Presently, NO_3+NO_2 load allocations in the West Fork Gallatin River are being met for natural background sources, and for the combination of residential/resort and septic sources. Wastewater loads entering the West Fork Gallatin River through the area of the Big Sky Golf Course are the predominant source affecting impairment through the segment and are responsible for load increases observed above the South Fork West Fork confluence. It is expected that eliminating wastewater loads to the reach above the South Fork will result in the entire segment meeting the TMDL for NO_3+NO_2. Below the South Fork, water quality improves as the low-nitrogen waters of the South Fork dilute the West Fork Gallatin River. To illustrate loading conditions and TMDLs, **Table 6-29** and **6-29** provide numeric loading estimates, TMDLs, allocations and NO_3+NO_2 reductions necessary to meet water quality targets for the West Fork Gallatin River. Loading estimates in **Table 6-29** and **6-30** are based on average August flows in the West Fork Gallatin River. **Table 6-29** shows loading estimates and allocations for the West Fork upstream of the South Fork, while **Table 6-30** shows loading estimates and allocations for the West Fork downstream of the South Fork.

Table 6-29. West Fork Gallatin River NO_3+NO_2 load allocations and TMDL* upper reach

Source Category	Existing Load (lbs/day)	Allocation & TMDL (lbs/day)	Percent Reduction
Natural Background	3.0	3.0	NA
Residential and Resort Landscape Management and Maintenance		5.1	NA
On-site Septic Systems	negligible		
Unpermitted Wastewater	9.0	0	100%
Total NO_3+NO_2 Load	**12.0**	**8.1 (TMDL)**	**33%**

**based on average August flows (15.0 cfs) upstream of the South Fork West Fork Gallatin River*

Table 6-30. West Fork Gallatin River NO_3+NO_2 load allocations and TMDL* lower reach

Source Category	Existing Load (lbs/day)	Allocation & TMDL (lbs/day)	Percent Reduction
Natural Background	6.6	6.6	NA
Residential and Resort Landscape Management and Maintenance		11.2	NA
On-site Septic Systems	negligible		
Unpermitted Wastewater	9.0	0	100%
Total NO_3+NO_2 Load	**15.6**	**17.8 (TMDL)**	**NA**

**based on average August flows (33.0 cfs) downstream of the South Fork West Fork Gallatin River*

The total maximum daily load of NO_3+NO_2 in the West Fork Gallatin River is calculated to be 17.8 lbs at the mouth and is presently being met under average august conditions (**Table 6-30**) due to the dilution provided by the South Fork West Fork Gallatin River. Upstream of the South Fork, however, wastewater loading to the reach results in exceedences of the NO_3+NO_2 TMDL, and contributes to excessive downstream algal growth. Loading allocations and reductions, therefore, focus on eliminating wastewater sources in this upper reach. By eliminating wastewater inputs to the upper reach, NO_3+NO_2 TMDLs will be met for the entire segment of the West Fork Gallatin River.

Meeting TMDLs and load allocations may be achieved through a variety of water quality planning and implementation actions, and are addressed in **Section 8.0**.

6.5.2.6 Total Nitrogen Load Allocations: West Fork Gallatin River

Soluble nitrogen (NO_3+NO_2) is the primary constituent causing impairment conditions in the West Fork Gallatin River. High total nitrogen values measured in the West Fork Gallatin River are primarily the result of high NO_3+NO_2 concentrations from wastewater derived NO_3+NO_2 (see **Section 6.5.2.2**). Therefore, TMDLs are prepared for both nitrogen fractions, NO_3+NO_2 and TN, with the understanding that elimination of wastewater NO_3+NO_2 loading will result in TN TMDLs being met.

Similar to NO_3+NO_2 load allocations, TN load allocations are provided for 1) natural background sources 2) wastewater and 3) cumulative septic and residential/recreational land use sources. In the absence of individual WLAs and an explicit MOS, the TN TMDL is equal to the sum of the individual load allocations as follows:

$TMDL = LA_{NB} + LA_{WW} + LA_{RES+Septic}$

LA_{NB} = Load Allocation to natural background sources
LA_{WW} = Load Allocation to wastewater sources
$LA_{RES+Septic}$ = Load Allocation to the combination of residential/recreational land use sources and septic sources

6.5.2.6.1 Natural Background Source Load Allocation

TN load allocations for natural background sources are based on a natural background TN concentration of 0.050 mg/L measured in late august at the head of the West Fork Gallatin River (site WFGR01), and is believed to approximate naturally-occurring water quality conditions. Load allocations to natural background sources are calculated as follows:

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

LA_{NB}= TN load allocated to natural background sources in pounds per day
X= 0.050 mg/L natural background TN concentration
Y= streamflow in cubic feet per second
5.393 = dimensionless conversion factor

6.5.2.6.2 Wastewater Source Load Allocation

Wastewater sources include both spray-irrigated wastewater applied to the Big Sky Golf Course and potential sewer or service line disruptions. Spray-irrigated wastewater systems must adhere to design standards and not allow discharge to either surface waters or ground water. Likewise, wastewater discharges from leaking or failing sewer system infrastructure are not allowed. The TN load allocation to these sources is therefore zero pounds/day at all flows.

$LA_{ww} = 0$ lbs/day

6.5.2.6.3 Residential/Recreational Land Use and Septic Source Load Allocation

The load allocation to the combination of residential/recreational sources and septic sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load as follows:

$LA_{RES+Septic} = TMDL - LA_{NB}$

6.5.2.7 TN Load Allocation Summary: West Fork Gallatin River

TN load allocations are provided for the West Fork Gallatin River (MT41H005_040) and include allocations to the following source categories: 1) natural background, 2) wastewater and 3) the combination of residential/recreational land use and septic sources (**Table 6-31**). Because allowable loads are a function of stream flow, load allocations are provided as equations. **Figure 6-27b** presents TMDLs and TN load allocations as a function of streamflow.

Table 6-31. TN load allocation descriptions, West Fork Gallatin River

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils & local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby water bodies.	LA_{NB} = (X) (Y) (5.393)
Wastewater	• Wastewater from spray-irrigated effluent applied to the Big Sky Golf Course • Wastewater from failing sewer or service line infrastructure	LA_{WW} = 0 lbs/day
Combination of Residential and Recreational Land Use and Septic Systems	• vegetative decay from detritus derived from land clearing or land maintenance activities • landscape nutrient (fertilizer) application • general refuse inherent in residential resort development (pet waste, garbage, etc) • On-site septic systems	$LA_{RES+Septic}$ = TMDL - LANB

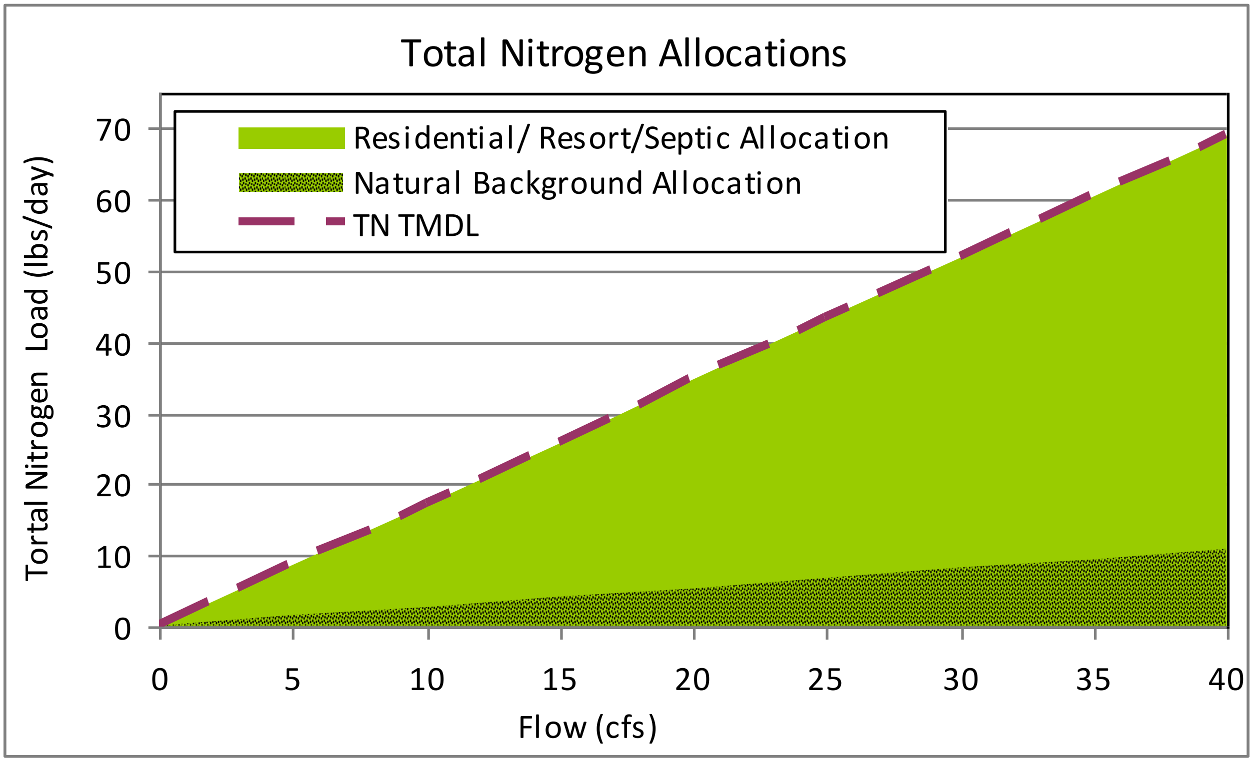

Figure 6-27b.TN TMDL and Load Allocations, West Fork Gallatin River

As wastewater-sourced NO_3+NO_2 loads are the primary factor causing impairment conditions in the West Fork Gallatin River and is driving high TN concentrations, elimination of wastewater NO_3+NO_2 loading will result in attainment of TN TMDLs and source allocations. **Appendix A**,

Figures 6-28 illustrates nitrogen loading conditions and TN TMDLs in the West Fork Gallatin River in late August, 2008. **Appendix A**, **Figure 6-29** represents the same nitrogen loading conditions with estimated wastewater NO_3+NO_2 loads removed. **Table 6-32** represents estimated loading conditions and calculated allocations from this specific sampling event following the allocation scheme presented in **Table 6-31**.

Table 6-32. West Fork Gallatin River TN load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Allocation & TMDL (lbs/day)	Percent Reduction
Natural Background	3.5	3.5	NA
Residential and Resort Landscape Management and Maintenance		18.9	NA
On-site Septic Systems	negligible		
Unpermitted Wastewater	31.6	0	100%
Total TN Load	**35.1**	**22.4(TMDL)**	**36%**

**based on August 27, 2008 sampling event upstream of the South Fork West Fork Gallatin River confluence (WFGR02)*

The total maximum daily load of TN in the West Fork Gallatin River is calculated to be 55 lbs/day at the mouth and is presently being met under average August conditions due to the dilution provided by the South Fork West Fork Gallatin River. Upstream of the South Fork West Fork Gallatin River, however, wastewater loading to the reach results in exceedences of the TN TMDL, and contributes to excessive downstream algal growth. Loading allocations and reductions, therefore, focus on eliminating wastewater sources in this upper reach (**Table 6-32**). By eliminating wastewater inputs to the upper reach, TN TMDLs will be met for the entire segment of the West Fork Gallatin River. **Table 6-32** shows percent reductions in wastewater loading and how they affect the TMDL in the West Fork Gallatin River above the South Fork confluence.

6.5.3 South Fork West Fork Gallatin River (MT41H005_060)

The South Fork West Fork Gallatin River flows into the West Fork Gallatin River below the Big Sky Meadow Village area. Land use along the South Fork West Fork Gallatin River consists primarily of recreational and resort development in the upper watershed (the Yellowstone Club) on forested lands, and light residential and commercial development in the lower reaches.

As determined in **Section 6.4.3.3** the segment exceeded nutrient water quality targets for chlorophyll-*a*, and implicate NO_3+NO_2 and as the likely cause of impairment. TMDLs are therefore presented herein for NO_3+NO_2. Instream NO_3+NO_2 concentrations did not exhibit exceedences of water quality targets; however, high algal densities observed in recorded in 2005 verify impairment suggesting that NO_3+NO_2 inputs are being utilized by algae, resulting in low in-stream NO_3+NO_2 concentrations. **Table 6-33** and **Figure 6-30** present summary statistics of NO_3+NO_2 concentrations at sampling sites in the South Fork West Fork Gallatin River.

Table 6-33. Summertime NO_3+NO_2 Summary Statistics for sampling sites on the South Fork West Fork Gallatin River (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
South Fork West Fork Gallatin: Upstream of Ousel Falls	**6**	**0.010**	**0.096**	**0.048**	**0.022**	**0.046**	**0.069**
SFWF02	28	0.001	0.076	0.022	0.004	0.012	0.031
SFWF04	3	0.005	0.040	0.022	0.013	0.020	0.030
SFWF03	27	0.002	0.058	0.015	0.004	0.010	0.020

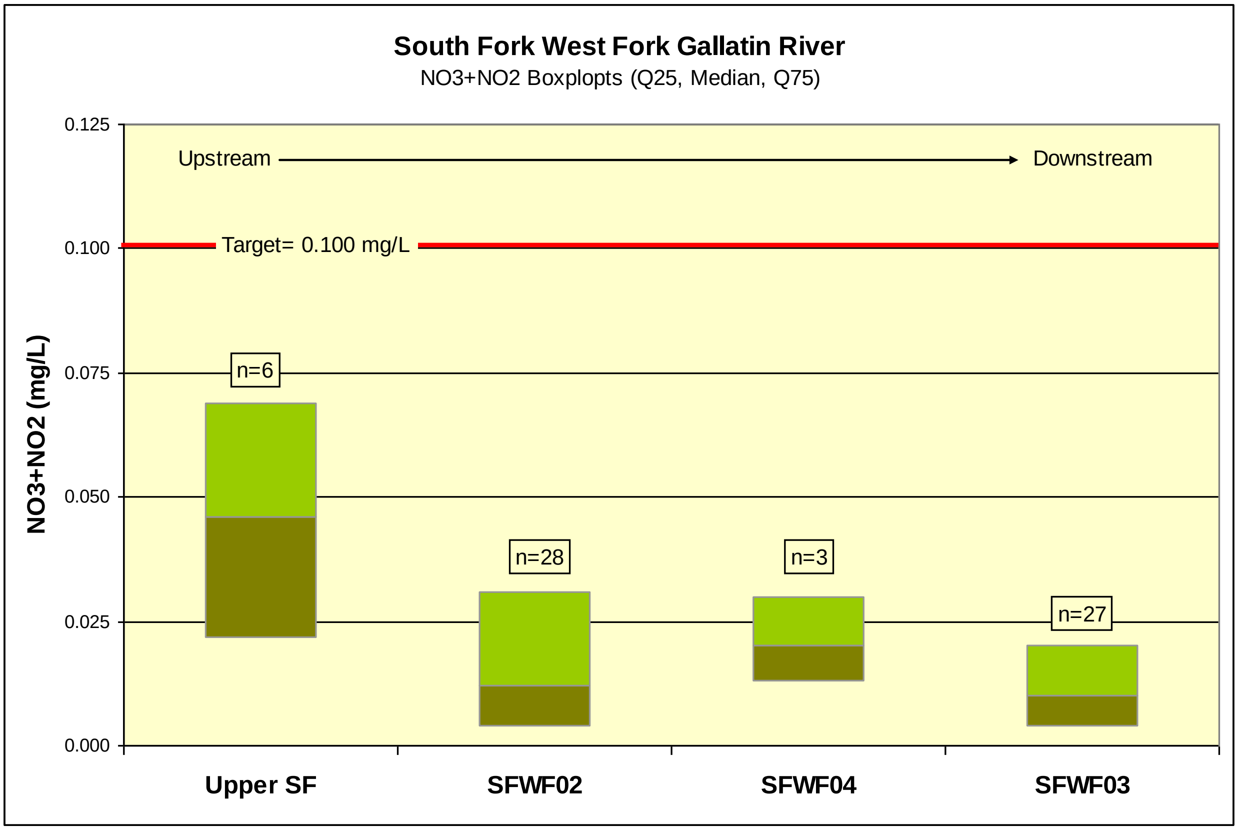

Figure 6-30. NO_3+NO_2 Boxplots: South Fork West Fork Gallatin River

Sampling events in 2008 did not record high chlorophyll-*a* concentrations; however algal biomass density (measured as g/m2 ash-free dry weight) was exceptionally high, indicating significant senescent algal mass present in samples collected for analysis. Qualitative observations of algal growth by local resource professionals and DEQ investigators has shown that elevated algal concentration persist in the lower South Fork West Fork Gallatin River, and appear to be greater than recorded chlorophyll-*a* concentrations, perhaps due to late summer senescence of algal communities. **Figures 6-31** through **6-40** show algal concentrations at sampling sites in the South Fork West Fork Gallatin River from 2005 to present. Sites SFWF02 and SFWF03 exhibited excessive algal growth during all sampling periods. It appears that nutrient inputs are being rapidly assimilated and affecting algal growth in the lower South Fork West Fork Gallatin River. Nitrogen sources affecting algal growth include nitrogen derived from development activity as well as wastewater inputs.

As instream nitrogen concentrations are below target levels, calculated NO_3+NO_2 load reductions are not possible from measured instream NO_3+NO_2 data. Allocations, however, incorporate allowed loading from general source categories. Natural and anthropogenic sources contributing to NO_3+NO_2 loads entering the reach are described below.

6.5.3.1 Naturally-occurring Nitrogen Sources: South Fork West Fork Gallatin River

Naturally-occurring background sources of nitrogen include a variety of natural processes and sources and may include: soils & local geology, natural vegetative decay, wet and dry airborne deposition, wild animal waste, and other biochemical processes that contribute nitrogen to nearby water bodies. Background concentrations have been estimated at <0.037 mg/l NO_3+NO_2 (see **Section 6.5.1.1**) based on local reference data. Assuming a naturally-occurring background concentration of <0.037 mg/L NO_3+NO_2 and a typical August baseflow of 20 cfs at the mouth of the South Fork West Fork Gallatin River (WFGR03) the average background NO_3+NO_2 load to the segment is calculated to be <4.0 lbs/day.

6.5.3.2 Anthropogenic Nitrogen Sources: South Fork West Fork Gallatin River

Anthropogenic nutrient sources within this reach are similar in nature to those found in the lower segment of the Middle Fork West Fork Gallatin River and are believed to consist of a variety of variable sources and include nutrients derived from:
- Residential and resort lawn and landscape management
- Wastewater (on-site septic systems, land-applied wastewater, sewer system infrastructure)

Residential & Resort Landscape Management Sources
General residential and resort landscape management nitrogen sources in the South Fork West Fork Gallatin River include a variety of variable and diffuse NO_3+NO_2 sources associated with widespread land clearing and development and may include nitrogen derived from:
- vegetative decay of detritus derived from land clearing or land maintenance activities
- residential landscape fertilizer application
- general refuse inherent in residential resort development

Water quality data and did not identify specific load increases due to residential or resort land management activities, however potential for baseflow inputs from residential NO3+NO2 sources through the segment exist. It is believed that these additional inputs are of low significance and do not pose immediate threats to water quality. Non-wastewater residential NO_3+NO_2 loads fall within the range of naturally-occurring NO_3+NO_2 concentrations (<0.037 mg/L) and are therefore included within the NO_3+NO_2 load estimate provided for naturally-occurring NO_3+NO_2 sources.

Wastewater

While synoptic water quality data did not identify specific wastewater sources loads requiring load reductions to meet water quality targets, water quality modeling and isotope data analysis did identify wastewater contributions to the lower South Fork West Fork Gallatin River, possibly from localized septic influences, compromised sewer infrastructure or land-applied wastewater effluent making its way to the South Fork via preferred subsurface flow-paths. While modeled wastewater contributions to the South Fork were <2% (Garner et al, in review), isotope water quality data indicated that approximately 28%(Garner et al, in preparation) of the summer baseflow load in the lower South Fork was attributed to wastewater sources, indicating potential discrete or localized nutrient inputs not accounted for in modeling assumptions. Complicating estimation of cumulative wastewater loads is seasonal uptake of NO_3+NO_2 loads by algal growth (**Figures 6-31 through 6-40**), as witnessed on the lower South Fork West Fork Gallatin River in recent years.

Empirical water quality data does not allow differentiation of wastewater nitrogen loads to specific wastewater sources. Consequently, load estimates to specific wastewater sources are not provided, but are instead addressed in the allocation scheme in **Section 6.5.3.4**.

6.5.3.3 Nitrite +Nitrate (NO_3+NO_2) Total Maximum Daily Loads: South Fork West Fork Gallatin River

As established in **Section 6.4**, NO_3+NO_2 Total Maximum Daily Loads are presented herein for the South Fork West Fork Gallatin River (MT41H005_060). A Total Maximum Daily Load (TMDL) is a calculation of the maximum pollutant load a water body can receive while maintaining water quality standards. The total maximum daily load (lbs/day) of NO_3+NO_2 is calculated using water quality target value established in **Section 6.4**. The total maximum daily NO_3+NO_2 load applies during the summer season (July 1st through Sept 30th) is based on an instream target value of 0.100 mg/L NO_3+NO_2 and the stream flow (**Figure 6-41**). TMDL calculations are based on the following formula:

TMDL = (X) (Y) (5.393)

TMDL= Total Maximum Daily Load NO_3+NO_2 in lbs/day
X= NO_3+NO_2 water quality target in mg/L (0.100 mg/L)
Y= streamflow in cubic feet per second
5.393 = conversion factor

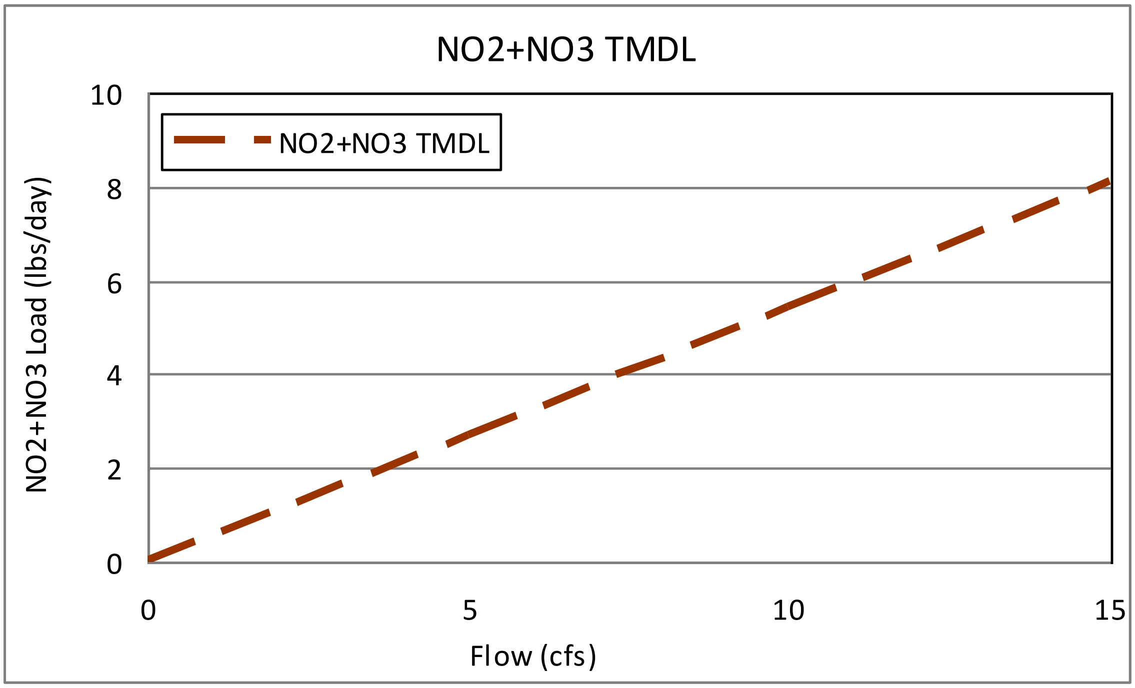

Figure 6-41. NO_3+NO_2 TMDL as a function of flow: South Fork West Fork Gallatin River

TMDL are allocated to point (wasteload) and nonpoint (load) NO_3+NO_2 sources. The TMDL is comprised of the sum of all point sources and nonpoint sources (natural and anthropogenic), plus a margin of safety that accounts for uncertainties in loading and receiving water analyses. In addition to pollutant load allocations, the TMDL must also take into account the seasonal variability of pollutant loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

These elements are combined in the following equation:

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

Where:

- WLA = Waste Load Allocation or the portion of the TMDL allocated to point sources. Since there are no individual permitted point sources in the West Fork Gallatin watershed, the WLA=0.
- LA = Load Allocation or the portion of the TMDL allocated to nonpoint recreational/residential sources and natural background
- MOS = Margin of Safety or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. Where the MOS is implicit an additional numeric MOS is unnecessary; therefore the “explicit” MOS is set equal to 0 here.

6.5.3.4 Nitrite +Nitrate (NO_3+NO_2) Load Allocations: South Fork West Fork Gallatin River

For the South Fork West Fork Gallatin River (MT41H005_060) the NO_3+NO_2 TMDL is comprised of the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations and relevant NO_3+NO_2 nonpoint sources include natural background sources, wastewater sources, and a variety of diffuse sources associated with residential and resort development in the watershed. Potential wastewater NO_3+NO_2 loads derived from land-applied effluent or failing sewer infrastructure are not permitted and are given a zero load allocation. Allowable wastewater loads, therefore include wastewater loads derived from properly functioning on-site septic systems

Due to septic association with residential development sources, load allocations to on-site septic systems are included within the load allocation for residential and resort land use sources. Load allocations are therefore provided for 1) natural background sources and 2) cumulative on-site septic and residential/recreational land use sources. In the absence of individual WLAs and an explicit MOS, NO_3+NO_2 TMDLs in the watershed are equal to the sum of the individual load allocations as follows:

TMDL = LA_{NB} + $LA_{RES+SEP}$

LA_{NB} = Load Allocation to natural background sources

$LA_{RES+SEP}$ = Load Allocation to the combination of residential/recreational land use sources and on-site septic sources

6.5.3.4.1 Natural Background Source Load Allocation

Load allocations for natural background sources are based on a natural background NO_3+NO_2 concentration of 0.037 mg/L (**see Section 6.5**), and are calculated as follows:

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

LA_{NB}= NO_3+NO_2 *load allocated to natural background sources*

X= 0.037 mg/L natural background concentration

Y= streamflow in cubic feet per second

5.393 = conversion factor

6.5.3.4.2 Residential/Recreational Land Use and On-site Septic Source Load Allocation

The load allocation to the combination of residential/recreational sources and on-site septic sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$LA_{RES+SEP}$ = TMDL - LA_{NB}

6.5.3.5 NO_3+NO_2 Load Allocation Summary: South Fork West Fork Gallatin River

NO_3+NO_2 load allocations (**Table 6-34**) are provided for the South Fork West Fork Gallatin River and include allocations to the following source categories: 1) natural background (LANB), and 2) the combination of residential/recreational land use and on-site septic sources (LARES+SEP). NO_3+NO_2 loads derived from land-applied effluent (LALAWW) or failing sewer infrastructure (LASS) are not permitted and are given a load allocation of zero.

Table 6-34. NO_3+NO_2 load allocation descriptions, South Fork West Fork Gallatin River

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils & local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby water bodies.	**LA_{NB} = (X) (Y) (5.393)**
Combination of Residential and Recreational Land Use and On-site Septic	• vegetative decay from detritus derived from land clearing or land maintenance activities • landscape nutrient (fertilizer) application • general refuse inherent in residential resort development (pet waste, garbage, etc) • on-site septic systems	**$LA_{RES+SEP}$ = TMDL - LA_{NB}**
Sewer System Infrastructure Failure	• sewer pipe or connection failure • seepage or failure of retention facilities	**LA_{SS} = 0**
Land-Applied Wastewater	• spray-irrigated effluent applied to the Big Sky Golf Course	**LA_{LAWW} = 0**

Because measured instream NO_3+NO_2 concentrations are within naturally occurring conditions and below target concentrations, water quality data precludes calculation of NO_3+NO_2 load reductions to specific source categories using empirical data. Load allocations, however, incorporate allowed loading from general source categories and establish allowable NO_3+NO_2 loads. NO_3+NO_2 presents TMDLs and cumulative NO_3+NO_2 load allocations as a function of streamflow in accordance with the allocation scheme presented in **Table 6-34**, and **Table 6-35** presents load allocations at summer baseflow conditions at the mouth of the South Fork West Fork Gallatin River.

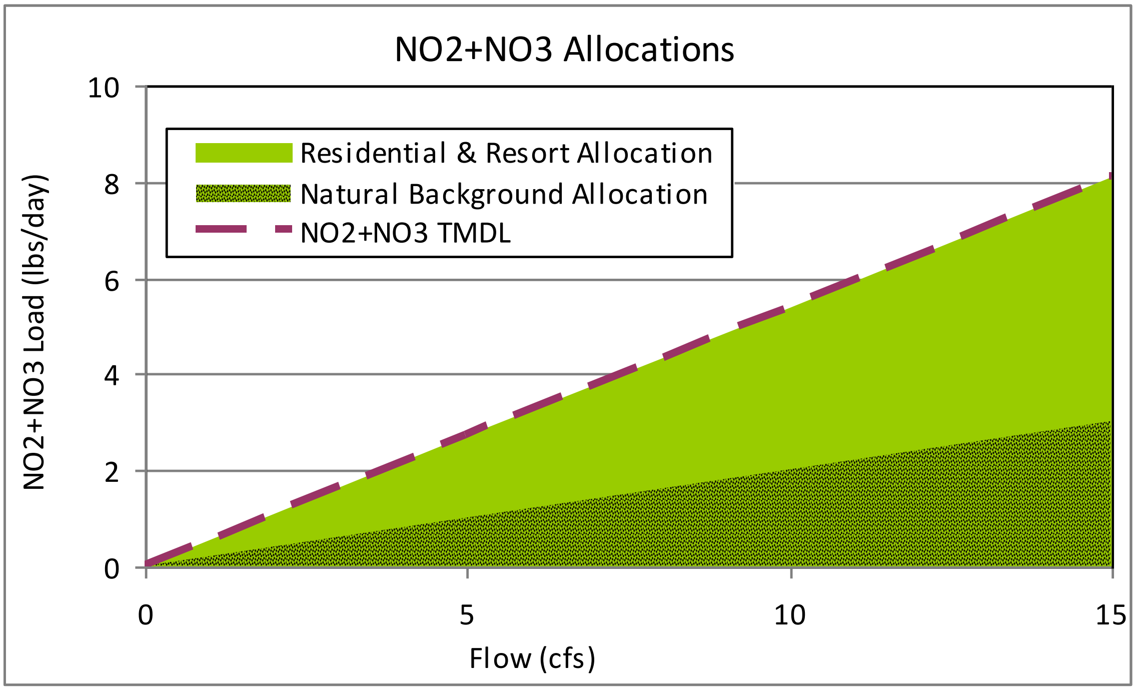

Figure 6-42. NO_3+NO_2 TMDL and Load Allocations, South Fork West Fork Gallatin River

Table 6-35. South Fork West Fork Gallatin River NO_3+NO_2 load allocations and TMDL*

Source Category	**Allocation & TMDL (lbs/day)**
Natural Background	4.0
Residential and Resort Landscape Management and Maintenance	6.8
On-site Septic Systems	
Unpermitted Wastewater	0
TMDL	**10.8**

**based on average August flow of 20 cfs*

6.5.4 Seasonality, Margin of Safety and Uncertainty

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 water body, 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 West Fork Gallatin River watershed nutrient TMDL development process

6.5.4.1 Seasonality

Addressing seasonal variations is an important and required component of TMDL development and throughout this plan seasonality is an integral consideration. Water quality and particularly nitrogen concentrations are recognized to have seasonal cycles. Specific examples of how seasonality has been addressed within this document include:

- Water quality targets and subsequent allocations are applicable for the summer-time growing season (July1st – Sept 30th), to coincide with seasonal algal growth targets.
- Nutrient data used to determine compliance with targets and to establish allowable loads was collected during the summertime period to coincide with applicable nutrient targets
- Nutrient water quality data from all seasons was collected to evaluate nutrient concentrations outside of growing season timeframes in order to evaluate nutrient source prevalence during time when algal growth was not occurring.
- Nutrient data and sources were evaluated based on and understanding of local seasonal source prevalence and seasonal pathways.
- Load duration curves were developed to demonstrate the typical seasonal flow regimes when e.coli concentrations become a problem.

6.5.4.2 Margin of Safety

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

- Static nutrient target values (0.100 mg/L NO_3+NO_2, 0.320 mg/L TN) were used to calculate allowable nitrogen loads (TMDLs). Allowable exceedences of nutrient targets (see **Section 6.4.3**) were not incorporated into the calculation of allowable loads, thereby adding a MOS to established nitrogen allocations.
- The 90th %ile value of summer natural background concentrations was used to establish a natural background concentration for load allocation purposes. This is a conservative approach, and provides an additional MOS for anthropogenically –derived nutrient loads during most conditions.
- By considering seasonality (discussed above) and variability in nutrient loading.
- By using an adaptive management approach to evaluate target attainment and allow for refinement of load allocation, assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development.
- A NO_3+NO_2 TMDL was developed for the South Fork West Fork Gallatin River due to high chlorophyll-*a* concentrations, and in the absence of elevated nitrogen concentrations. This provides a protective approach to water quality for the South Fork West Fork Gallatin River by proactively allocating loads to sources thought to be contributing to algal growth.

6.5.4.3 Uncertainty and Adaptive Management

Uncertainties in the accuracy of field data, target development, source assessments, loading calculations, and other considerations are inherent when assessing and evaluating environmental variables for TMDL development. While uncertainties are an undeniable fact of TMDL development, mitigation and reduction of uncertainties through adaptive management approaches is a key component of ongoing TMDL implementation and evaluation. Uncertainties, assumptions, and considerations are applied throughout this document and point to the need to refine analysis, conduct further monitoring, and address unknowns in order to develop better understanding of nutrient impairment conditions and the processes that affect impairment. This process of adaptive management is predicated on the premise that TMDL targets, allocations, and the analyses supporting them are not static, but are processes subject to modification and adjustment as new information and relationships are understood. For instance, numeric nutrient targets provided in **Table 6-2** are based on the best information and analyses available at the time of document production, and represent water quality concentrations believed to limit algal growth below nuisance levels within the West Fork Gallatin River watershed. As numeric nutrient criteria development efforts by the DEQ progress, nutrient water quality targets may be modified or adjusted based on the outcomes of the State's numeric nutrient criteria development process.

As further monitoring of water quality and source loading conditions is conducted, uncertainties associated with these assumptions and considerations may be mitigated and loading estimates may be refined to more accurately portray watershed conditions. As part of this adaptive management approach, land use activities, nutrient management and control should be tracked. Changes in land use or management may change nutrient dynamics and may trigger a need for additional monitoring. The extent of monitoring should be consistent with the extent of potential impacts, and can vary from basic BMP assessments to a complete measure of target parameters above and below the project area before the project and after completion of the project. Cumulative impacts from multiple projects must also be a consideration as nutrient sources are ubiquitous in many developed areas of the West Fork watershed. This approach will help track the recovery of the system and the impacts, or lack of impacts, from ongoing management activities in the watershed.

Uncertainties in assessments and assumptions should not paralyze, but should point to the need to be flexible in our understanding of complex systems, and to adjust our thinking and analysis in response to this need. Implementation and monitoring recommendations presented in **Section 8.0** provide a basic framework for reducing uncertainty and furthering understanding of these issues.

SECTION 7.0
ESCHERICHIA COLI (E. COLI)

This portion of the document focuses on **escherichia coli** (e. coli) as a cause of water quality impairments in the Upper Gallatin TPA. It addresses:

- Beneficial use impacts
- Stream segments of concern
- Water quality data sources
- Water quality targets and comparison to existing conditions
- E. coli source assessment
- E. coli total maximum daily loads
- E. coli source load allocations
- Seasonality and margin of safety

7.1 E. Coli Impacts to Beneficial Uses

Elevated in-stream concentrations of pathogenic pollutants put humans at risk for contracting water-born illnesses and can lead to impairments to a waterbody's contact recreation beneficial use. E. coli is a nonpathogenic indicator bacteria that is usually associated with pathogens transmitted by fecal contamination. While the presence of e. coli does not always prove or disprove the presence of pathogenic bacteria, viruses, or protozoans, e. coli correlates highly with the presence of fecal contamination (USEPA 2001) and is an indicator that other pathogenic bacteria are likely present. EPA recommends the use of e. coli as an indicator organism for pathogenic bacteria forms due to its strong correlation with swimming-related gastroenteritis. Consequently, the Montana DEQ has adopted an e. coli standard for the protection of beneficial uses in Montana waterbodies. In order to assess impacts to recreational beneficial uses caused by pathogenic bacteria, in-stream e. coli concentrations are evaluated against the in-stream water quality standard for e. coli (**Table 7-1**).

7.2 Stream Segments of Concern

The Middle Fork West Fork Gallatin River is listed as impaired due to e. coli on the 2008 303(d) List. The West Fork Gallatin River and the South Fork West Fork Gallatin River are not listed as impaired due to e. coli, but are evaluated herein in order to provide supporting information for e. coli sources throughout the West Fork Gallatin River watershed. For each stream, assessment reaches were established, and e. coli criteria attainment was evaluated for each assessment reach (**Section 7.4.2**).

7.3 Water Quality Data Sources

Several data sources were evaluated in assessing existing and historical fecal coliform and e. coli conditions in West Fork Gallatin River watershed streams.

- Fecal coliform data collected at 14 sites in the West Fork Gallatin watershed from 1970-1974 (Stuart et al 1976).

- Fecal coliform data collected by the Big Sky Water and Sewer District from 1994-1998
- Fecal coliform and e. coli data collected by volunteers with the Blue Water Task Force from 2000-2004
- Fecal coliform and e. coli data collected by DEQ from 1990-2001

The available e-coli data was limited and historical data consists primarily of fecal coliform counts. In order to better represent existing conditions on the Middle Fork West Fork Gallatin River and evaluate existing e. coli conditions in the watershed, the Montana DEQ sampled several streams in the watershed from 2006 through 2008. Water samples were collected and analyzed for e. coli at 16 sites throughout the West Fork Gallatin River watershed in 2006 and 2007 and at 24 sites in 2008 (**Figure 7-1**). In 2006 and 2007, sampling was conducted during August, November, February/March and May/June in order to evaluate attainment of seasonal e. coli water quality targets (**Table 7-1**) on the Middle Fork West Fork Gallatin River. Two additional monitoring events were conducted during the summer of 2008 to provide supporting information regarding summer e. coli concentrations and potential sources. Water quality data from these events is used as the primary source of data for the evaluation of water quality targets and assessment of e. coli sources.

7.4 E. Coli Water Quality Targets and Comparison to Existing Conditions

TMDL water quality targets are numeric indicator values used to evaluate attainment of water quality standards, and are discussed conceptually in **Section 4.0**. The following section presents e. coli water quality targets, and compares those target values to recently collected e. coli data in the West Fork Gallatin watershed.

7.4.1 E. Coli Water Quality Targets

The Montana in-stream numeric water quality criteria (standard) for Escherichia coli are adopted as the basis for e. coli targets for streams in the Upper Gallatin TMDL Planning Area. The Montana e. coli standard for B-1 waterbodies specifies:

> *The geometric mean number of e. coli may not exceed 126 cfu/100mL and 10% of the total samples may not exceed 252 cfu/100mL during any 30-day period between April 1 through October 31 [ARM 17.30.623 (2)(i)] (***Table 7-1***). From November 1 through March 31, the geometric mean number of e. coli may not exceed 630 cfu/100mL and 10% of the samples may not exceed 1,260 cfu/100mL during any 30-day period [ARM 17.30.623 (2)(ii)]. The E. coli bacteria standard is based on a minimum of five samples obtained during separate 24-hour periods during any consecutive 30-day period that are analyzed by the most probable number (MPN) or equivalent membrane filter method [ARM 17.30.620(2)]. The geometric mean is the value obtained by taking the Nth root of the product of the measured values where values below the detection limit are taken to be the detection limit [ARM 17.30.602(13)].*

Table 7-1. Montana Water Quality Criteria for e. coli for B-1 Waterbodies

Applicable Period	Standard	Geometric mean of 5 samples collected over a 30-day time period	No more than 10% of the samples shall exceed:
Apr 1 – Oct 31 (“summer”)	The geometric mean number of e. coli may not exceed 126 colony forming units per 100 milliliters and 10% of the total samples may not exceed 252 colony forming units per 100 milliliters during any 30-day period (ARM 17.30.623 (2)(i)).	<126 cfu/100mL	252 cfu/100mL
Nov 1 – Mar 31 (“winter”)	The geometric mean number of e. coli may not exceed 630 colony forming units per 100 milliliters and 10% of the samples may not exceed 1,260 colony forming units per 100 milliliters during any 30-day period (ARM 17.30.623 (2)(ii)).	<630 cfu/100mL	1,260 cfu/100mL

Evaluation of target compliance is conducted by comparing exiting water quality conditions to the established water quality target (in this case, the e. coli water quality standard provided in **Table 7-1**). Total maximum daily loads require the establishment of a maximum allowable daily pollutant load that will result in the attainment and maintenance of water quality standards. In order to ensure that daily maximum allowable loads do not result in an exceedence of the 30-day geometric mean e. coli criteria, values of 126 cfu/100ml and 630 cfu/100ml , are used for the calculation of seasonal e. coli TMDLs and allocations.

7.4.2 Existing Conditions and Comparison to Water Quality Targets

Attainment of E. coli water quality targets was evaluated for several discrete stream reaches (**Figure 7-2**) within each stream segment of concern (**Table 7-2**). For each assessment reach, e. coli data collected in 2006-2008 was compared to e. coli water quality targets. E. coli geometric mean values were evaluated as were single sample values above the ‘10% criteria’. For each segment evaluated, only mainstem data was used to make target attainment determinations: tributary data was used to evaluate general condition and, where appropriate, to assess the distribution and magnitude of e. coli loading.

Table 7-2. E. Coli Assessment Reaches

Stream Segment	Segment ID	Assessment Reaches
West Fork Gallatin River (WFGR)	MT41H005_040	West Fork Gallatin River
Middle Fork WFGR	MT41H005_050	Upper Middle Fork WFGR
		Middle Fork WFGR
South Fork WFGR	MT41H005_060	Upper South Fork WFGR
		Lower South Fork WFGR

7.4.2.1 Middle Fork West Fork Gallatin River (MT41H005_050)

The Middle Fork West Fork Gallatin River is the only stream in the Upper Gallatin TPA that is listed as impaired due to e. coli. E. coli monitoring was conducted in 2006, 2007 and 2008. Due to differences in land use and pollutant sources above and below lake Levinsky, the Middle Fork West Fork Gallatin River was broken into two assessment reaches: upstream of Lake Levinsky and downstream of Lake Levinsky. Upstream of Lake Levinsky, land uses consist primarily of active ski resort and residential development, while downstream of Lake Levinsky land use is primarily lower level development and relatively unimpacted natural vegetation. Two sites on the Middle Fork West Fork Gallatin River were located upstream of Lake Levinsky (MFWF03, MFWF04), while four sites were located downstream of Lake Levinsky (MFWF01, MFWF02, MFWF05, MFWF06). In addition, additional monitoring sites were established on three tributaries upstream of Lake Levinsky and three tributaries downstream of Lake Levinsky.

Upper Middle Fork West Fork Gallatin River

Land use in the Middle Fork West Fork Gallatin River watershed upstream of Lake Levinsky is dominated by recreational resort development associated with Big Sky Ski Resort and Moonlight Basin Ski Resort. No permitted point sources of e. coli exist in the upper watershed. Primary e. coli sources are believed to consist of a variety of variable and diffuse sources that include domestic pets, geese and waterfowl, wildlife, and refuse from runoff from streets, parking lots and other impervious surfaces in the developed area. Sewer or service line failures or leaks, while difficult to identify, may also be a potential source.

Upstream of Lake Levinsky in the Mountain Village area of Big Sky Resort, 56 e. coli samples were taken at 5 sites from 2006-2008 (**Figure 7-3**). A seasonal statistical summary of data collected from 2006-2008 in the Upper Middle Fork West Fork watershed is given in **Table 7-3**. Geometric means and target exceedence values are presented in **Table 7-4**.

Table 7-3. E. Coli Summary Statistics for the Upper Middle Fork West Fork Gallatin River

Season	n	min	max	avg	25th Percentile	median	75th Percentile
Feb-March	12	1	10	3	1	3	4
May-July	16	1	488	54	2	26	43
Aug	15	11	770	126	18	61	100
Nov	13	10	308	119	32	115	157

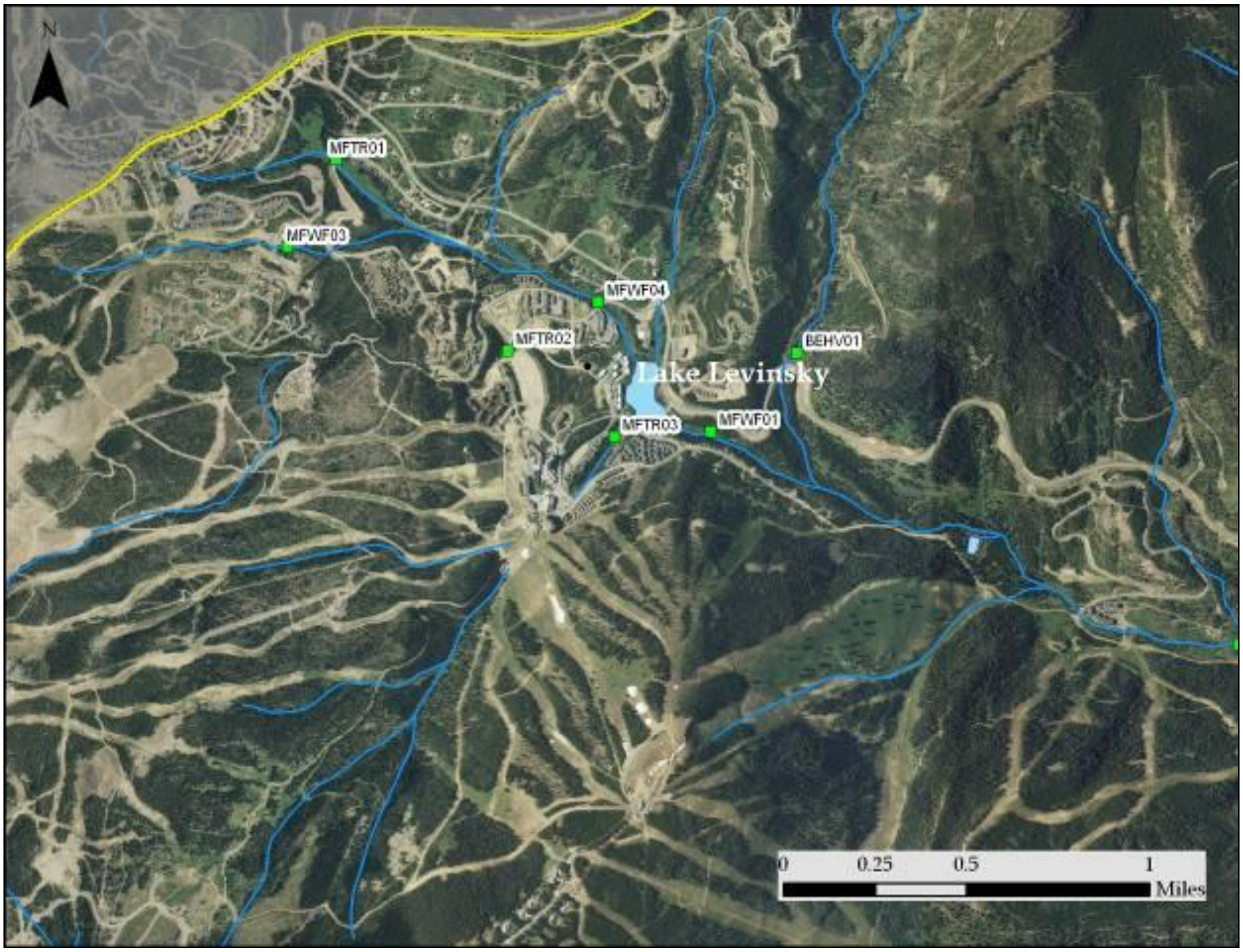

Figure 7-3. Upper Middle Fork West Fork Gallatin River Sampling Sites

The target geometric mean concentration was not exceeded in the Middle Fork West Fork Gallatin River at either site during any of the seasonal monitoring timeframes in 2006 and 2007 (**Table 7-4**). An e. coli concentration of **488 cfu/100mL** recorded at site MFWF04 on June 6, 2007 however, fails to meet the “summer” requirement that “10% of the total samples may not exceed 252 cfu/100mL during any 30-day period”. In 2008, only site MFWF04 was assessed, with a maximum E. coli concentration of 86 cfu/100mL recorded on August 27. Elevated e. coli levels were also observed in November 2006, but values did not exceed the seasonal e. coli targets.

Samples were also collected on three tributaries (MFTR01, MFTR02, MFTR03) of the Middle Fork West Fork Gallatin River upstream of Lake Levinsky once during each seasonal monitoring timeframe in 2006 and 2007, and again during the summer of 2008. Periodic elevated E. coli concentrations were documented at both sample site MFTR02 and site MFTR03. Site MFTR02 is located on a unnamed tributary that has it’s headwaters under the Lone Peak Tram and flows into the northern end of Lake Levinsky, while site MFTR03 is on an unnamed tributary that drains Lone Mountain and Andesite Mountain and flows under the Big Sky Resort base area to join lake Levinsky at its southern end. In August of 2006, an E. coli concentration of **770**

cfu/100mL was recorded at site MFTR03, while in August of 2008 an E. coli concentration of 365 cfu/100mL was recorded at site MFTR02, both vales being e. coli target exceedences.

Table 7-4. Upper Middle Fork West Fork Gallatin River E. Coli Concentrations

Sampling Site ID	Sample Site Name	Season	Geometric Mean E. Coli Concentration (cfu/100mL)
MFWF03	Diamond Hitch	August 2006	14
		November 2006	69
		February/March 2007	2
		May/June 2007	4
MFWF04	Sitting Bull 1	August 2006	100*
		November 2006	113
		February/March 2007	4
		May/June 2007	60
Sampling Site ID	**Sample Site Name**	**Sampling Date**	**Summer Target Exceedence Values (cfu/100ml)**
MFWF04	Sitting Bull 1	June 6, 2007	**488**
MFTR02		August 27, 2008	**365**
MFTR03		August 18, 2006	**770**

Bold indicates target value was not met. * Geometric mean based on 4 samples.

Lower Middle Fork West Fork Gallatin River

The Middle Fork West Fork Gallatin River watershed downstream of Lake Levinsky consist primarily of a relatively less-impacted stream corridor than the upper reaches, however some lower level development exists in the within the segment. Primary e. coli sources in this reach are believed to consist of a variety of variable and diffuse sources that include wildlife, waterfowl, and to a lesser extent, runoff from developed areas. Failing or leaking sewer and service lines may also be considered potential e. coli sources in this segment.

Downstream of Lake Levinsky on the mainstem Middle Fork West Fork Gallatin River, 68 e. coli samples were taken at 4 sites from 2006-2008 (**Figure 7-4**). A statistical summary of mainstem data collected from 2006-2008 on the Upper Middle Fork West Fork Gallatin River is given in **Table 7-5**, and **Table 7-**6 provides geometric means and target exceedence values. An additional 9 samples were taken from three tributary streams, BEHV01, MFTR04 and MFTR05. With the exception of MFTR05, which yielded e. coli results of 72 and 77 cfu/100ml in the summer of 2008, all other e. coli results were below 30 cfu/100ml.

Table 7-5. E. Coli Summary Statistics for the Lower Middle Fork West Fork Gallatin River

Season	n	min	max	mean	25th Percentile	median	75th Percentile
Feb-March	15	1	19	6	1	2	8
May-July	19	1	50	16	8	11	22
Aug	19	1	866	159	18	75	201
Nov	15	1	125	50	14	47	85

Figure 7-4. Lower Middle Fork West Fork Gallatin River Sampling Sites

Downstream of Lake Levinsky, the target geometric mean concentration was exceeded in the Middle Fork West Fork Gallatin River at the lowermost site (MFWF02) during August of 2006, with a value of 239 cfu/100mL (**Table 7-6**). Target geometric means were not exceeded at the other two monitoring sites (MFWF01 and MFWF05) during any of the seasonal monitoring timeframes in 2006 and 2007, however an e. coli concentration of 326 cfu/100mL recorded at site MFWF01 on August 22, 2006, fails to meet the “summer” target requirement that “10% of the total samples may not exceed 252 cfu/100mL during any 30-day period”. In addition, an e. coli concentration of 866 cfu/100mL exceeded the “summer” requirement at site MFWF05 on August 21, 2006. In 2008, all three of these sites were sampled again, along with a fourth site (MFWF06) located between sites MFWF05 and MFWF02. A maximum e. coli concentration of 99 cfu/100mL was recorded in 2008. Of all sampling periods, the highest overall e. coli concentrations occurred during the August 2006 sampling event.

Table 7-6. Lower Middle Fork West Fork Gallatin River E. Coli Concentrations

Sampling Site ID	Sample Site Name	Season	Geometric Mean E. Coli Concentration (cfu/100mL)
MFWF01	below Lake Levinsky	August 2006	14
		November 2006	8
		February/March 2007	1
		May/June 2007	15
MFWF05	Lone Moose	August 2006	100
		November 2006	30
		February/March 2007	5
		May/June 2007	10
MFWF02	Beaver Dam	August 2006	**239**
		November 2006	66
		February/March 2007	6
		May/June 2007	18
Sampling Site ID	**Sample Site Name**	**Sampling Date**	**Summer Target Exceedence Values (cfu/100ml)**
MFWF01	below Lake Levinsky	August 22, 2006	**326**
MFWF05	Lone Moose	August 21, 2006	**866**

Bold indicates target value/e.coli standard was not met.

7.4.2.2 West Fork Gallatin River (MT41H005_040)

The West Fork Gallatin River begins where the North Fork West Fork Gallatin River flows into the Middle Fork West Fork Gallatin River. The segment is not listed as impaired on the 2008 303(d) List. Land use along the West Fork Gallatin River is consists of recreational and residential development, and includes a golf course through a third of the segment. No permitted point sources of e. coli exist. Primary e. coli sources are believed to consist of a variety of variable and diffuse sources that include domestic pets, geese and waterfowl, wildlife, and refuse from runoff from streets, parking lots and other impervious surfaces in the residential and commercial areas. Sewer or service line failures or leaks, while difficult to identify through surface water sampling, may also be a potential source in this segment. Land application of treated effluent is not believed to be a source of e. coli as land-applied water is disinfected before application per land-application guidelines issued by the DEQ (DEQ, 1999).

On the West Fork Gallatin River, 27 e. coli samples were collected from 6 sites from 2006 through 2008 (**Figure 7-5**). A statistical summary is given in **Table 7-7**. Sites WFGR01, WFGR04, WFGR02 and WFGR03 were assessed in 2006, 2007 and 2008, while sites WFGR05 and WFGR06 were added for the 2008 assessment (**Table 7-8**).

Table 7-7. E. Coli Summary Statistics for the West Fork Gallatin River

Season	n	min	max	mean	25th Percentile	median	75th Percentile
Feb-March	4	1	8	4	2	3	4
May-July	10	2	31	12	7	10	16
Aug	10	55	411	145	81	106	171
Nov	3	26	39	32	29	32	36

Figure 7-5. West Fork Gallatin River Sampling Sites

Table 7-8. West Fork Gallatin River E. Coli Concentrations

Sampling Site ID	Sampling Site Name	Date	E. Coli Concentration (cfu/100mL)
WFGR01	Two Moons	8/18/2006	219
		11/17/2006	39
		3/1/2007	8
		6/4/2007	6
		7/23/2008	2
		8/27/2008	179
WFGR05	Golf 1.5	7/23/2008	5
		8/27/2008	91
WFGR04	Little Coyote	8/18/2006	148
		11/17/2006	26
		3/1/2007	3
		6/4/2007	17
		7/23/2008	9
		8/27/2008	80
WFGR06	BSWSD	7/23/2008	12
		8/27/2008	62
WFGR02	J Walker	8/18/2006	411
		11/17/2006	32
		3/1/2007	2
		6/4/2007	31
		7/23/2008	11

Table 7-8. West Fork Gallatin River E. Coli Concentrations

Sampling Site ID	Sampling Site Name	Date	E. Coli Concentration (cfu/100mL)
		8/27/2008	83
WFGR03	West	8/18/2006	121
		3/1/2007	1
		6/4/2007	17
		7/23/2008	10
		8/27/2008	55

Bold indicates target value was not met.

The highest e. coli concentrations were recorded during the August 2006 and August 2008 sampling events. Data did not meet the requirements (**Table 7-1**) for direct evaluation of water quality target attainment and precise evaluation of e.coli water quality standards attainment, but may be used to inform further source assessment and water quality evaluation.

7.4.2.3 South Fork West Fork Gallatin River (MT41H005_060)

The South Fork River flows into the West Fork Gallatin River. The segment is not listed as impaired on the 2008 303(d) List. On the South Fork West Fork Gallatin River, 14 samples from 5 different sites were collected from 2006 through 2008 (**Figure 7-6**).

Figure 7-6. South Fork Gallatin River Sampling Sites

Results indicate that e. coli concentrations in the South Fork West Fork Gallatin River watershed are relatively low, with the highest concentrations occurring during August monitoring: a maximum value of 66 cfu/100mL was recorded at site SFWF02 on August 27, 2008. No exceedences of target geometric means or single sample (10%) values were recorded in the South Fork West Fork watershed.

7.4.3 E. Coli Target Compliance Summary

Recent data (2006-2008) verify that the Middle Fork West Fork exceeded water quality targets at sampling sites MFWF01, MFWF02, MFWF04 and MFWF05. E. coli water quality targets were not exceeded on the West Fork Gallatin River during the same sampling period, however several elevated values were observed. No exceedences of the e. coli targets were observed in the South Fork West Fork Gallatin River. An e. coli TMDL (**Section 7.6**) is subsequently provided for the Middle Fork West Fork Gallatin River.

7.5 E. Coli Source Characterization and Assessment

Assessment of existing e. coli sources is necessary in order to develop load allocations to specific source categories. The following section characterizes sources contributing to e. coli loading and assesses e. coli contributions from individual source categories.

Seasonal e. coli sampling conducted from 2006 through 2008 provides the most recent data for characterization of existing e. coli water quality conditions in the West Fork Gallatin watershed. Over 180 samples were taken from 25 sampling sites over a three year period with the objectives of 1) evaluating seasonal attainment of e. coli water quality targets, and 2) assessing e. coli load contributions from sources within the West Fork Gallatin River watershed.

As described in **Section 7.5**, data results show e. coli target exceedences on the lower Middle Fork West Fork Gallatin River (MFWFGR), and periodic exceedences of water quality targets in the Mountain Village area and on the lower West Fork Gallatin River during the summer low flow period. Of three summer synoptic sampling events (Aug 2006, July 2008, Aug 2008) the highest e. coli values were recorded during August of 2006. Water quality samples collected during wintertime low flows and springtime runoff flows in the West Fork watershed did not show elevated e. coli concentrations. Samples collected during November were significantly higher than winter and spring values but well below seasonal criteria (**Figure 7-7**).

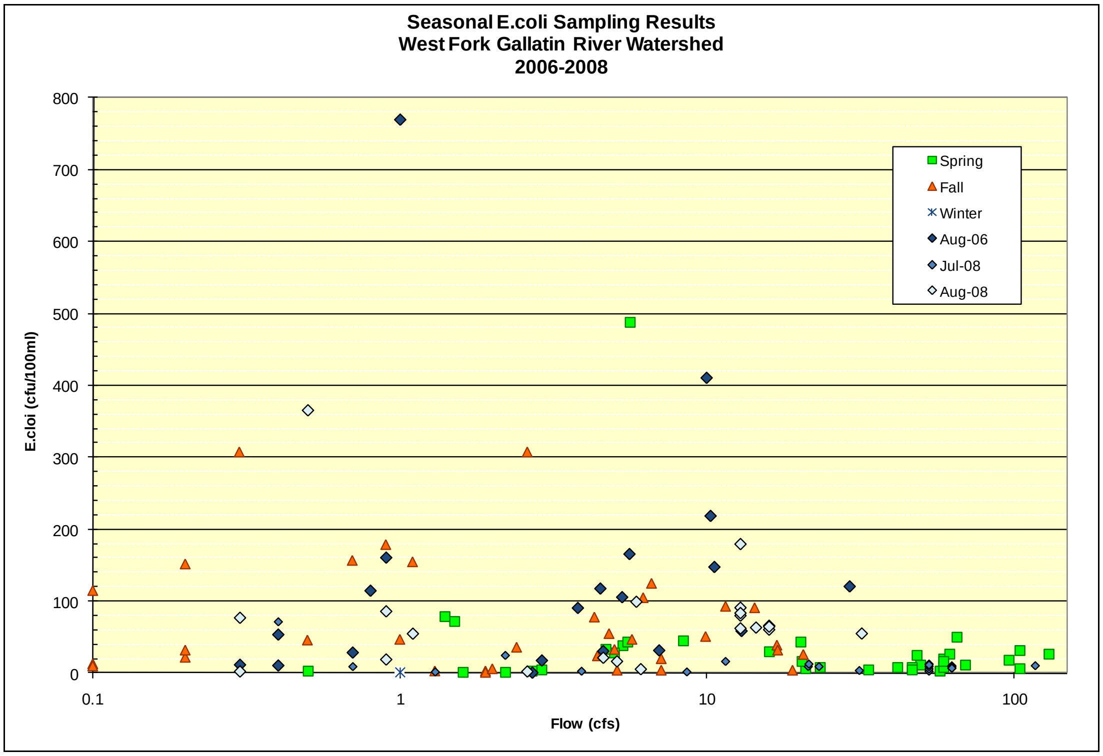

Figure 7-7. Seasonal E. Coli Concentrations in the West Fork Gallatin Watershed, 2006-2008

Typically, anthropogenic e. coli sources in western watersheds consist of agricultural nonpoint sources and wastewater point sources. Agricultural nonpoint e. coli sources are typically significant during wet, high flow periods (USEPA, 2001) and may cause water quality impairments during these times if proper controls are not in place. Alternatively, point sources of e. coli are the most significant during the lowest flows when a stream's dilution capacity is at its lowest. E. coli load duration curves provide a representation of the flow regimes when water quality impacts are observed, and can inform source assessments and the development of potential pollutant control measures.

An e. coli load a duration curve at MFWF02 on the lower MFWFGR (**Figure 7-8**) presents e. coli loads in excess of allowable loading levels during the summertime low flow period. E. coli loads during high (spring) and low (winter) flow periods are below allowable load levels. Site WFGR02, downstream on the West Fork Gallatin River, also exceeds allowable loading levels and exhibits a similar seasonal loading pattern. E. coli source characterization therefore focuses on identifying and assessing sources that may contribute e. coli loads during the late summer and early fall low-flow season. *It is expected that practical pollutant controls designed to reduce loading from these summertime sources may apply to year-round e. coli source reductions.*

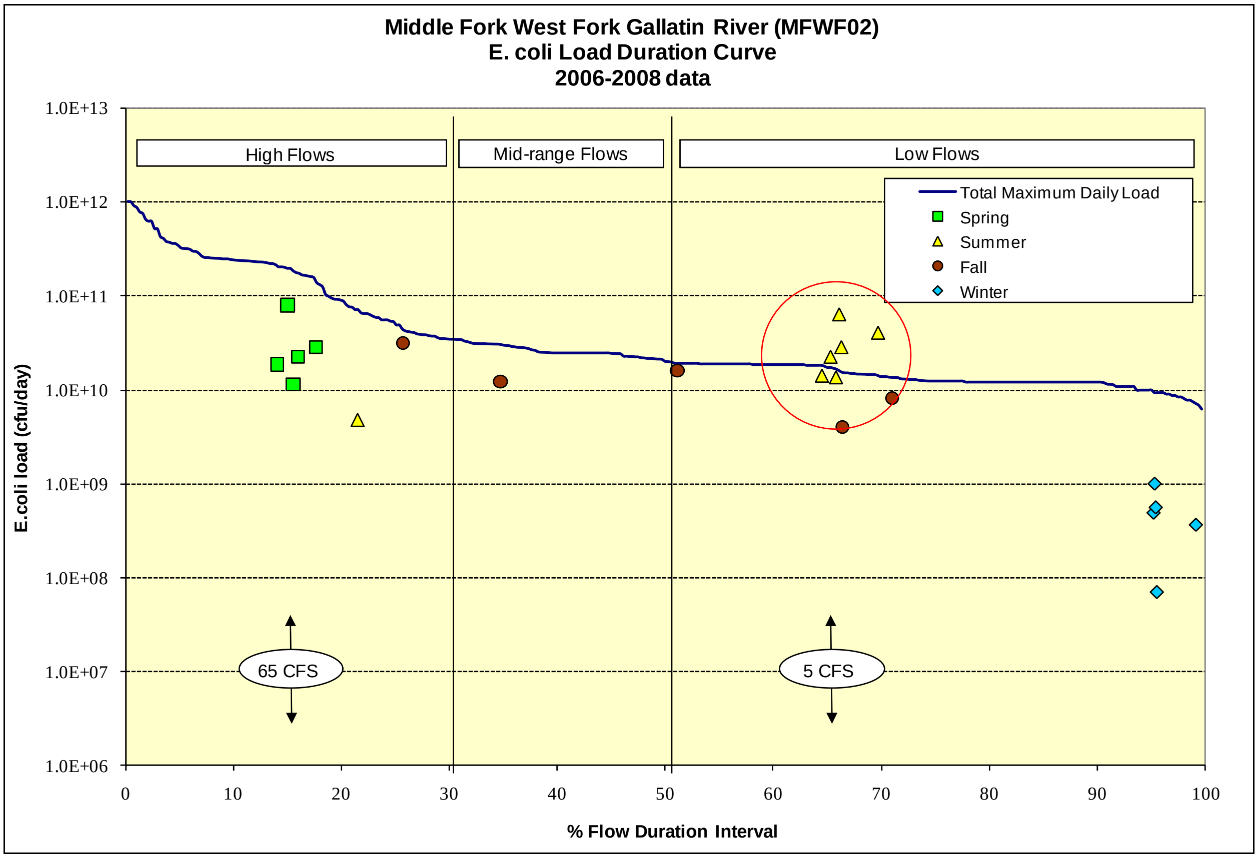

Figure 7-8. E. Coli Load Duration Curve at MFWF02 on the Middle Fork West Fork Gallatin River.

Land uses in the West Fork Gallatin River watershed are primarily residential and recreational, stemming from rapid growth of summer and winter resort developments and associated infrastructure. The West Fork Gallatin watershed has no agricultural sources of any significance, nor does it harbor any permitted point source discharges. The Big Sky Water and Sewer District land-applies treated wastewater to the Big Sky Golf Course at Meadow Village, however this water is disinfected before application and is not considered a likely e. coli source. E. coli sources in the West Fork Gallatin watershed include natural sources (beaver, moose, deer) and those sources associated with residential and recreational development and its infrastructure.

7.5.1 Natural E. Coli Sources

Natural background sources of e. coli are primarily from wildlife excrement, and may include moose, deer, beaver, waterfowl and other types of wildlife that utilize riparian and stream corridors. Estimates of natural background conditions for e. coli rely on historical data and, more importantly, recent reference data collected on nearby streams.

Historical/pre-development e. coli data with which to estimate natural background levels is limited for the West Fork Gallatin River watershed. Fecal coliform data collected by Stuart (Stuart et, al, 1976) in the early 1970’s showed low levels of fecal coliform in West Fork Gallatin watershed: reported annual geometric means at over 10 sites ranged from 1 to 45, with most sites (>90%) reporting annual geometric means of <10 organisms/100ml. These values are well below the former pathogen standard for fecal coliform, which did not allow for a geometric mean above 200 and less than 10% of the samples had to be below 400 organisms/100ml. While fecal coliform data cannot be reliably translated to associate e. coli concentrations, it assists in establishing low fecal bacteria conditions before the onset of large-scale residential growth and development since the recorded values are significantly below the allowable standards suggesting that natural background for e-coli would also be well below applicable standards.

Data collected on undeveloped or ‘reference’ areas also is used to inform natural background e. coli conditions. During e. coli data collection in 2006-2008, several sampling sites were chosen in undeveloped areas in order to estimate natural background e. coli conditions. Sites include undeveloped areas of Swan Creek, Hellroaring Creek, Beehive Creek, the North Fork West Fork Gallatin River, and the South Fork West Fork Gallatin River. Late summer/fall e. coli concentrations averaged 24 cfu/100ml (**Table 7-9**).

Table 7-9. E. Coli Reference Data and summary statistics

Site	Sample Date	E. Coli (cfu/100ml)
BEHV01	08/18/06	29
BEHV01	11/17/06	6
BEHV01	08/27/08	19
NFWF01	08/18/06	91
NFWF01	11/17/06	20
SFTR01	08/27/08	5
HLRG01	08/27/08	3
SWAN03	08/27/08	23
	mean	24
	90th percentile	48
	max	91
	min	3

For purposes of estimating natural background concentrations for TMDL development, the 90th percentile reference value of 48 e. coli cfu/100ml is adopted as an estimate of nature background sources for calculation of daily load allocations in **Section 7.7**.

7.5.2 Anthropogenic Sources

7.5.2.1 Residential/Recreational E. Coli Sources

Anthropogenic e. coli sources in the watershed include a variety of nonpoint sources associated with residential and recreational land uses. These sources include a variety of lesser individual source categories that together may be categorized as recreational/residential sources and include:

Domestic pets, livestock and geese/waterfowl.
Animals associated with human residential and recreational lands are included as a component of ‘recreational/residential’ sources. Dogs are common in the residential areas of the West Fork, and recreational stock (commercial trail and hobby horses) are maintained by individuals and

businesses. Geese and waterfowl are observed using Lake Levinsky, the Big Sky Golf Course and ponds lower on the West Fork Gallatin River during the summer, and may be periodic, if not significant, contributors to e. coli loads at times.

Storm Water runoff & sediment
Storm water runoff from residential and commercial areas can carry a variety of contaminated refuse to local streams and ponds, contaminating stream and lake/pond sediments. Resuspension of e. coli in substrate sediments as a result of recreational usage (anglers, waders, dogs, etc) or disturbance may contribute to in-stream e. coli loads during the summer usage season, particularly in the Mountain Village and Meadow Village areas.

7.5.2.2 Wastewater E. Coli Sources

Possible wastewater sources with the potential to contribute e. coli loads to surface waters include individual septic systems and sewer system main lines and residential service connections. Properly designed, installed and maintained, these systems pose no significant loading threat to surface waters. Failing systems or leaking pipes have the potential contribute e. coli loads where they are in close proximity to surface waters.

Failing or malfunctioning septic systems
Failing and malfunctioning septic systems include individual wastewater systems that are not providing adequate treatment of bacterial contaminants before they reach surface waters. Typically such systems exhibit evidence of failure by surface ponding and routing of effluent. Malfunctioning systems may also include improperly installed systems or those that intercept ground water or are susceptible to flooding. While no information is available regarding failing septic systems, the number of septic systems in close proximity to surface waters within the watershed is low and not expected to contribute significantly to e. coli loads.

Broken sewer lines or domestic service lines
Compromised underground sewer and service lines are not uncommon to sewer systems, and have the potential to contribute e. coli loads to nearby waterbodies. While the significance of this source is unknown, the proximity of sewer mainlines and residential service connections to the West Fork and Middle Fork West Fork of the Gallatin River (**Figure 6-9b**) does not rule out the potential for sewer failure to impact surface waters. Maintenance of sewer and service lines is conducted routinely by the Big Sky Water and Sewer District.

Because of the diffuse nature of nonpoint source loads and the variability in e. coli results, identification and estimation of discrete of e. coli loads from specific sources is difficult to estimate. Synoptic sampling events conducted in 2006 and 2008, while not adequate to unveil definitive source linkages show the spatial and temporal variability in e. coli measurements throughout the watershed. **Figures 7-9**, **7-10**, and **7-11** present e. coli concentrations (bars) and associated streamflows (background) from three summertime synoptic sampling events. Sites are arranged left to right from upstream to downstream with tributaries to the mainstem marked in bright green.

In general the higher e. coli concentrations were observed in the more developed areas of the watershed, and may be attributable to a variety of sources associated with residential land use and development. In the absence of genetic microbial source tracking information, it is difficult to assign specific load estimations to individual residential/recreational and wastewater source categories. Consequently, numeric load estimations are not calculated for cumulative residential/recreational and wastewater e. coli sources. Rather, load allocations given in **Section 7.7** provide allowable e. coli loading levels to these source categories.

7.6 E. Coli Total Maximum Daily Loads

As established in **Section 7.5**, e. coli Total Maximum Daily Loads are presented herein for the Middle Fork West Fork Gallatin River (MT41H005_050).

A Total Maximum Daily Load (TMDL) is a calculation of the maximum pollutant load a waterbody can receive while maintaining water quality standards. The total maximum daily load (cfu/day) of e. coli for streams in the West Fork Gallatin watershed is calculated using seasonal e. coli target values. The total maximum daily e. coli load during the 'summer' season (Apr 1 – Oct 31) is based on an instream e. coli target value of 126 cfu/100ml, while the e. coli TMDL during the winter season (Nov 1 – March 31) is based on an instream e. coli target value of 630 cfu/100ml (**Figure 7-12**). TMDL calculations are based on the following calculation:

TMDL = (X) (Y) (2.44E+7)
TMDL= Total Maximum Daily Load in cfu/day
X= e. coli water quality target in cfu/100ml
Y= streamflow in cubic feet per second
(2.44E+7) = conversion factor

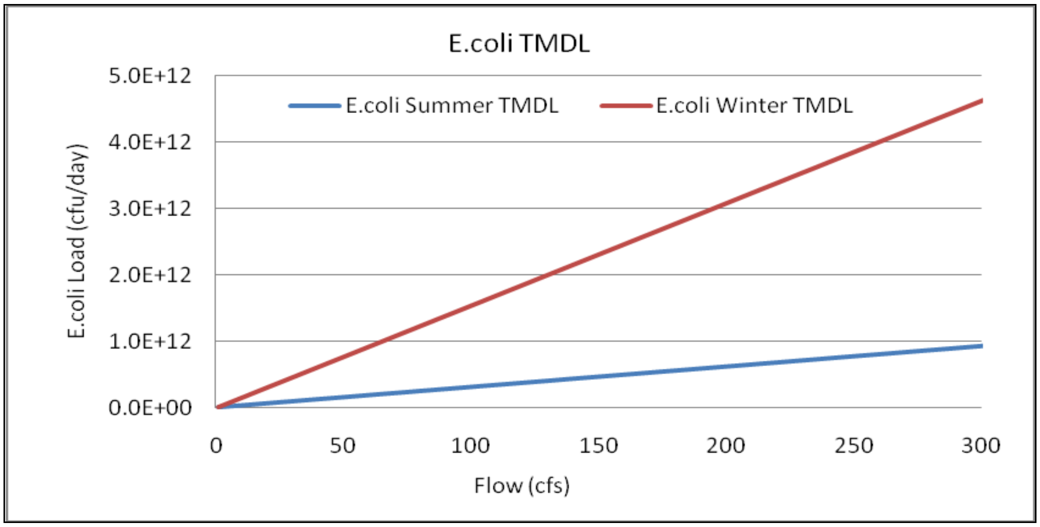

Figure 7-12. Seasonal E. Coli TMDLs as a function of flow

TMDL are allocated to point (wasteload) and nonpoint (load) e. coli sources. The TMDL is comprised of the sum of all point sources and nonpoint sources (natural and anthropogenic), plus a margin of safety that accounts for uncertainties in loading and receiving water analyses. In addition to pollutant load allocations, the TMDL must also take into account the seasonal variability of pollutant loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

These elements are combined in the following equation:

TMDL = ∑WLA + ∑LA + MOS

Where:

- WLA = Waste Load Allocation or the portion of the TMDL allocated to point sources. Since there are no permitted point sources in the West Fork Gallatin watershed, the WLA=0.
- LA = Load Allocation or the portion of the TMDL allocated to nonpoint recreational/residential sources and natural background
- MOS = Margin of Safety or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. Where the MOS is implicit (see **Section 7.9.2**), an additional numeric MOS is unnecessary; therefore the “explicit” MOS is set equal to 0 here.

7.7 E. Coli Load Allocations (MT41H005_050)

For the Middle Fork West Fork Gallatin River (MT41H005_050) the e. coli TMDL is equal to the sum of the individual load allocations to source categories. As discussed in **Section 7.6**, significant e. coli sources include natural background sources, potential wastewater sources, and a variety of diffuse sources associated with residential and resort development in the watershed. Load allocations are therefore provided for 1) natural background sources 2) wastewater sources and 3) cumulative residential/recreational land use sources. In the absence of WLA and an explicit MOS, e. coli TMDLs are equal to the sum of the individual load allocations:

TMDL = LA_{NB} + LA_{WW} + LA_{RES}

LA_{NB} = Load Allocation to natural background sources
LA_{WW} = Load Allocation to wastewater sources
LA_{RES} = Load Allocation to residential/recreational land use sources

7.7.1 Natural Background Load Allocation

Load allocations for natural background sources are based on a natural background e. coli concentration of 48 cfu/100ml (see **Section 7.6.1**), and are calculated using the equation:

LA_{NB} = (X) (Y) (2.44E+7)

X= e. coli natural background concentration in cfu/100ml
Y= streamflow in cubic feet per second
(2.44E+7) = conversion factor

7.7.2 Wastewater Load Allocation

The load allocation for unpermitted wastewater sources is set at zero: municipal and residential wastewater is prohibited from entering state waterbodies without an MPDES permit. Properly maintained sewer and septic systems are designed to prevent e. coli loads from entering waterbodies and are assumed to meet this allocation. System failures that contribute e. coli loads to surface waters are not meeting this allocation.

$\mathbf{LA_{WW} = 0}$

7.7.3 E. Coli Source: Residential/Recreational Land Use and Development

Load allocations for residential/recreational sources are calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$\mathbf{LA_{RES} = TMDL - LA_{NB}}$

7.7.4 E. Coli Load Allocation Summary

E. coli load allocations are provided for the Middle Fork West Fork Gallatin River (MT41H005_050) and include allocations to the following source categories: natural background, wastewater, and residential/recreational land uses (**Table 7-11**). **Figures 7-13** and **7-14** present TMDLs and cumulative e. coli load allocations for the summer and winter seasons as a function of streamflow. E. coli targets and load allocations were met during most sampling periods, however data collected during late summer of 2006 showed e. coli targets and load allocations were not being met at site MFWF02 (**Table 7-6**). Using this condition, **Table 7-10** illustrates existing summer e. coli loading, and e. coli load reductions necessary to meet the total maximum daily load for e. coli.

Table 7-10. E. Coli Loads and Allocations*

E. Coli Source Category	Existing E. Coli Load (Mcfu/day)	Load Allocation (Mcfu/day)	Reduction
Natural	5,873	5,873	0%
Wastewater	~	0	~
Residential & Recreational	28,139	9,543	66%
Total	34,012	15,415	55%

**based on 5 cfs summer baseflow at sampling site MFWF02*

Meeting load allocations may be achieved through a variety of water quality planning and implementation actions: implementation strategies that will help to meet e. coli allocations are provided in **Section 8.0**. As the nature of e. coli sources are similar throughout the watershed, the load allocations and pollutant control actions provided for the Middle Fork West Fork Gallatin River may be used as a guide for potential e. coli allocations and e. coli control actions to be applied to other streams in the West Fork Gallatin River watershed.

Table 7-11. E. Coli Load allocation descriptions

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• naturally occurring wildlife (beaver, moose, deer, etc).	**LANB = (X) (Y) (2.44E+7)** *X= e. coli background concentration in cfu/100ml* *Y= flow in cfs* *(2.44E+7) = conversion factor*
Wastewater	• Failing septic systems • Failing sewer infrastructure (main and service lines)	**LAWW = 0**
Residential and Recreational Land Use	• Domestic pets, commercial or residential stock, waterfowl associated with developed areas. • Storm water runoff and contaminated sediments • Urban/residential refuse and litter	**LARES = TMDL - LANB**

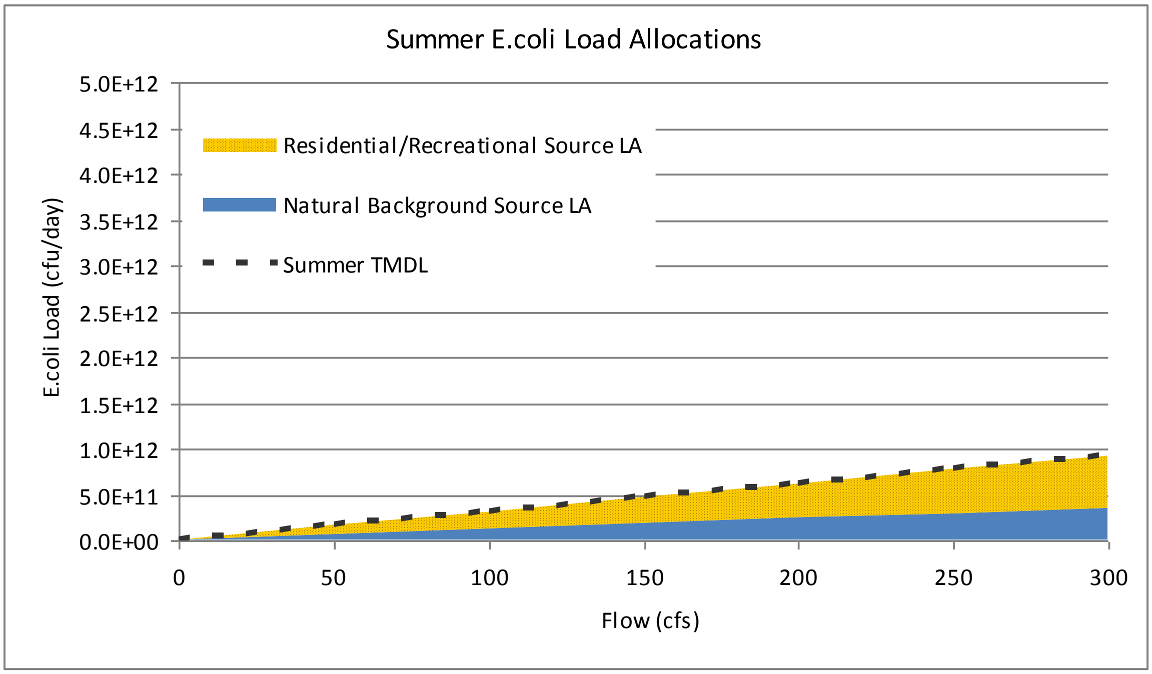

Figure 7-13. Summer E. Coli TMDL and Load Allocations

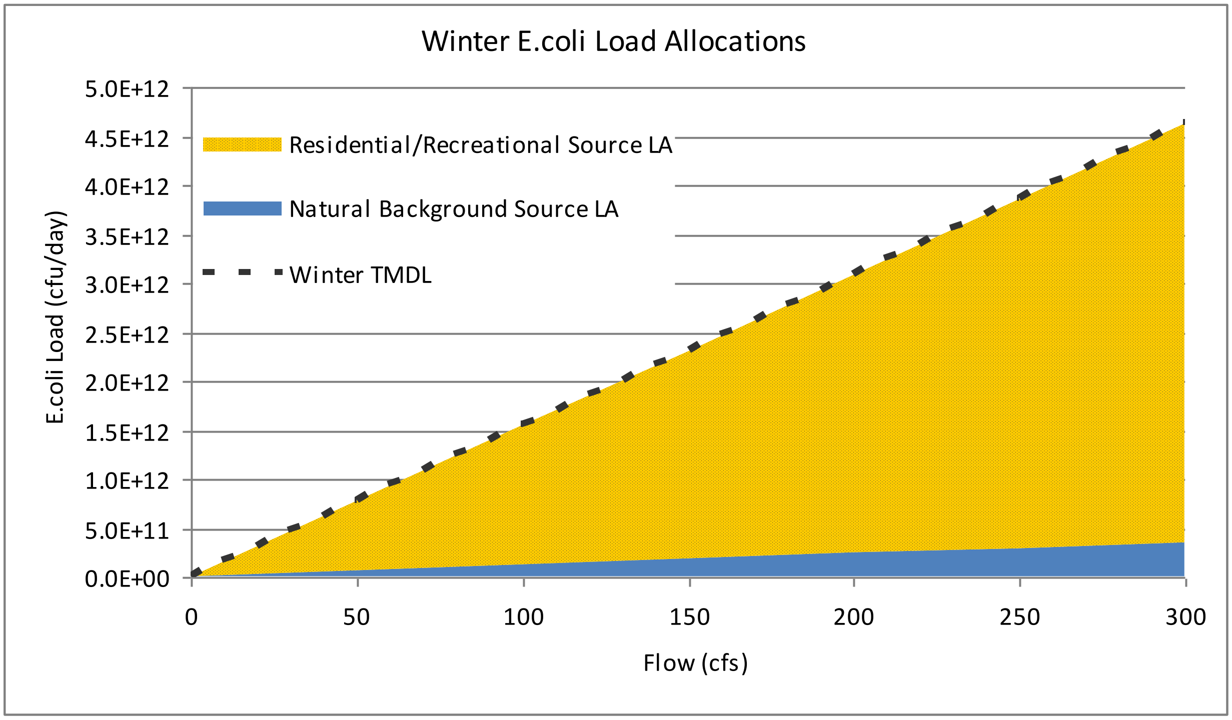

Figure 7-14. Winter E. Coli TMDL and Load Allocations

7.8 Seasonality and Margin of Safety

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

7.8.1 Seasonality

Addressing seasonal variations is an important and required component of TMDL development and throughout this plan seasonality is an integral consideration. Water quality and particularly e. coli concentrations are recognized to have seasonal cycles. Specific examples of how seasonality has been addressed within this document include:

- Water quality standards and consequent e. coli water quality targets are developed based on application of seasonal beneficial uses (recreational use) and use a 126 cfu/100 ml value for the summer months and 630 cfu/100ml during the winter months.
- Water quality data from four difference seasons was collected to evaluate target compliance seasonally.
- E. coli data and sources were evaluated based on and understanding of local seasonal source prevalence and seasonal pathways.

- Load duration curves were developed to demonstrate the typical seasonal flow regimes when e. coli concentrations become a problem.

7.8.2 Margin of Safety

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

- The geometric mean value of 126 cfu/100ml (summer) or 630 cfu/100ml (winter) is used to calculate TMDLs and load allocations. This provides a margin of safety by ensuring that allowable daily load allocations do not result in the exceedence of water quality targets.
- The 90th percentile value of summer natural background concentrations was used to establish a natural background concentration for load allocation purposes. This is a conservative approach, and provides an additional MOS for anthropogenically –derived e. coli loads during most conditions.
- Summertime natural background conditions (the highest natural concentrations) were used to establish natural background conditions during all seasons.
- By considering seasonality (discussed above) and variability in e. coli loading.
- By using an adaptive management approach to evaluate target attainment and allow for refinement of load allocation, assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development.

7.8.3 Uncertainty and Adaptive Management

Uncertainties in the accuracy of field data, source assessments, loading calculations, and other considerations are inherent when assessing and evaluating environmental variables for TMDL development. While uncertainties are an undeniable fact of TMDL development, mitigation and reduction of uncertainties through adaptive management approaches is a key component of ongoing TMDL implementation and evaluation. Uncertainties, assumptions, and considerations are applied throughout this document and point to the need to refine analysis, conduct further monitoring, and address unknowns in order to develop better understanding of e. coli impairment conditions and the processes that affect impairment. This process of adaptive management is predicated on the premise that TMDLs, allocations, and the analyses supporting them are not static, but are processes subject to modification and adjustment as new information and relationships are understood. As further monitoring of water quality and source loading conditions is conducted, uncertainties associated with these assumptions and considerations may be mitigated and loading estimates may be refined to more accurately portray watershed conditions.

As part of this adaptive management approach, land use activities should be tracked. Changes in land use may trigger a need for additional monitoring. The extent of monitoring should be consistent with the extent of potential impacts, and can vary from basic BMP assessments to a complete measure of target parameters above and below the project area before the project and after completion of the project. Cumulative impacts from multiple projects must also be a consideration. This approach will help track the recovery of the system and the impacts, or lack of impacts, from ongoing management activities in the watershed.

Uncertainties in assessments and assumptions should not paralyze, but should point to the need to be flexible in our understanding of complex systems, and to adjust our thinking and analysis in response to this need. Implementation and monitoring recommendations presented in **Section 8** provide a basic framework for reducing uncertainty and furthering understanding of these issues.

SECTION 8.0
FRAMEWORK WATER QUALITY RESTORATION AND MONITORING STRATEGY

8.1 TMDL Implementation and Monitoring Framework

It is important to note that while certain land uses and human activities are identified as sources and causes of water quality impairment, the management of these activities is of more concern than the activities themselves. This document does not advocate for the removal of land uses or human activities 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

The DEQ does not implement TMDL pollutant reduction projects for nonpoint source activities, but can provide technical and financial assistance for stakeholders interested in improving their water quality. The DEQ will work with participants to use the TMDLs as a basis for developing locally-driven Watershed Restoration Plans (WRPs), administer funding specifically to help fund 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 which will progress toward meeting water 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 Blue Water Task Force (BWTF), The Big Sky Water and Sewer District, Big Sky Resort, Moonlight Basin Resort, USFS, DNRC, FWP and DEQ. Additional local organizations or entities such as local homeowner associations, conservation groups, universities or non-governmental organizations may be helpful in providing technical, financial or coordination assistance.

It must be noted that the Blue Water Task Force, the Big Sky Water and Sewer District, and Big Sky Resort and Golf Course have been instrumental in assisting in water quality assessment, analysis and implementation efforts in the watershed, are key players and should be included in the planning and execution of restoration efforts in the watershed.

8.1.2 Water Quality Restoration Plan Development

A water quality restoration plan (WRP) provides a framework strategy for water quality restoration and monitoring in the West Fork Gallatin River watershed, 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. Water quality 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. The 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. The 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 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 Blue Water Task Force has taken the lead in developing a Water Quality Restoration Plan for the West Fork Gallatin River Watershed, and receives financial and technical support from the DEQ under a '319 grant' to initiate Plan development. DEQ encourages collaboration among local stakeholders, interested parties, state and federal agencies in the development of West Fork Gallatin River Watershed water quality restoration planning.

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 West Fork Gallatin River watershed and target variables move towards reference 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 25 percent or more 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 BWTF recently received 319 funding to assist with the development of the WRP and for additional monitoring to refine the source assessment.

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 West Fork Gallatin watershed 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.

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 the major source categories of human-caused pollutant loads in the West Fork Gallatin River watershed, 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 West Fork Gallatin River watershed should focus on all major sources for each pollutant category. 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 ongoing BMPs is the core of TMDL implementation but only forms a part of the restoration strategy. 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 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 Land Application Design Review & Evaluation

The Big Sky Golf Course irrigates its grounds using treated wastewater supplied by the Big Sky Water & Sewer District. Water quality data and isotope analysis indicate that wastewater loads contribute substantially to instream NO_3+NO_2 load increases through the area of the Big Sky Golf Course, and are resulting in excessive algal growth in the West Fork Gallatin River downstream of Meadow Village. Field investigations have identified deficiencies in the wastewater spray-irrigation delivery system, and water quality modeling conducted by MSU researchers indicate that wastewater applied to the golf course is making its way to surface waters.

Spray irrigation systems are designed to 1) apply wastewater at agronomic uptake rates for nitrogen assimilation into turf grass and 2) limit application to rates that will be wholly taken up and used by turf within the root zone by evapotranspiration or plant growth. It appears that the spray irrigation system as it is presently being operated is not meeting design standards as specified in *Environmental Protection Agency (EPA) Process Design Manual: Land Treatment of Municipal Wastewater (and incorporated into Circular DEQ2: Design Standards for Wastewater Facilities*), and thus may not meet the intent of the ‘condition of approval’ as defined in the *Public Water Supplies, Distribution and Treatment Act*. To evaluate this assumption further and determine whether wastewater is being applied properly and at rates believed to result in zero discharge to surface and ground water, a detailed evaluation of the operation, maintenance and application of wastewater loads should be conducted.

Coordination between the DEQ (Technical and Financial Assistance Bureau), the Big Sky Water and Sewer District, and the Big Sky Resort and Golf Course is essential for the review and evaluation of the existing spray-irrigation system, and for the development of a Nutrient Management Plan (NMP). A Nutrient Management Plan should be developed that addresses deficiencies in the implementation and management of spray-irrigated wastewater, and incorporates standards for the land-application of wastewater (DEQ, 1999). Ideally, the NMP should be developed in such a way as to provide personnel a practical guide in the proper application and implementation of land-applied wastewater for landscape and golf course turf management.

8.2.2 Sewer System Investigation

It is possible that leaking or broken sewer pipes may be contributing to NO_3+NO_2 load contributions through the Big Sky Golf Course at Meadow Village. Several sewer and service lines transect the area of concern. The Big Sky Water and Sewer District routinely conducts maintenance of sewer infrastructure. It is recommended that the sewer infrastructure be investigated for potential leaks or failures that may be contributing to wastewater loads entering the West Fork Gallatin River through the area of the golf course.

Source tracking of wastewater loads may also be evaluated by addition of tracers to either the spray-irrigation or sewer system, and monitoring stream water quality for presence of added tracers. At present, the BSWSD is aware of the wastewater loading through the reach and is planning to investigate potential leaks or failures through the affected area with sewer cameras (Ron Edwards, personal communication).

8.2.3 Storm Water Mitigation and Planning

All permitted storm water sources in the West Fork Gallatin watershed are associated with construction, which is discussed below in **Section 8.2.6**. In addition to permitted sources, other sources of storm water have the potential to be significant pollutant sources. Buildings and other impervious surfaces associated with land development prevent water from infiltrating into the ground and can alter watershed hydrology and transport built-up pollutants into nearby waterbodies. An important component to effectively managing storm water is comprehensive planning that integrates land and infrastructure management. Smart growth and low impact development are two closely related planning strategies that help reduce storm water volume, slow its transport to surface waterbodies, and improve ground water recharge. Smart growth emphasizes structuring development to preserve open space, reduce the use of impervious surfaces, and improve water detention so more precipitation can be retained on the landscape before runoff occurs. Low impact development mimics natural processes of water storage and infiltration and can limit the harmful effects that increased percentages of impervious surface have on surface waters. Both concepts focus on applying simple, non-structural, and low cost methods to treat storm water on the landscape and they can be used to retrofit existing development and also applied to new development. Generally, newer developments in the watershed have better BMP implementation than older developments, and although planning for future development and retrofitting older developments with better levels of treatment are important, consistent maintenance and effectiveness evaluation of new and recently implemented storm water BMPs is also an important component of effective storm water management and TMDL implementation. Examples low impact development and smart growth practices include drain chains, rain barrels, vegetated swales, sidewalk storage, permeable pavers, native landscaping, reducing parking areas, and mixed-use development. Parking lot drainage into a swale and a mixed use development are shown in **Figure 8-1**. Additional information about smart growth and low impact development can be found in Montana's Nonpoint Source Management Plan (DEQ 2007) and at the EPA's website (www.epa.gov/nps/lid; www.epa.gov/dced).

Figure 8-1. Storm water BMPs: Parking lot designed to drain into a swale and a mixed use development.

8.2.4 Riparian and Floodplain Management

Riparian areas and floodplains are critical for wildlife habitat, ground water 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 an important of TMDL implementation in the Upper Gallatin River Watershed. The value of these areas is increasingly being recognized; over the past several years, Gallatin and Madison counties have incorporated construction setbacks and floodplain development restrictions into county ordinances. In Gallatin County, there is a 300 foot setback from the high water mark for the West Gallatin and 150 feet for other water courses (Gallatin County 2009).

The recent land use planning 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 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). The following recommended restoration measures would help stabilize the soil, decrease sediment reaching the streams, and increase nutrient absorption from overland runoff:

- Harvest and transplant locally available sod mats with dense root mass to immediately promote bank stability and capture nutrients and sediments.
- Transplant mature shrubs, particularly willows (Salix sp.), to rapidly restore instream habitat and water quality by providing overhead cover and stream shading, as well as uptake of nutrients.
- 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, it generally redirects channel energy and exacerbates 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.

8.2.5 Forestry and Timber Harvest

Currently, timber harvest is not a significant sediment or nutrient source in the West Fork Gallatin River watershed, but harvesting will likely continue in the future within the Gallatin National Forest and on private land. Future harvest activities should be conducted by all landowners according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana SMZ Law (77-5-301 through 307 MCA). The Montana Forestry BMPs cover timber harvesting and site preparation, harvest design, other harvesting activities, slash treatment and site preparation, winter logging, and hazardous substances. While the SMZ Law is intended to guide commercial timber harvesting activities in streamside areas (i.e. within 50 feet of a waterbody), the riparian protection principles behind the law can be applied to numerous land management activities (i.e. timber harvest for personal use, agriculture, development). Prior to harvesting on private land, landowners or operators are required to notify the Montana DNRC. 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.

8.2.6 Road BMPs and Road Sanding Management

The road sediment reduction represents the estimated sediment load that would remain once BMP effectiveness reaches 85 percent. This was selected based on literature values of buffer effectiveness and observations of existing conditions within the watershed. 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.

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

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

8.2.7 Construction Permitting & BMPs

Construction activities disturb the soil, and if not managed properly, they can be substantial sources of sediment, pathogens, and nutrients. Construction activity disturbing 1 acre or greater is required to obtain permit coverage under the General Permit. A Storm Water 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 percent 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 greater than 10 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. 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 new rule has extensive information about construction related BMPs, including limitations, costs, and effectiveness (EPA 2009).

8.2.8 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 slightly more than half of the culverts were designed to accommodate a 25-year storm event and that the potential annual sediment load from culvert failure across the watershed is significant. 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 25% of the estimated culverts in the watershed and it is recommended that an evaluation of 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 76 percent of the assessed culverts pose a passage risk to juvenile risk at all flows, and the primary reason was because of culvert steepness. 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.

8.2.9 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 Blue Water Task Force provides educational opportunities to both students and adults through programs at Ophir School and through local water quality workshops and informational meetings. Continued education is key to ongoing understanding of water quality issues in the West Fork Gallatin watershed, 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 MOS is put in place to reflect some of this uncertainty, but other issues only become apparent when restoration strategies are underway. Having a monitoring strategy in place allows for feedback on the effectiveness of restoration activities (whether TMDL targets are being met), if all significant sources have been identified, and whether attainment of TMDL targets is feasible. Data from long-term monitoring programs also provide technical justifications to modify restoration strategies, targets, or allocations where appropriate. 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 West Fork Gallatin River watershed include: 1) refining the source assessment for each pollutant, 2) assessing attainment of water quality targets, 3) tracking restoration projects as they are implemented and assessing their effectiveness, and 4) identifying long-term trends in water quality.

8.3.1 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 assessment work will be needed to ensure restoration activities are as cost effective as possible. Strategies for strengthening source assessments for each of the pollutants may include:

Sediment
More thorough examinations of bank erosion conditions and investigation of related contributing factors for each subwatershed of concern through site visits and subwatershed scale BEHI assessments. Additionally, the development of bank erosion retreat rates specific to the Upper Gallatin TPA would provide a more accurate quantification of sediment loading from bank erosion and help gain a better understanding of background loading rates, particularly in areas with naturally erosive geology. Bank retreat rates can be determined by installing bank pins at different positions on the streambank at several transects across a range of landscapes and stability ratings. Bank erosion is documented after high flows and throughout the year for several years to capture retreat rates under a range of flow conditions.

Review of land use practices specific to subwatersheds of concern to determine where the greatest potential for improvement and likelihood of sediment reduction can occur for the identified major land use categories. This should include evaluating upland sources, riparian vegetation, and the effectiveness of sediment control measures such as Lake Levinsky.

Additional field surveys of culverts, roads, and road crossings to help prioritize the road segments/crossings of most concern. Culverts should be assessed for fish passage and their capacity to pass storm event flows as culvert failure is often a source of discrete sediment loads.

E. Coli
E. Coli conditions in the watershed were highly variable, with the highest e.coli concentrations typically witnessed during late summer low flows when water temperatures are the warmest. Sources contributing to e.coli target exceedences include a variety of diffuse natural and anthropogenic inputs: discrete e.coli sources were not identified in either field investigations or water quality sampling results. Lack of information on discrete e.coli sources affecting impairment makes it difficult to target specific areas or e.coli sources for load reductions and may inhibit prioritization of implementation activities to address e.coli loading.

In order to better understand conditions contributing to e.coli loading, it is recommended that e.coli sampling be continued in areas where elevated e.coli concentrations were observed, and to note specific land uses and conditions at the time of sampling that could be contributing to elevated instream concentrations. Additionally, synoptic sampling events should be continued, particularly during late summer low-flow conditions in order to allow analysis of load contributions during times when water quality is most susceptible to impacts from e.coli contributions.

Nutrients
Nutrient sources believed to contribute to impairment of streams in the watershed include diffuse recreational and resort sources in the upper watershed (Mountain Village area) and wastewater sources in the lower watershed (Meadow Village area). In the upper watershed (upstream of Lake Levinsky) source assessment refinements should focus on identifying source areas where BMPs would help to alleviate nitrogen inputs to streams. These include areas that are more susceptible to runoff, or areas that are under active land clearing, land disturbance or are under active turf management. Identification and evaluation of existing BMPs and identification of potential BMPs to reduce nitrogen loading to streams is recommended and will require site-

specific evaluation on nitrogen management and control activities and structures (riparian vegetation, vegetative buffering of stream crossings, buffering of hydroseeding and revegetation projects, etc.).

In the Meadow Village area, nutrient sources contributing to impairment have been identified as wastewater-derived nitrogen. Source assessments conducted thusfar have identified potential sources as spray-irrigated effluent applied to the Big Sky Golf Course and/or leaks in the sewer or irrigation system infrastructure in the areas. While assessments have confidently implicated wastewater nitrogen as the primary component affecting impairment conditions, precise determination of the source of wastewater requires further investigation. Site visits have identified deficiencies in the implementation of the spray-irrigation system, however it is unknown whether the deficiencies observed contribute significantly to load increases documented through the reach. Since approval of spray-irrigation in 1997, no recent evaluation of the efficacy of the system, or evaluation of nitrogen application through land-applied wastewater has been conducted. Given the substantial nitrogen load increases measured through the segment, it is recommended that the design, operation, and maintenance of the spray-irrigation system be fully evaluated in order to assess potential load contribution and to correct any deficiencies in either design or implementation of the spray-irrigation system, and to update existing land-application agreement with site-specific requirements designed to ensure no discharge of nitrogen to either surface waters or ground water.

Likewise, investigation into whether leaking sewer, service line, or irrigation infrastructure may be contributing to wastewater loads should be conducted. Sewer and service lines traverse the affected area; creating the possibility that sewer infrastructure failure may be contributing to wastewater loading within the reach. Tracer addition, sewer-camera reconnaissance, or other means of assessing the potential of this source should be considered. The BSWSD routinely conducts video inspections of sewer lines, and it is recommended that sewer and irrigation pipe within the affected area be inspected.

In addition to wastewater sources identified in the West Fork Gallatin River, water quality isotope analysis also implicates wastewater nitrogen as a significant source of nitrogen in the lower South Fork West Fork Gallatin River. Sources that have the potential to contribute wastewater nitrogen loads to the South Fork include land-applied wastewater applied to the Big Sky Golf Course, failing sewer infrastructure, near-stream on-site septic systems, or other failing wastewater systems. Water quality data collected thus far did not allow positive identification of discrete wastewater loads, but persistent nuisance algae levels in the lower watershed suggest chronic nitrogen loading to the lower segment of the South Fork West Fork Gallatin River. Further monitoring and source assessments are recommended to further assess nitrogen sources to the segment and to identify wastewater nitrogen sources contributing to this segment.

8.3.2 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 West Fork Gallatin River watershed, each of the streams of interest was stratified into unique reaches based on physical characteristics and anthropogenic influence. The 16 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.

E. Coli & Nutrients

Since 2005 extensive e.coli and nutrient data has been collected, both to evaluate impairment conditions and to assess potential sources influencing impairment. Monitoring of e.coli and nutrient parameters to evaluate target attainment should follow existing Sampling and Analysis Plan guidance and include a subset of existing sampling sites to maintain consistency and comparability of sampling results. It is expected that as land uses change and new sources are introduced to the watershed, monitoring of baseline condition and target attainment will incorporate significant land use or management changes into the sampling scheme so that any potential impacts to water quality can be monitored and remedied if water quality impacts are realized.

8.3.3 Effectiveness Monitoring for Restoration Activities

As restoration activities begin throughout the watershed, all projects as well as the targeted pollutants should be tracked. Also, 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 will be evaluated based on a combination of target parameters and changes in land management practices that address the major sources. The monitoring locations and additional monitoring parameters needed will depend on the type of restoration projects implemented, the project locations, the land use influences specific to potential monitoring sites, and budget and time constraints.

SECTION 9.0
STAKEHOLDER AND PUBLIC INVOLVEMENT

9.1 TMDL Program and Public Participation Requirements

Development of TMDLs in the West Fork Gallatin River watershed was a multi-year process involving technical assessments and information gathering, synthesis and reporting of data and information, and information dissemination and outreach. Stakeholder and public involvement is a component of TMDL planning efforts supported by EPA guidelines and Montana State Law (MCA 75-5-703, 75-5-704), which directs the 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, advisory committees, and the public were solicited to participate in differing capacities through out the TMDL development process.

9.2 Description of Participants and Roles

9.2.1 Montana Department of Environmental Quality (DEQ)

The Montana Department of Environmental Quality is a state agency whose mission is to *'protect, sustain, and improve a clean and healthful environment to benefit present and future generations'*. State law (MCA 75-5-703) directs the DEQ to develop all necessary TMDLs, and responsibility and accountability for developing TMDLs within the legislatively mandated timeframe lies solely with the DEQ. The Department has provided resources toward this effort in terms of FTEs, funding, internal prioritization and planning. Where appropriate, DEQ partners with other state or federal agencies, local conservation districts and/or watershed organizations to conduct technical assessments and data collection, coordinate local outreach activities, act as a liaison to local stakeholders and communities, or conduct other activities that may assist and facilitate TMDL development.

9.2.2 United States Environmental Protection Agency (EPA)

The 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, and EPA has developed guidance and programs to assist states in that regard. In Montana, EPA has provided funding, development and technical assistance to the state's TMDL program and in some planning areas has taken the lead in TMDL development. In the West Fork Gallatin River watershed, the EPA developed a Phase I TMDL Status Report in 2005. Since 2005, the DEQ has maintained the lead in TMDL development in the watershed. Adoption of the completed TMDL is contingent on final EPA approval and must meet EPA requirements for acceptance.

9.2.3 Blue Water Task Force (BWTF)

The Blue Water Task Force (BWTF) is a locally-led non-profit watershed group headquartered in Big Sky, Montana. The BWTF's mission is to protect and preserve the health of the Gallatin River Watershed. The watershed group has three main programs: a volunteer water quality monitoring program; a community education program; and a watershed assessment program.

The BWTF administered several 319 contracts with the DEQ to conduct tasks related to watershed assessment and TMDL development; such as coordinating local public and stakeholder outreach activities, and conducting technical assessments in support of TMDL development. Outreach activities facilitated local involvement, disseminate information, and assisted in coordination and collaboration among technical advisors, stakeholders and the public. Technical assessments were designed to support TMDL development, are defined in scope by the DEQ, and implemented by consultants hired by the BWTF. In addition the BWTF acts as liaison between the DEQ and the local community by maintaining contact with local stakeholders and the public through workshops, public events and email and website updates.

The Blue Water Task Force was instrumental throughout the TMDL process in coordinating with and involving local organizations, specifically the Big Sky Water and Sewer District (BSWSD), Big Sky Resort and the Big Sky Golf Course. The assistance and local knowledge of the BWTF fostered common understanding of local water quality problems and significantly enhanced local involvement in water quality issues.

9.2.4 Gallatin & Madison Conservation Districts

The DEQ provided the Gallatin and Madison Conservation Districts with consultation opportunity during TMDL development in the West Fork Gallatin TMDL Planning Area consistent with State Law (75-5-703). This included opportunities for comment during the various stages of TMDL development, and an opportunity for CD participation in the Watershed Advisory Group defined below.

9.2.5 Upper Gallatin TMDL Watershed Advisory Group (WAG)

Representatives of applicable interest groups were requested to participate in the Upper Gallatin TMDL Watershed Advisory Group (WAG) to work with the DEQ and the Conservation Districts in an advisory capacity per State Law (75-5-703 & 704). WAG participation was requested from the interest groups defined in MCA 75-5-704, and included additional stakeholders, landowners, and resource professionals with an interest in maintaining and improving water quality and riparian resources. WAG involvement is voluntary and the level of involvement is at the discretion of individual WAG members. The WAG acted strictly in an advisory capacity during TMDL development and does not retain decision-making authority regarding TMDL activities. Communications with WAG members are typically conducted through email and scheduled meetings by the TMDL Project Manager or BWTF Executive Director. Opportunities for review and comment were provided for WAG participants at varying stages of TMDL development, including opportunities for TMDL draft document review prior to the public comment period.

9.2.6 Upper Gallatin TMDL Technical Advisory Group (TAG)

The Upper Gallatin 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 TPA. Individuals included representatives from State and Federal agencies, local resource professionals, and members of local government or resource planning institutions.

The Upper Gallatin TMDL TAG provided comment and review of technical TMDL assessments and reports. TAG members participate at their discretion, and in an advisory role in the TMDL process. TAG involvement included participation at TAG meetings and review of TMDL technical documents and reports. Typically draft technical documents were released to the TAG for review under a limited timeframe. Comments were compiled and evaluated, and final technical decisions regarding document modifications resided solely with the DEQ.

9.2.7 Stakeholders & General Public

Stakeholders are those persons or groups of persons with an interest in the Upper Gallatin TMDL, and have chosen to be informed and/or involved in the TMDL process. The BWTF and DEQ solicited stakeholder involvement early in the TMDL process through formal and informal means, and maintained contact with stakeholders throughout the process through a variety of information distribution and dissemination methods. Typically, communication with stakeholders is carried out through local watershed group meetings, workshops, email, and website distribution of information and reports. The Blue Water Task Force maintains a contact and distribution list of watershed stakeholders and provided avenues for information dissemination and feedback through public outreach events, watershed meetings and the BWTF website, http://www.bluewatertaskforce.org .

Though not directly involved in TMDL development, the general public plays a vital role with regard to eventual implementation of 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 and through information dissemination through the BWTF and the DEQ. In addition, the general public has the opportunity for review and comment of the final TMDL document during the formal Public Comment Period. The general public was encouraged to participate throughout the TMDL development process by attending meetings and events, reading local news articles, engaging in educational events, and keeping up-to-date on TMDL progress in their watershed.

9.3 Public Comment Period

Upon completion of the draft TMDL document, T*he West Fork Gallatin River Watershed Total Maximum Daily Loads (TMDLs) and Framework Watershed Water Quality Improvement Plan* and prior to EPA submittal, the DEQ issues a press release and enters into a Public Comment Period. During this time frame, the draft TMDL document is made available for general public comment, and DEQ addresses and responds to all formal public comments. The public comment period follows the process set forth in DEQ document, Montana DEQ Formal TMDL Public Review and Stakeholder Notification Procedure – WQPB WSM-001. The public comment period for T*he West Fork Gallatin River Watershed Total Maximum Daily Loads (TMDLs) and Framework Watershed Water Quality Improvement Plan* was initiated on August 24th, 2010 and concluded on Sept 13th, 2010. A public meeting was held in Big Sky, MT on August 25th. Comments received during this period, and DEQ's response to comments received is documented in **Appendix H**, Response to Public Comments.

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APPENDIX A
MAPS AND FIGURES

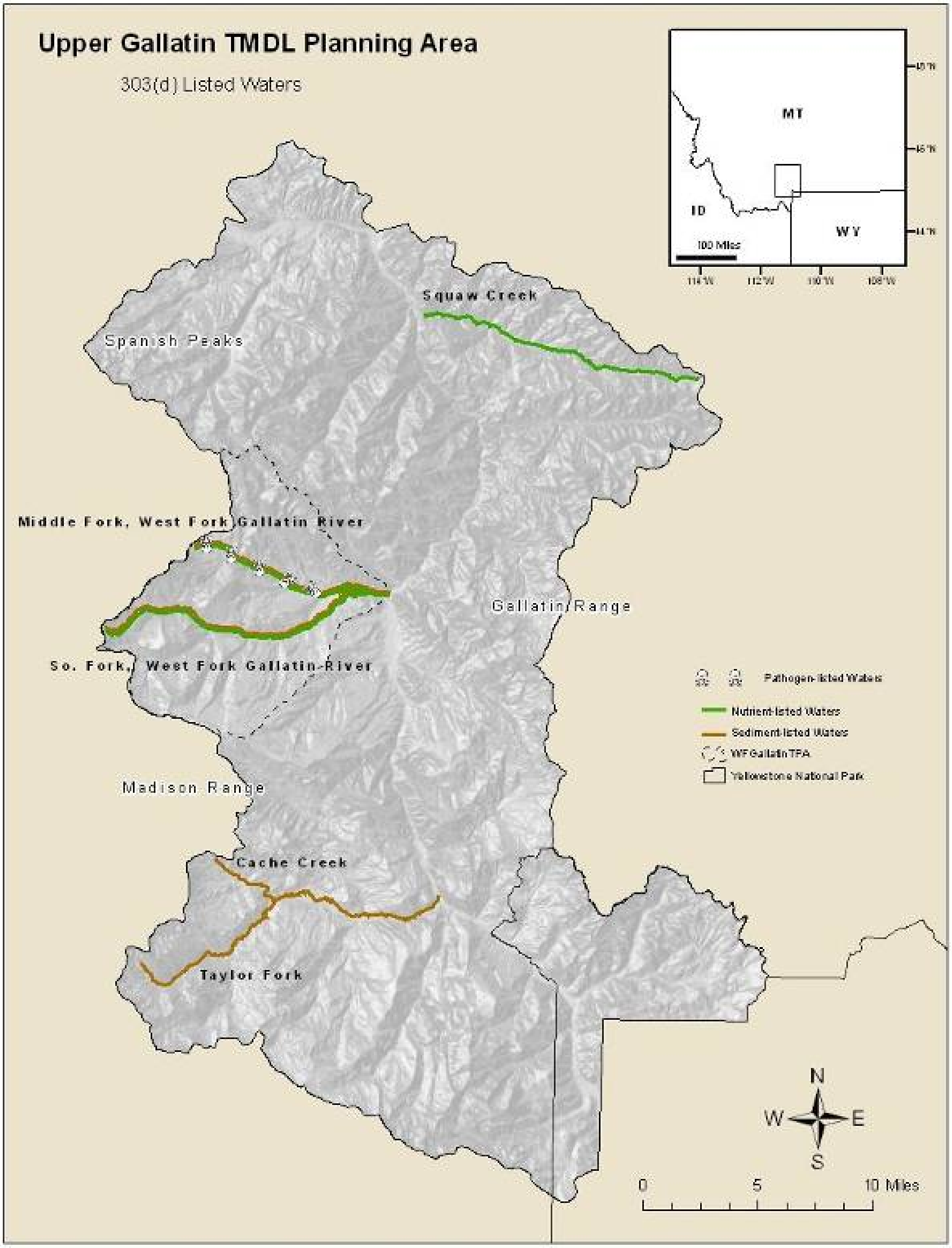


Figure 2-1. 303 (d) Listed Waters in the Upper Gallatin TMDL Planning Area

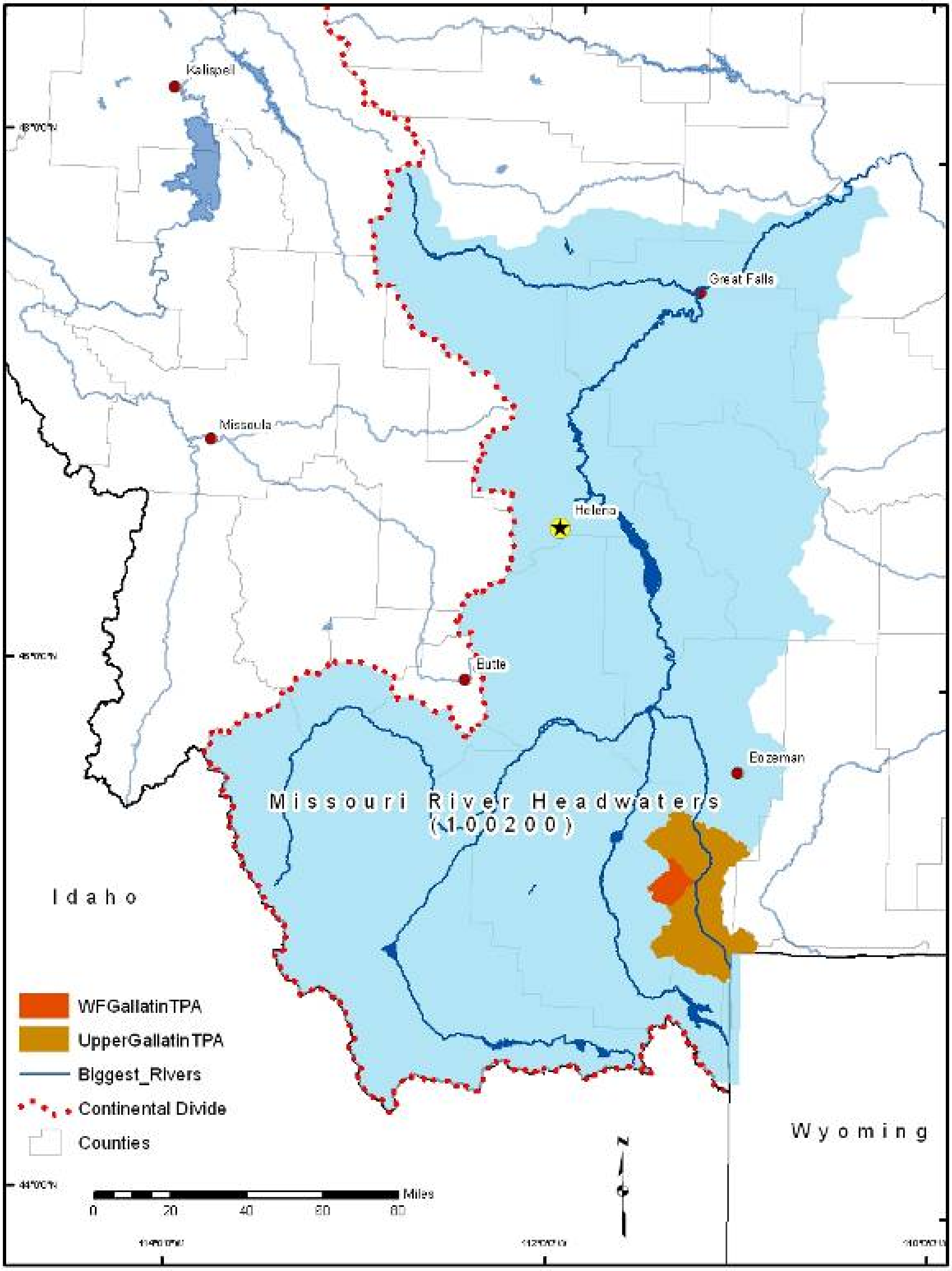
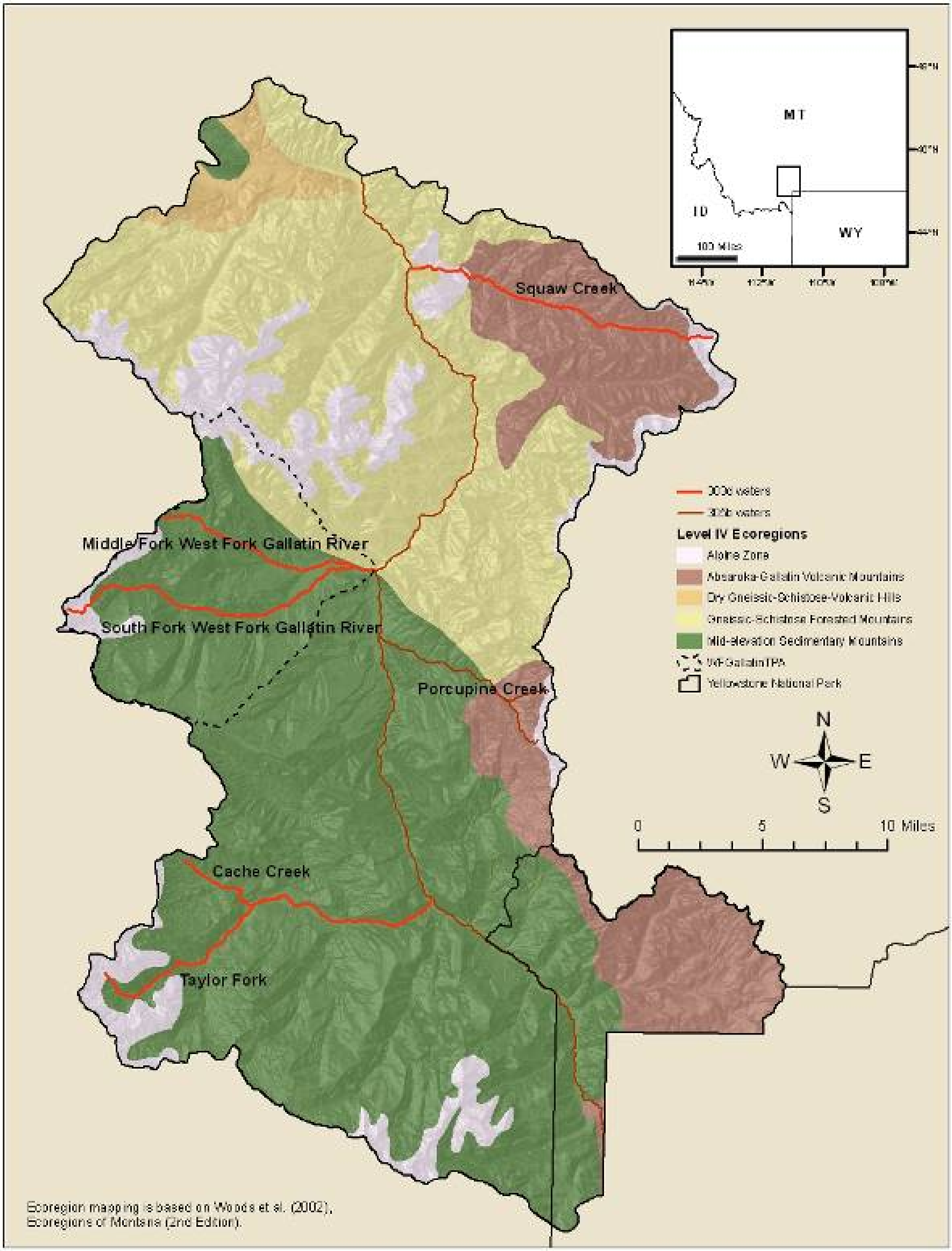


Figure 2-2. Overview Map: Upper Gallatin TMDL Planning Area



Ecoregion mapping is based on Woods et al. (2002), Ecoregions of Montana (2nd Edition).

Figure 2-3. Level IV Ecoregions in the Upper Gallatin TMDL Planning Area

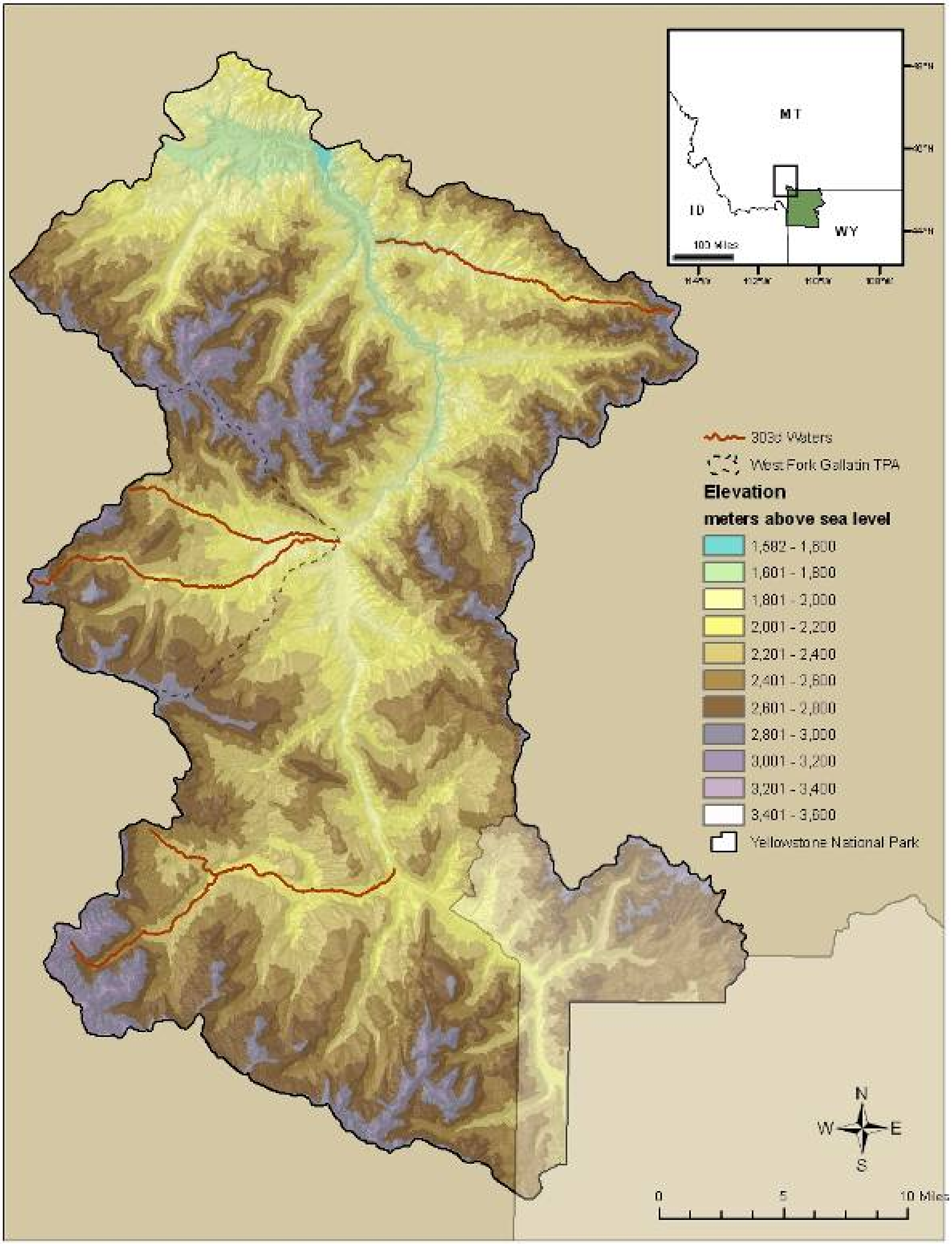
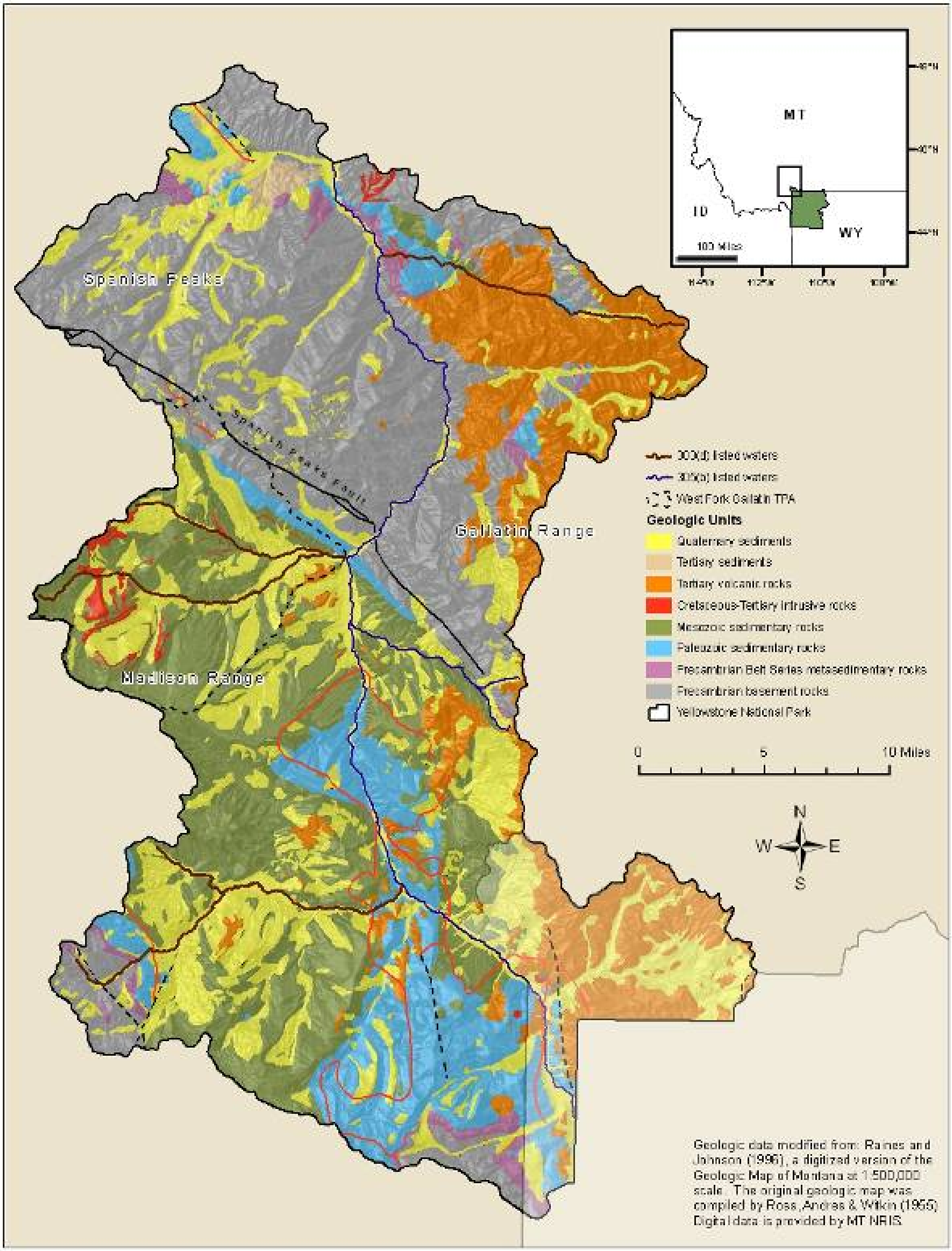
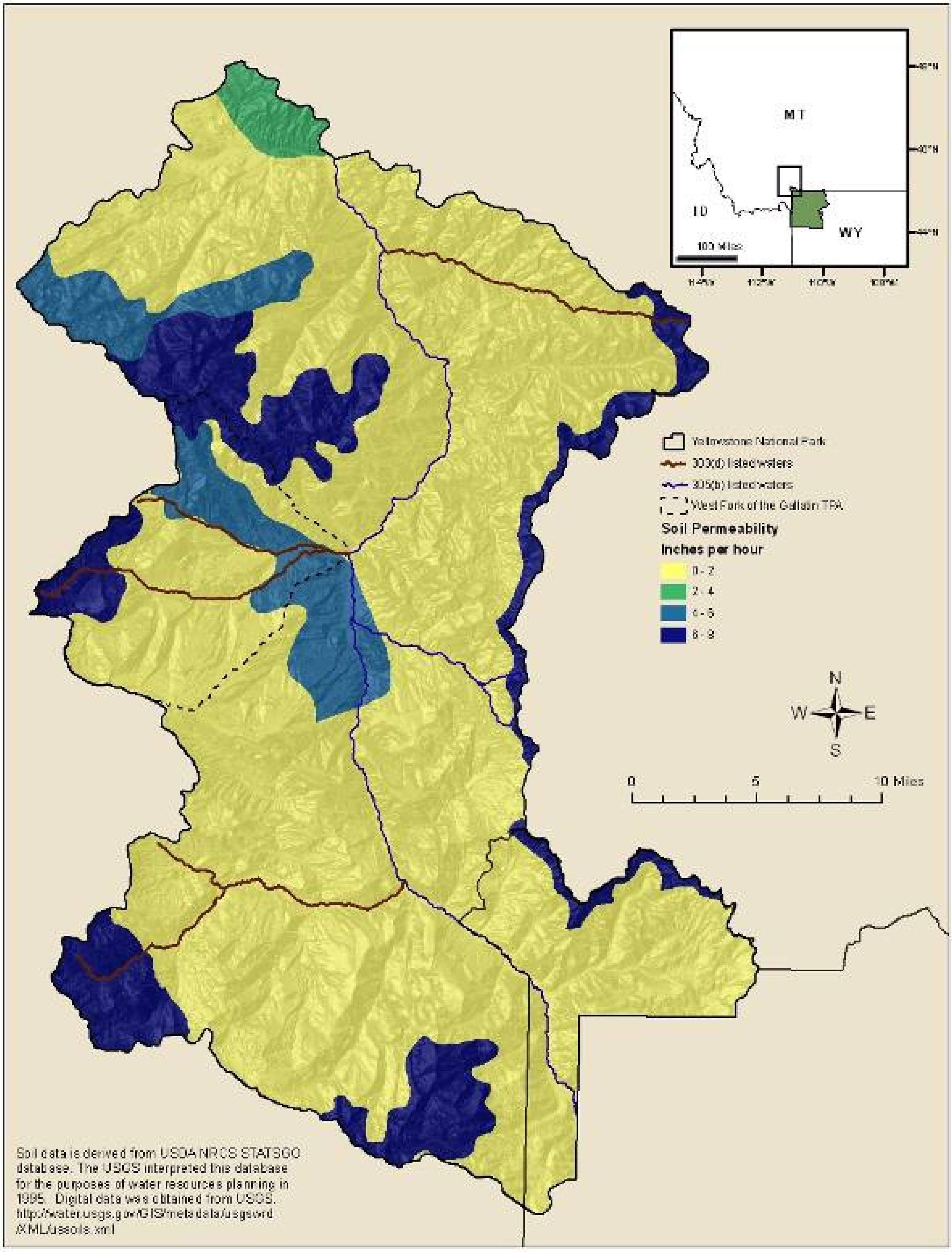


Figure 2-4. Topography of the Upper Gallatin TMDL Planning Area



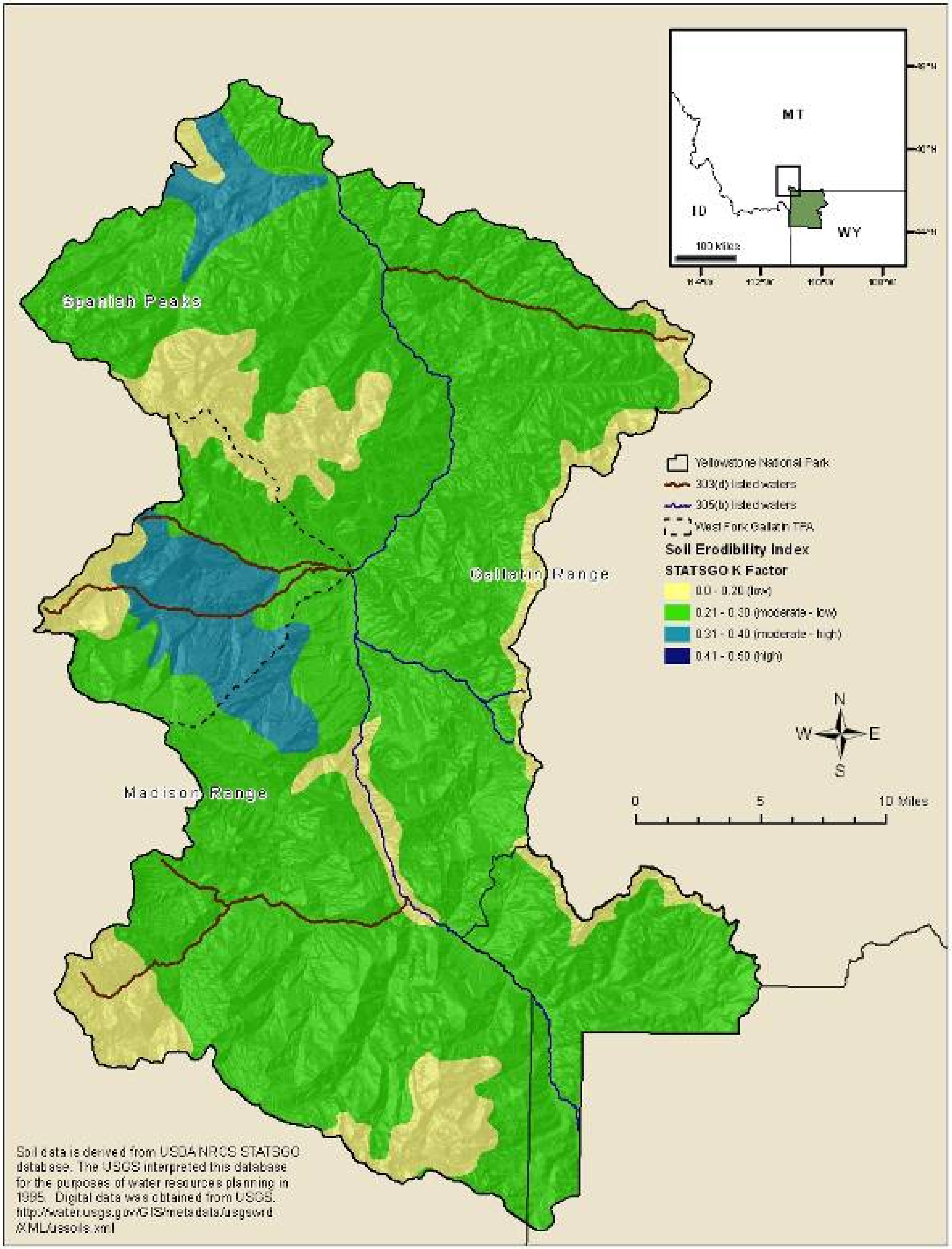
Geologic data modified from: Raines and Johnson (1996), a digitized version of the Geologic Map of Montana at 1:500,000 scale. The original geologic map was compiled by Ross, Andres & Witkin (1955). Digital data is provided by MT NRIS.

Figure 2-5. Geologic map of the Upper Gallatin TMDL Planning Area



Soil data is derived from USDA NRCS STATSGO database. The USGS interpreted this database for the purposes of water resources planning in 1995. Digital data was obtained from USGS. http://water.usgs.gov/GIS/metadata/usgswrd/XML/ussoils.xml

Figure 2-6. Soil permeability in the Upper Gallatin TMDL Planning Area



Soil data is derived from USDA NRCS STATSGO database. The USGS interpreted this database for the purposes of water resources planning in 1995. Digital data was obtained from USGS. http://water.usgs.gov/GIS/metadata/usgswrd/XML/ussoils.xml

Figure 2-7. Soil erodibility in the Upper Gallatin TMDL Planning Area

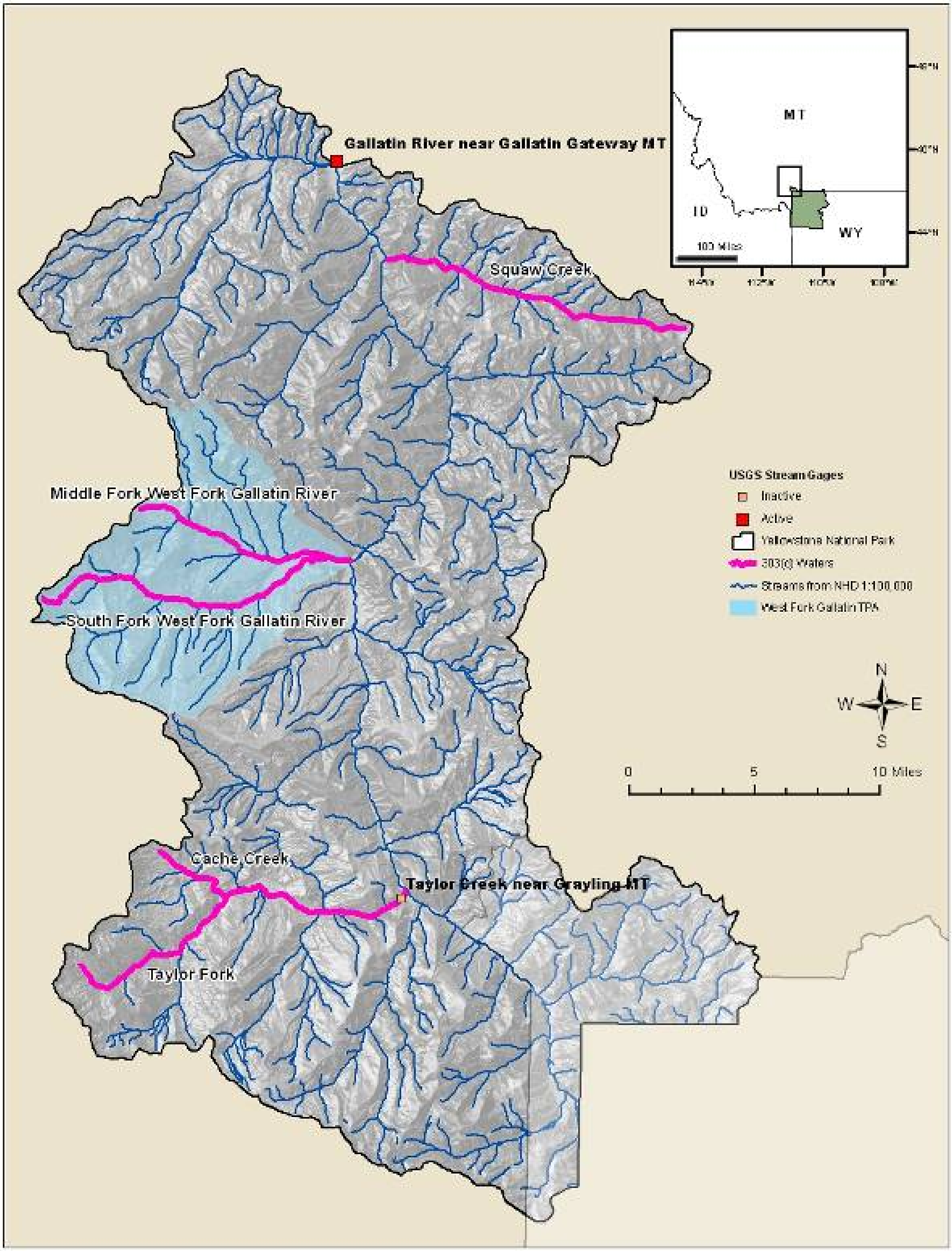


Figure 2-8. Hydrography and stream gaging stations in the Upper Gallatin TMDL Planning Area

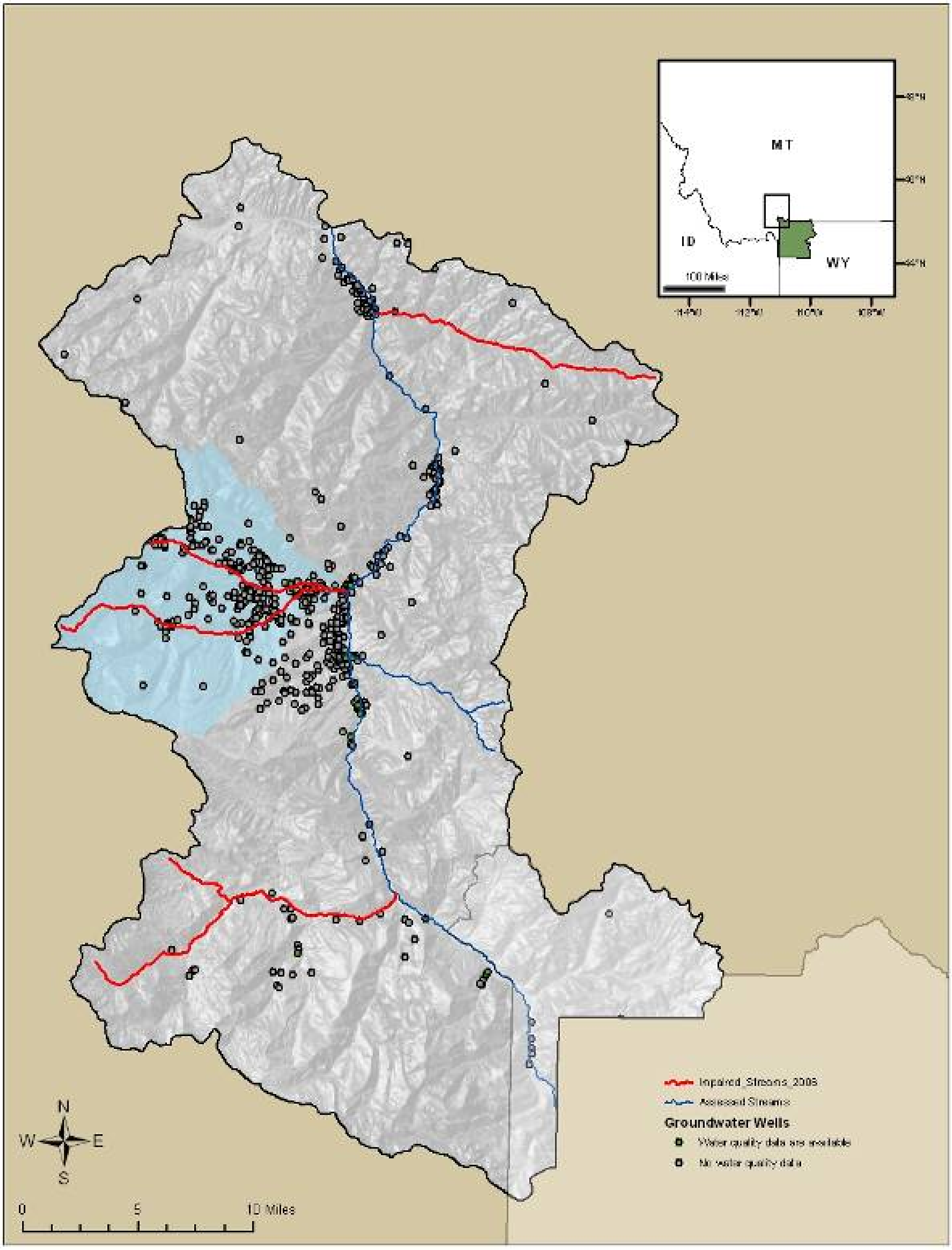


Figure 2-10. Groundwater wells in the Upper Gallatin TMDL Planning Area

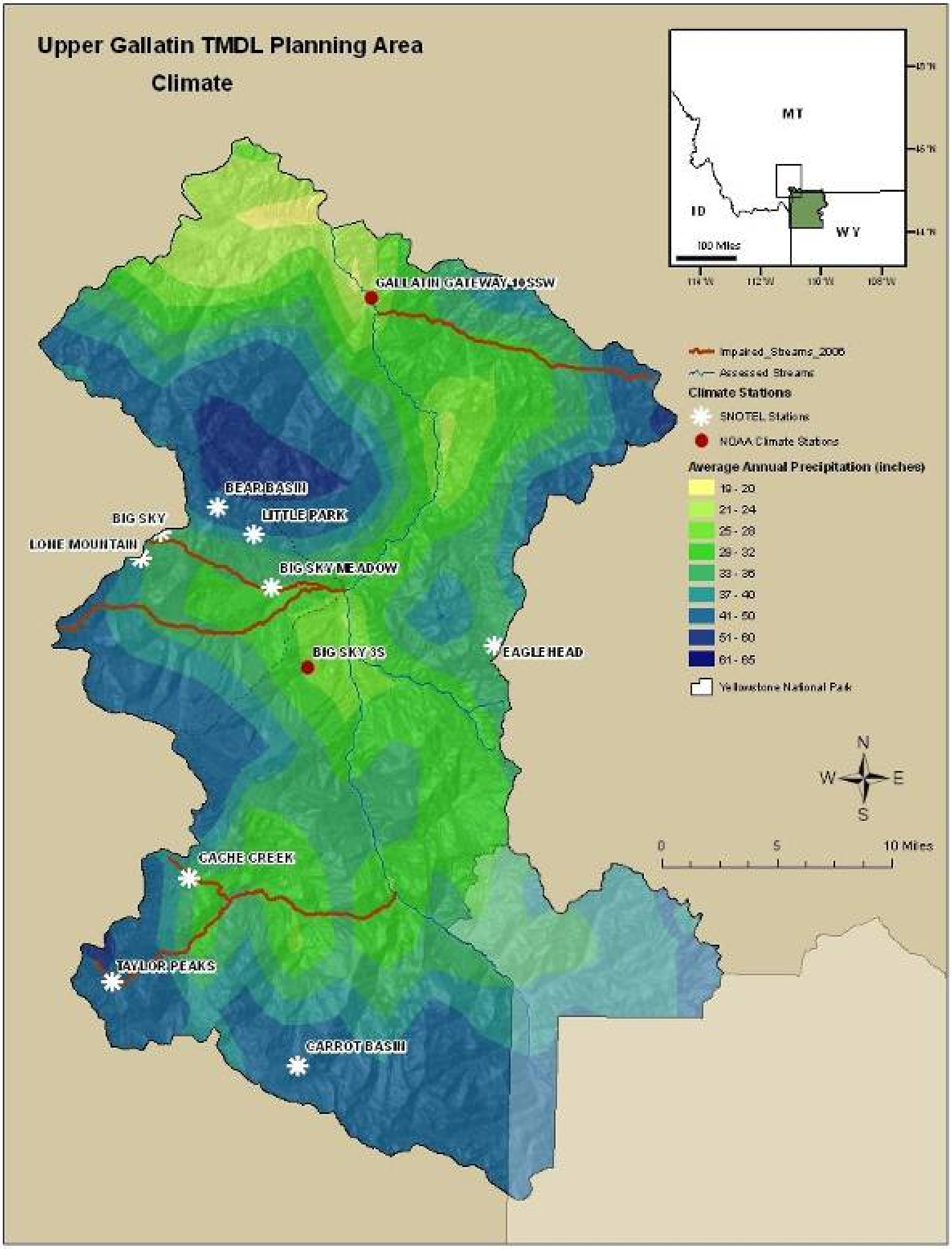
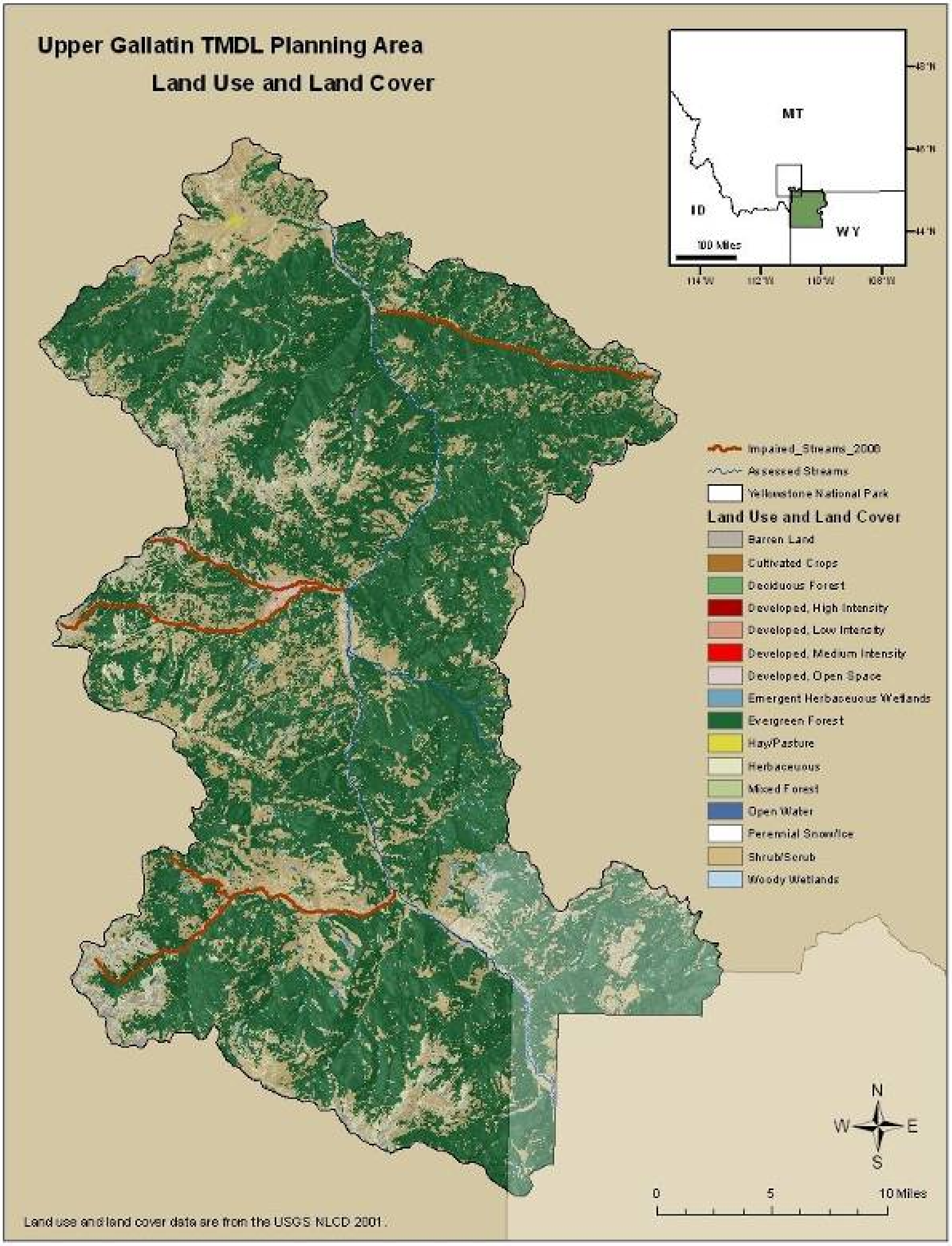
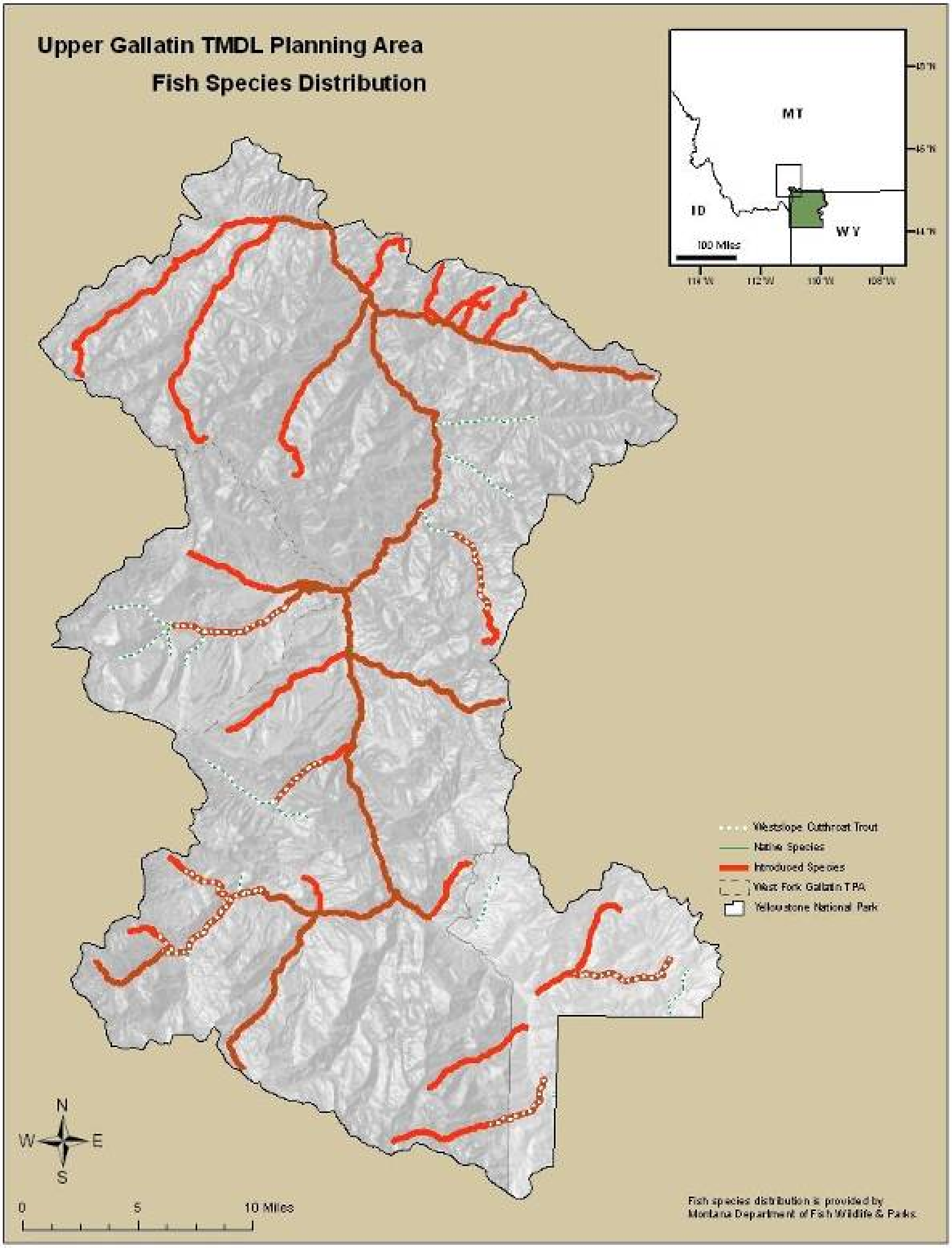


Figure 2-11. Average annual precipitation in the Upper Gallatin TMDL Planning Area



Land use and land cover data are from the USGS NLCD 2001.

Figure 2-12. Land cover in the Upper Gallatin TMDL Planning Area



Fish species distribution is provided by
Montana Department of Fish Wildlife & Parks

Figure 2-13. Fish species distribution in the Upper Gallatin TMDL Planning Area

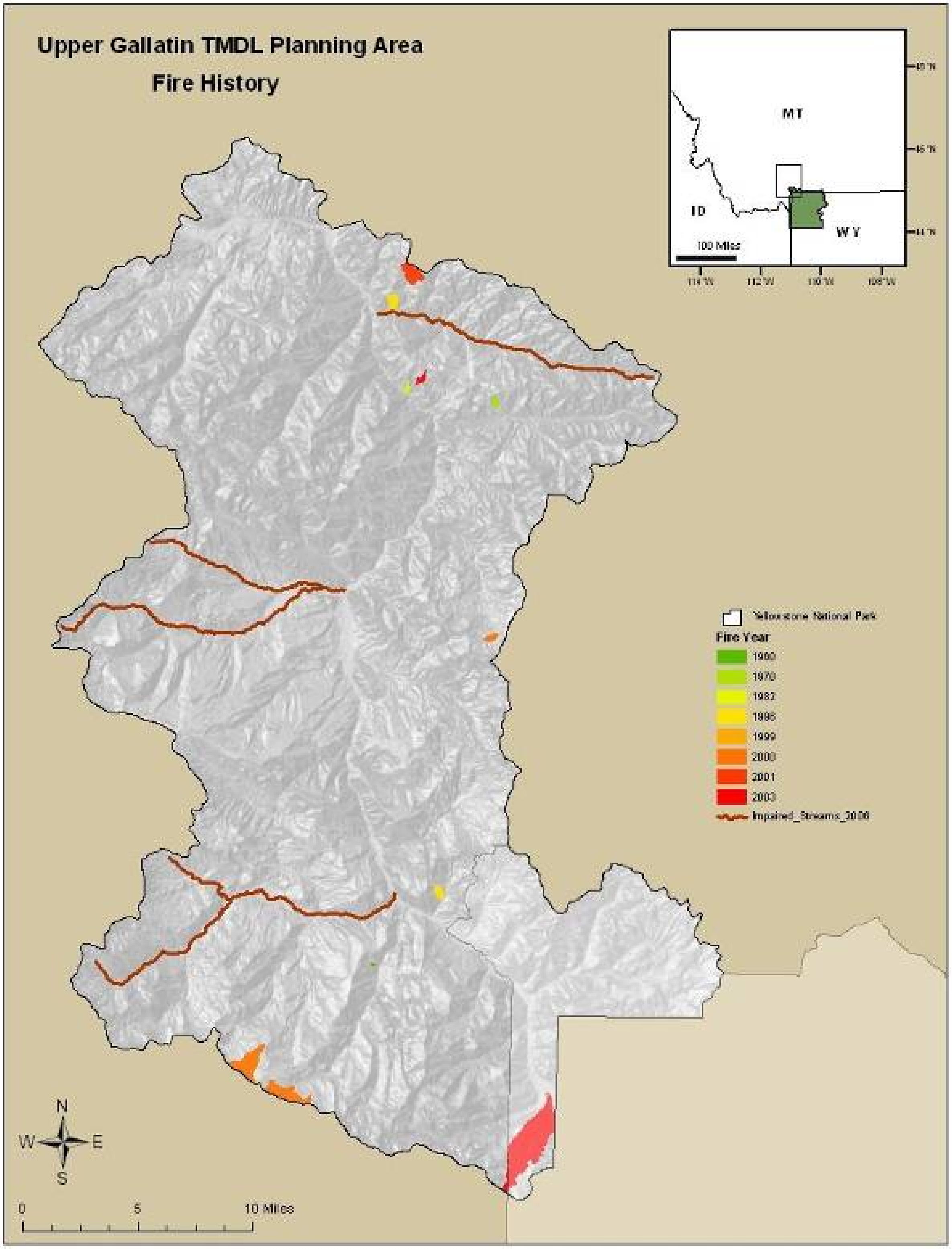


Figure 2-14. Wildfire history in the Upper Gallatin TMDL Planning Area

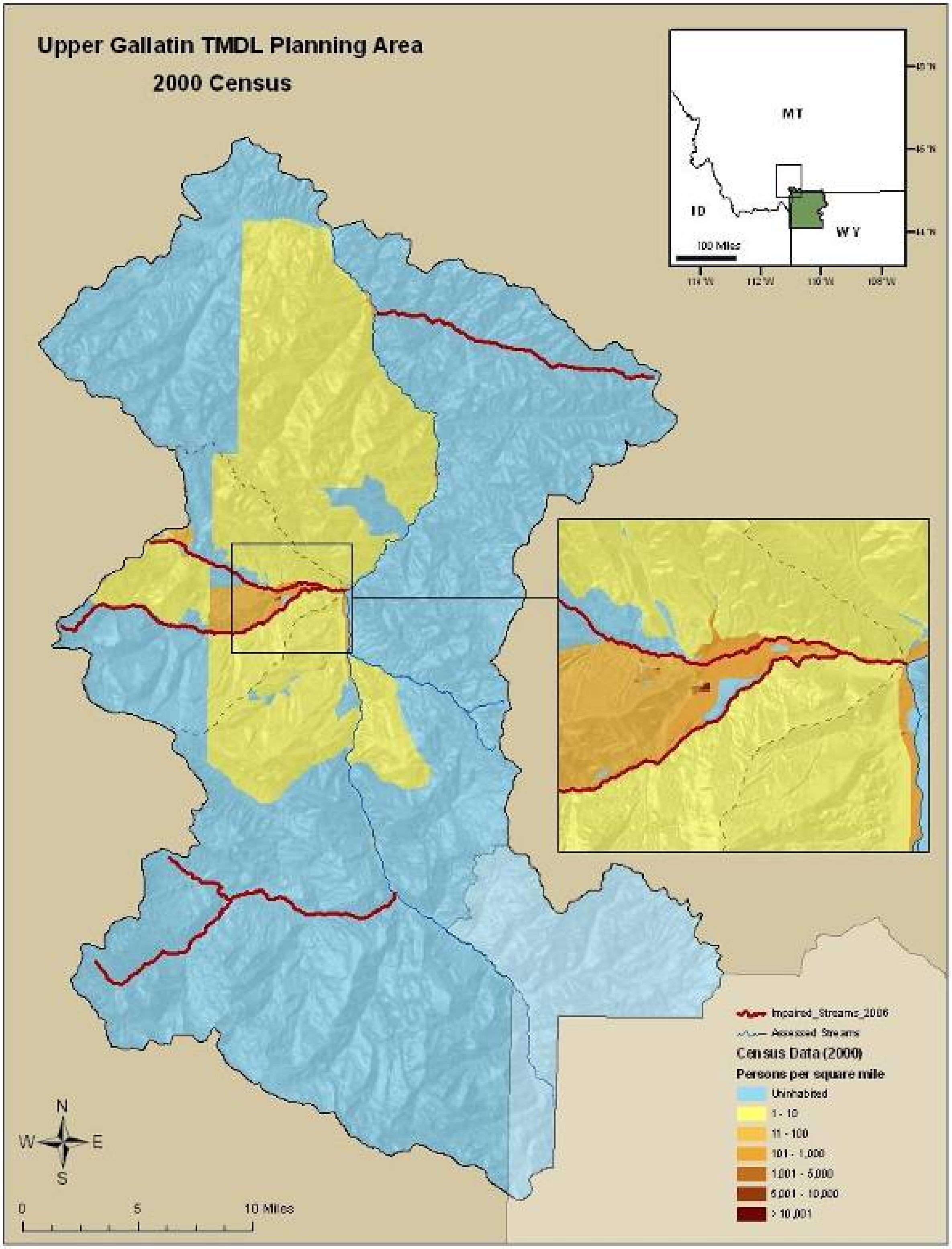


Figure 2-15. Population in the Upper Gallatin TMDL Planning Area (2000 Census)

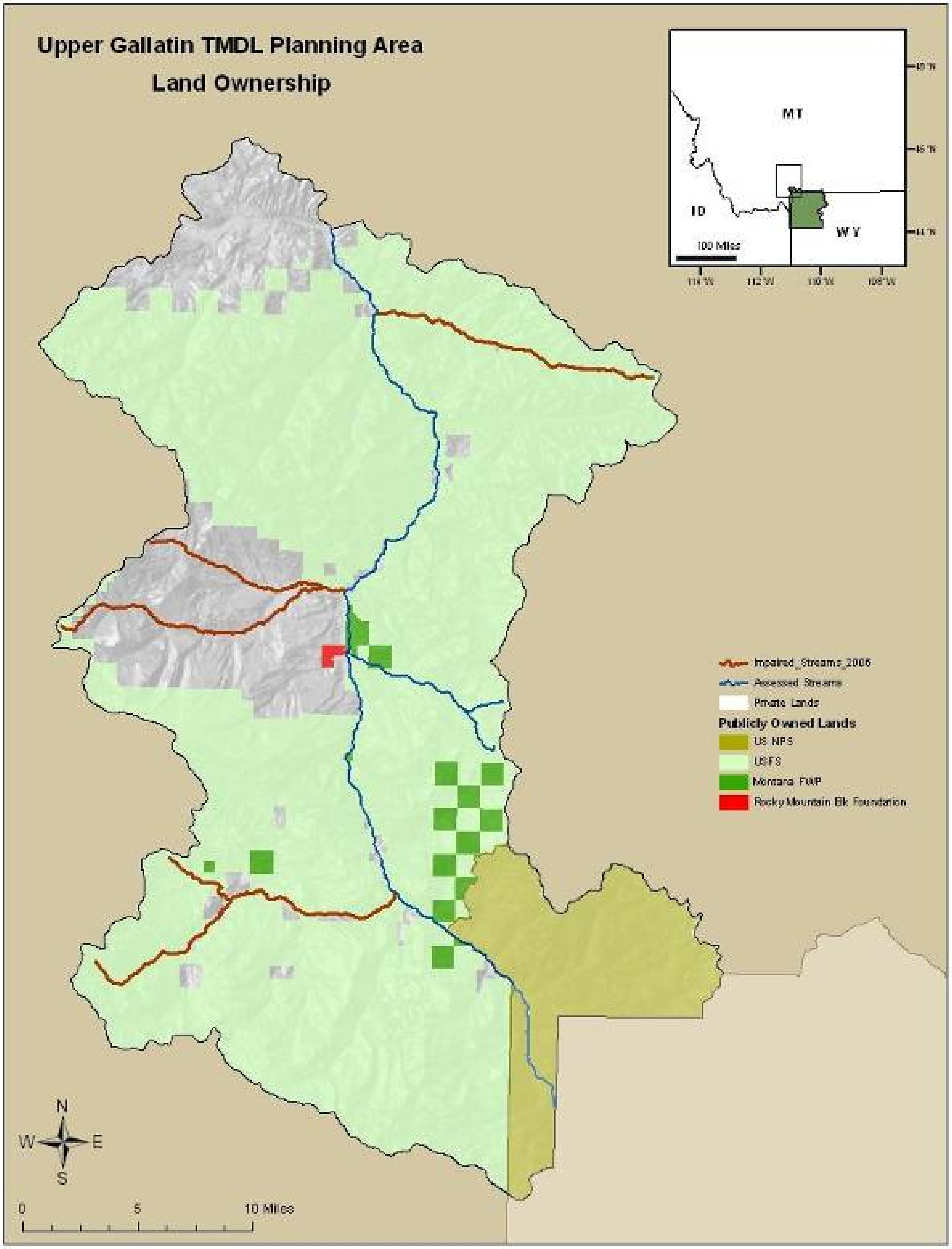


Figure 2-16. Land Ownership

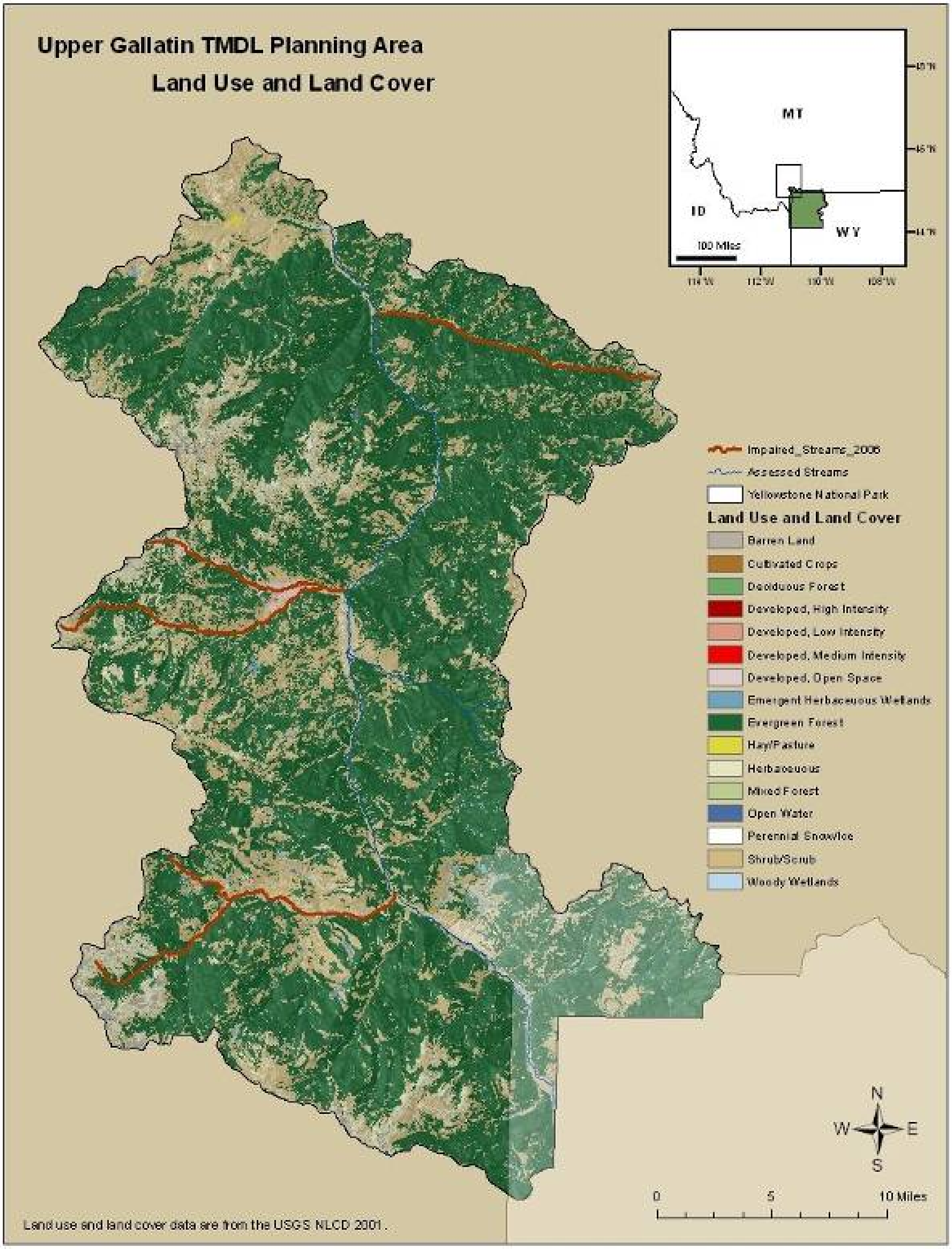


Figure 2-17. Land Use

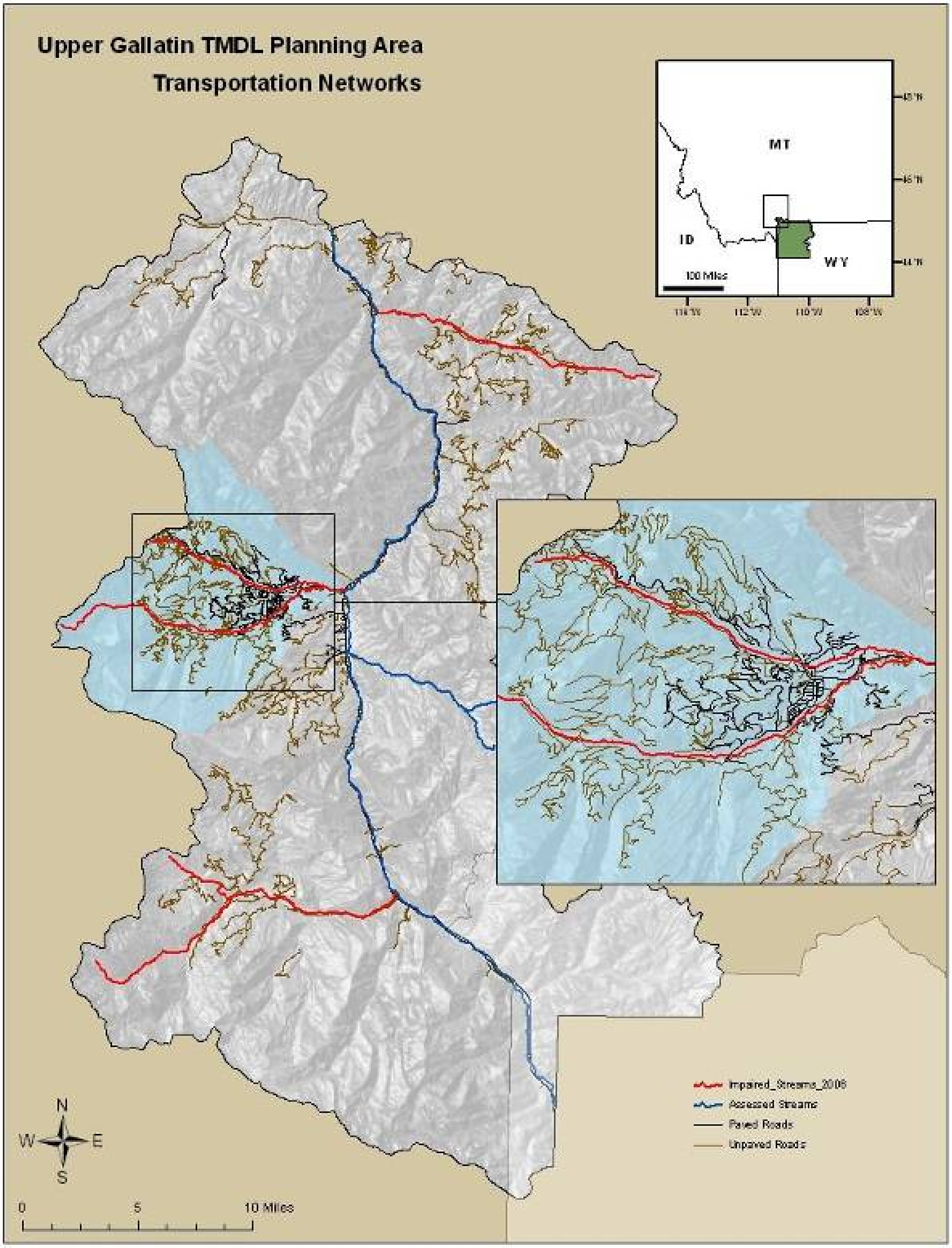


Figure 2-18. Transportation networks

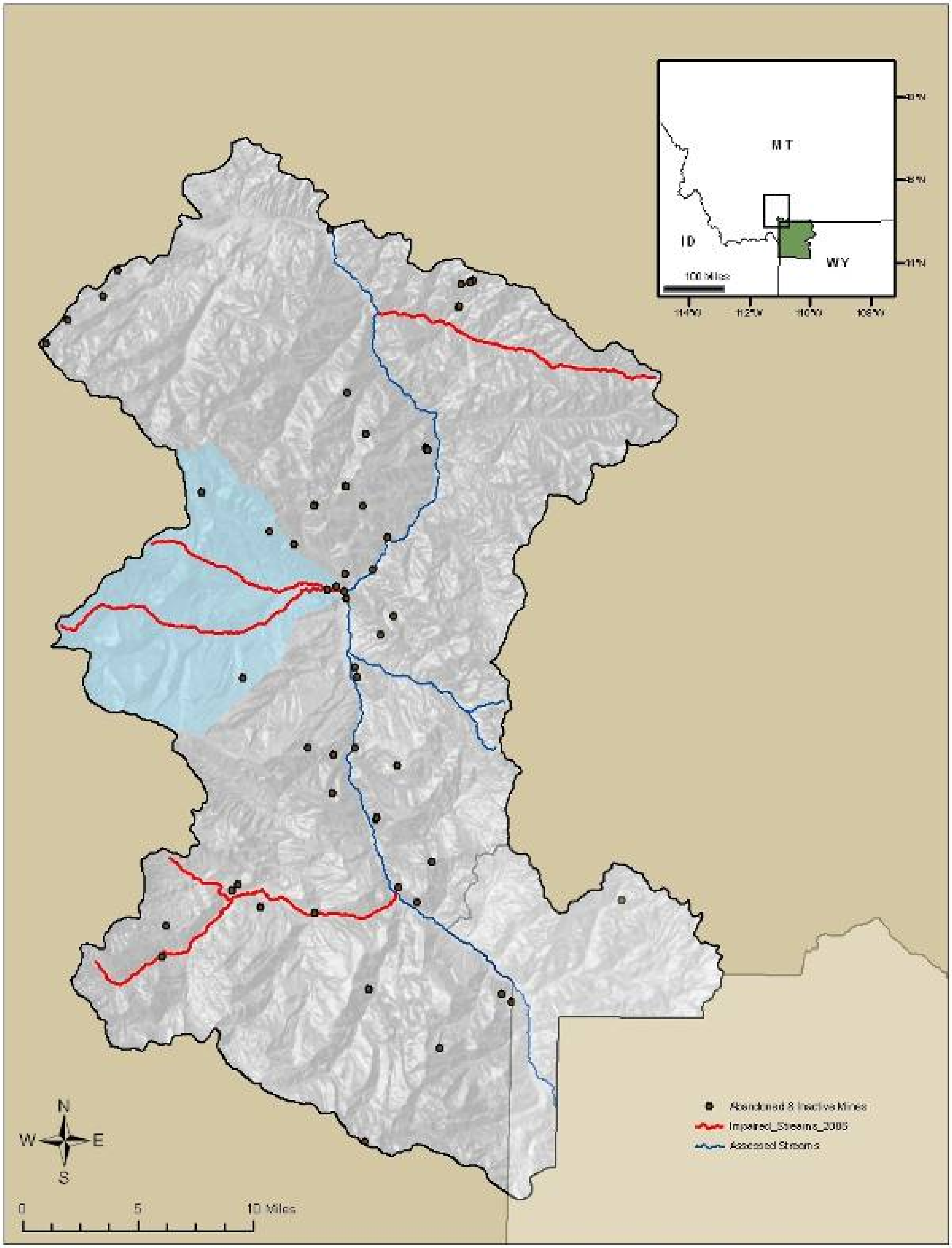


Figure 2-19. Abandoned and inactive mines are present

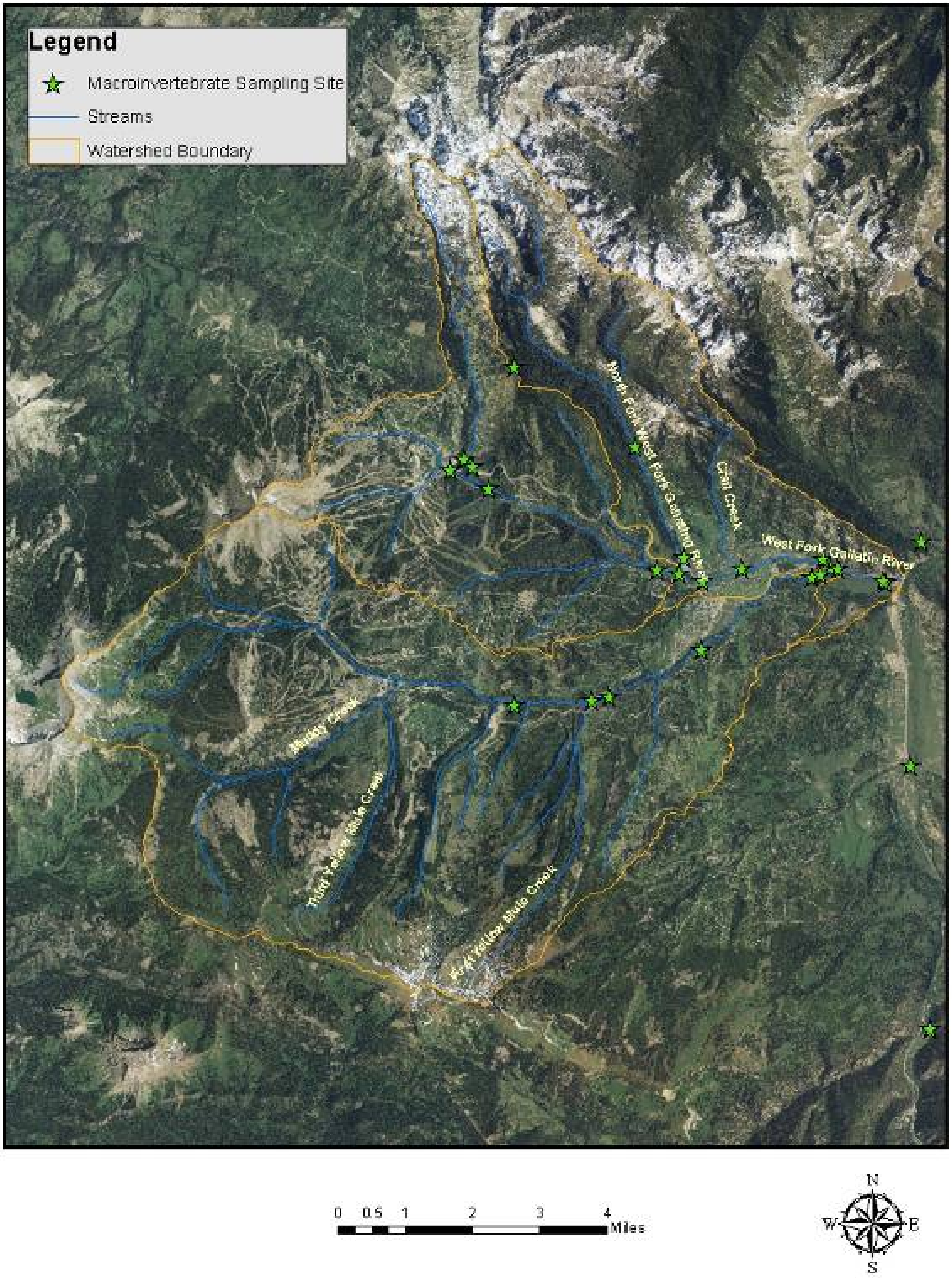


Figure 5-1. Macroinvertebrate sampling sites in the West Fork Gallatin Watershed

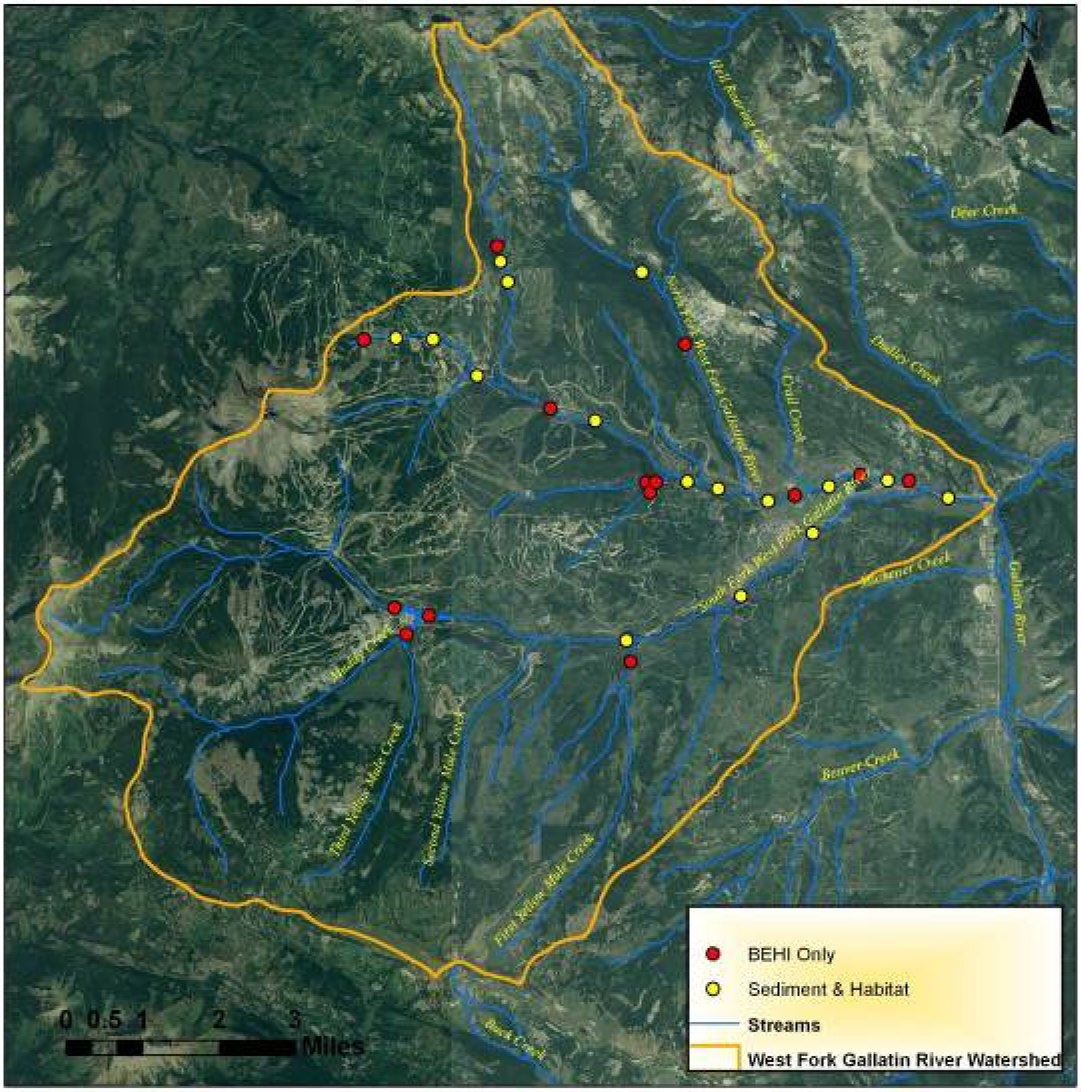


Figure 5-2. 2008 DEQ sediment and habitat assessment sites in the West Fork Gallatin Watershed

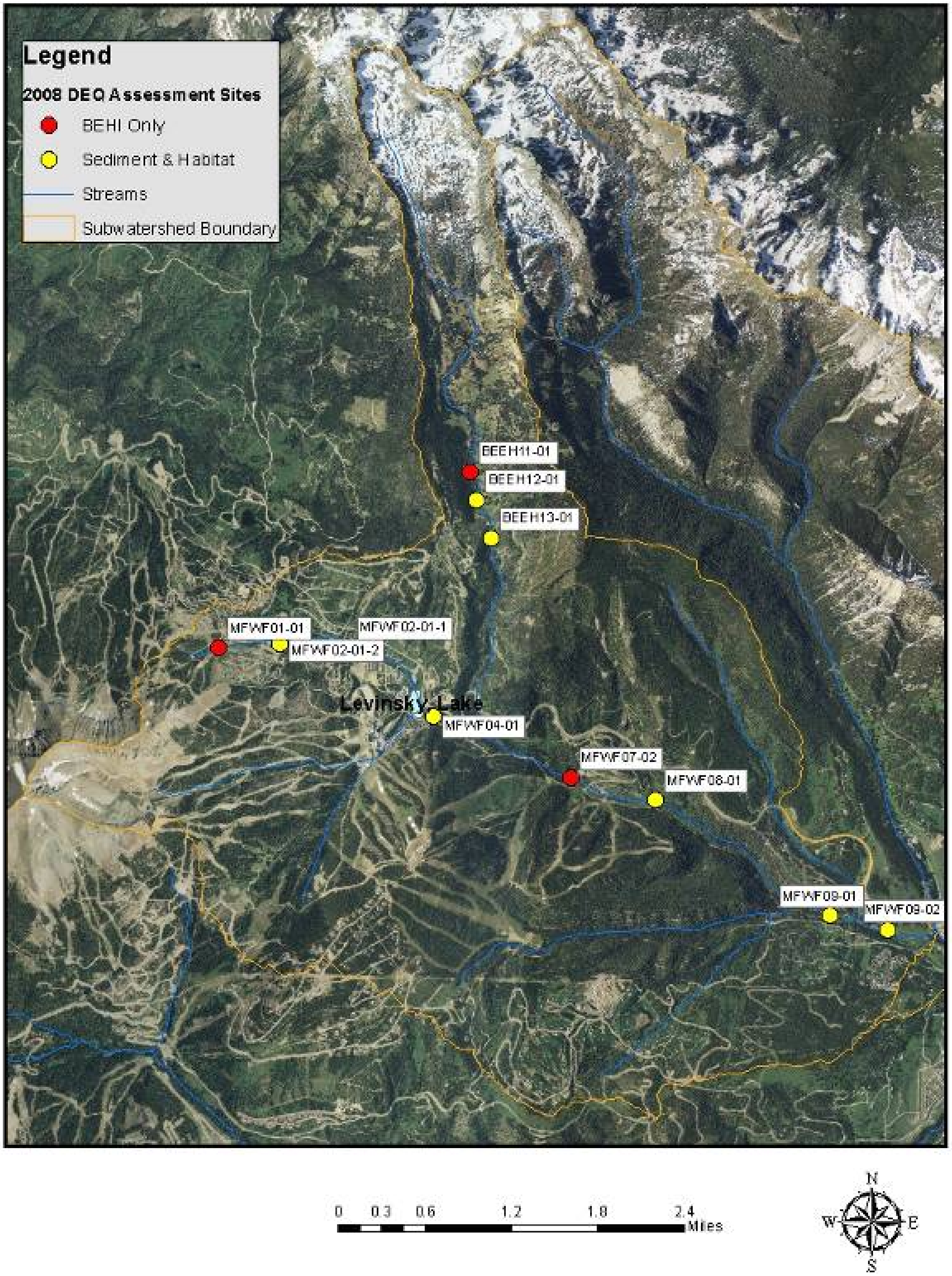


Figure 5-3. 2008 DEQ sediment and habitat assessment sites Middle Fork Watershed

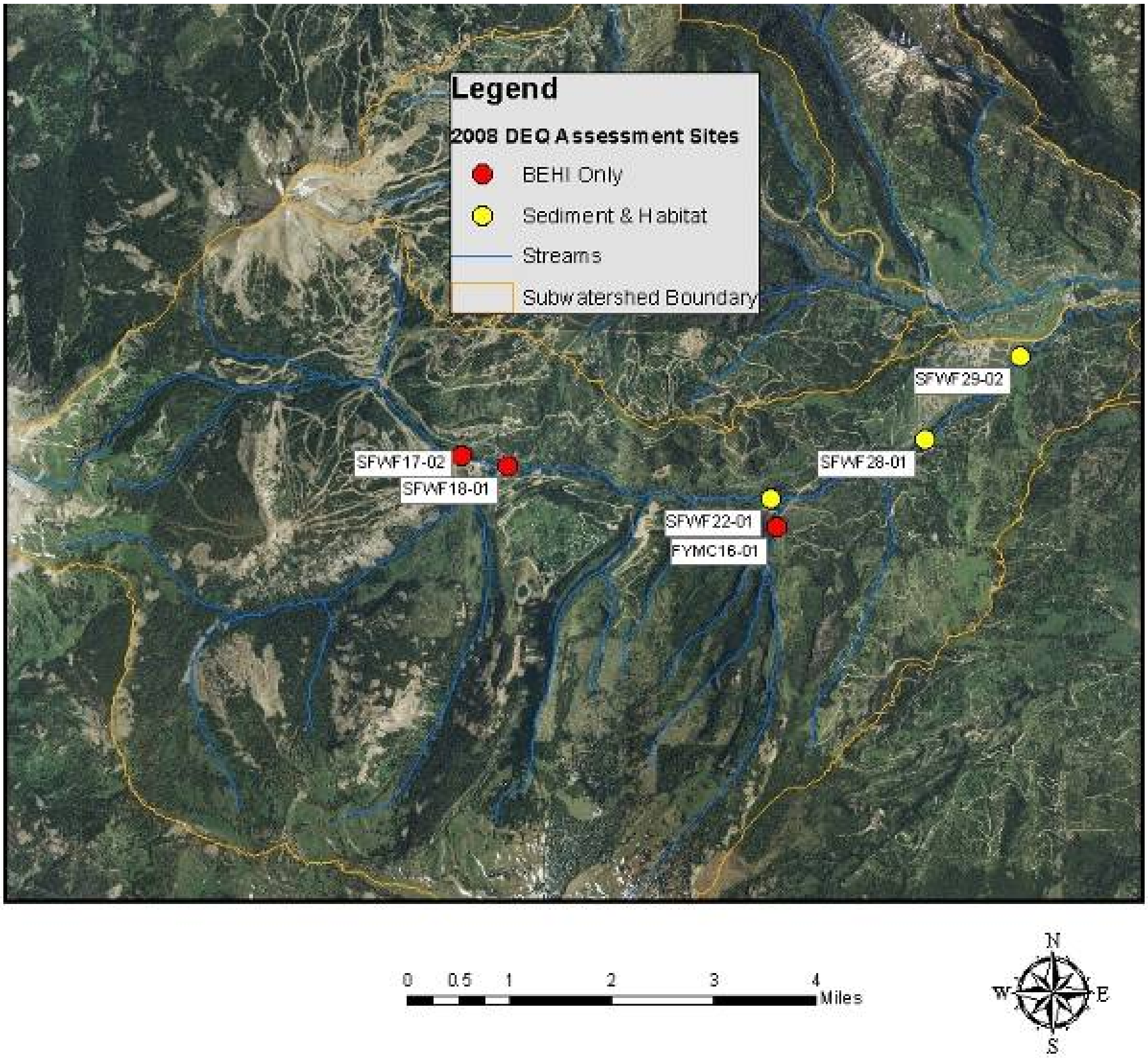


Figure 5-4. 2008 DEQ sediment and habitat assessment sites South Fork Watershed

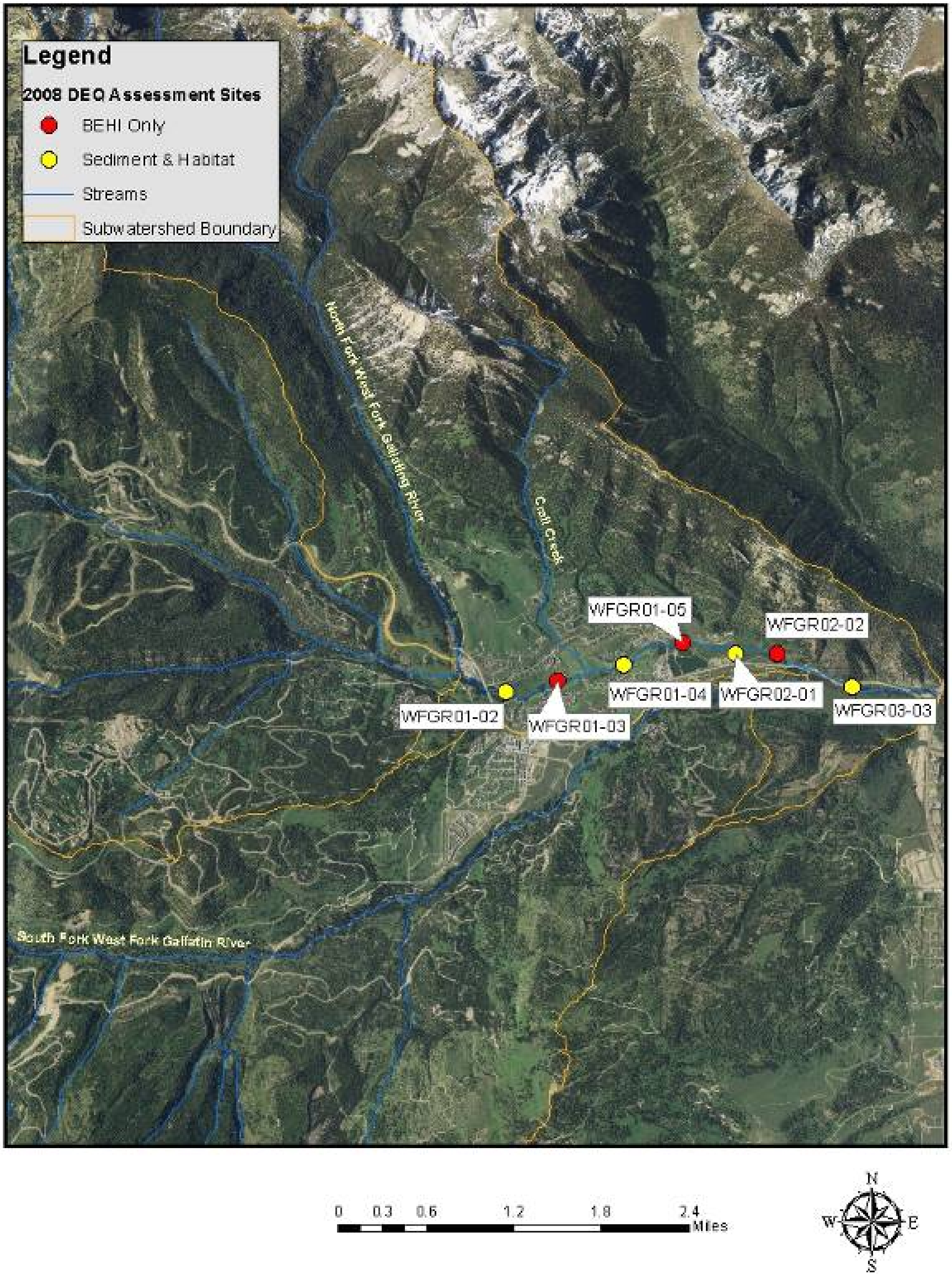


Figure 5-5. 2008 DEQ sediment and habitat assessment sites West Fork Watershed

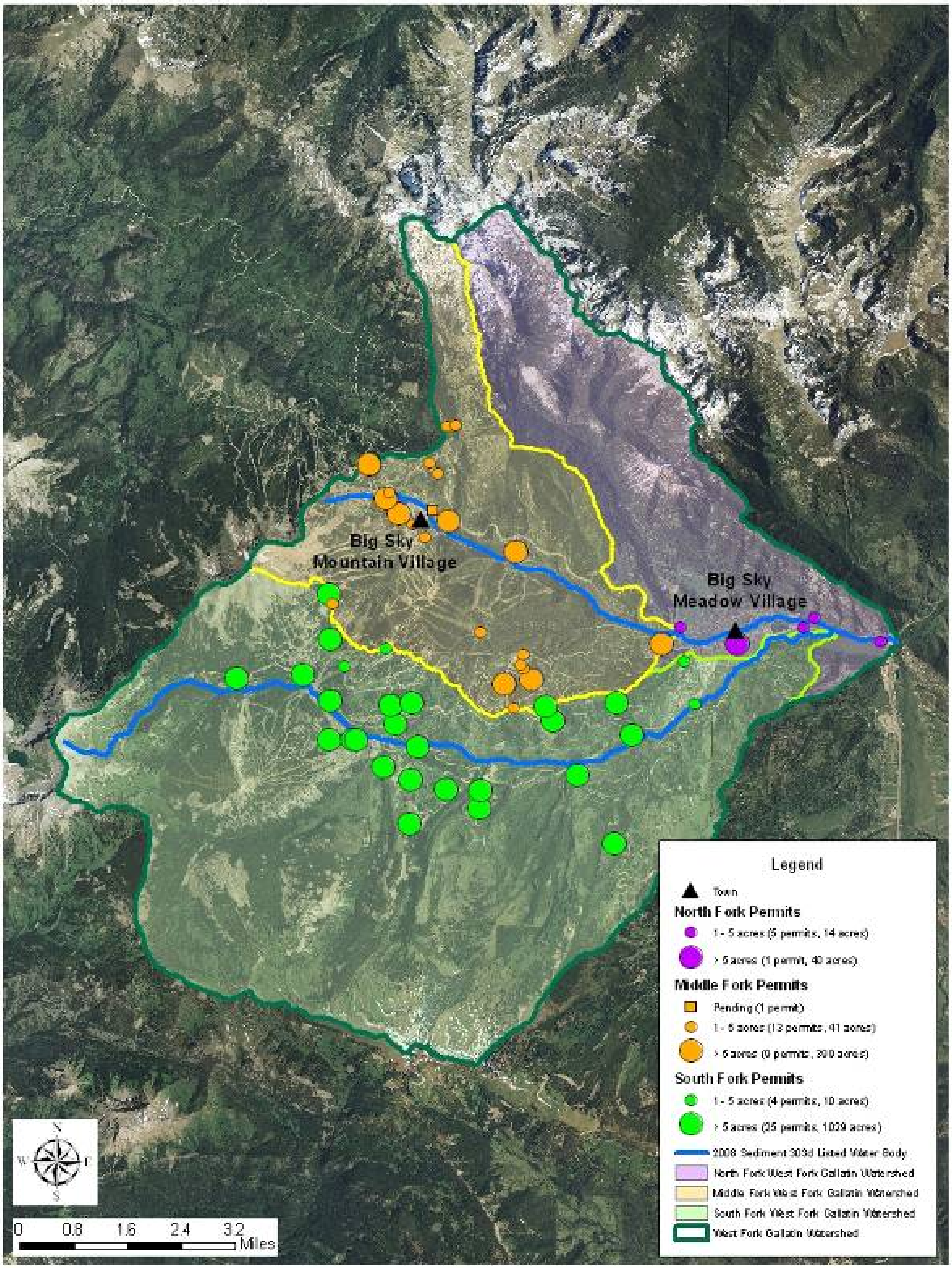


Figure 5-10. Storm water construction permits in the West Fork Watershed as of January 28, 2010

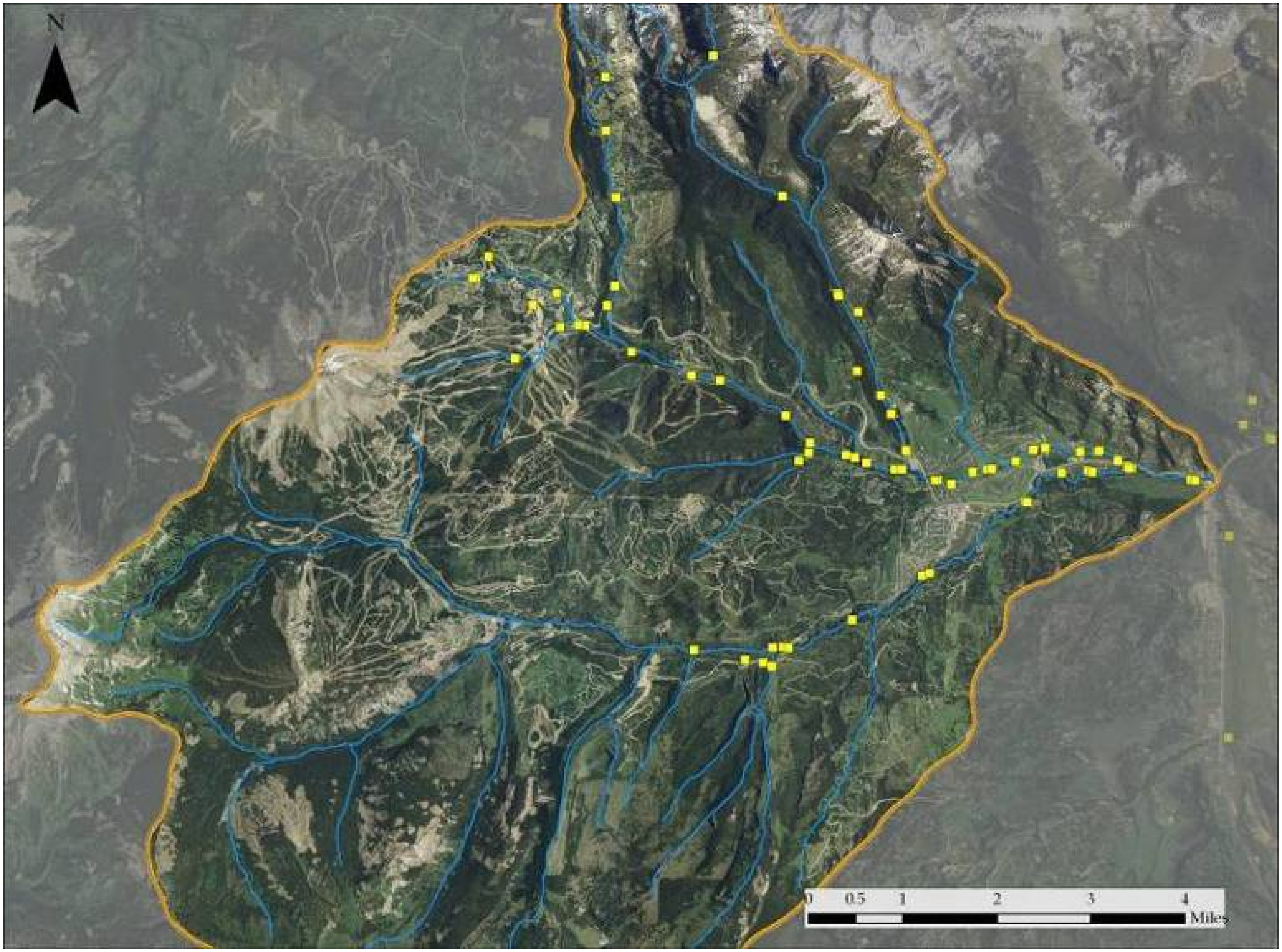


Figure 6-1. 2006-2008 Nutrient sampling sites in the West Fork Gallatin watershed

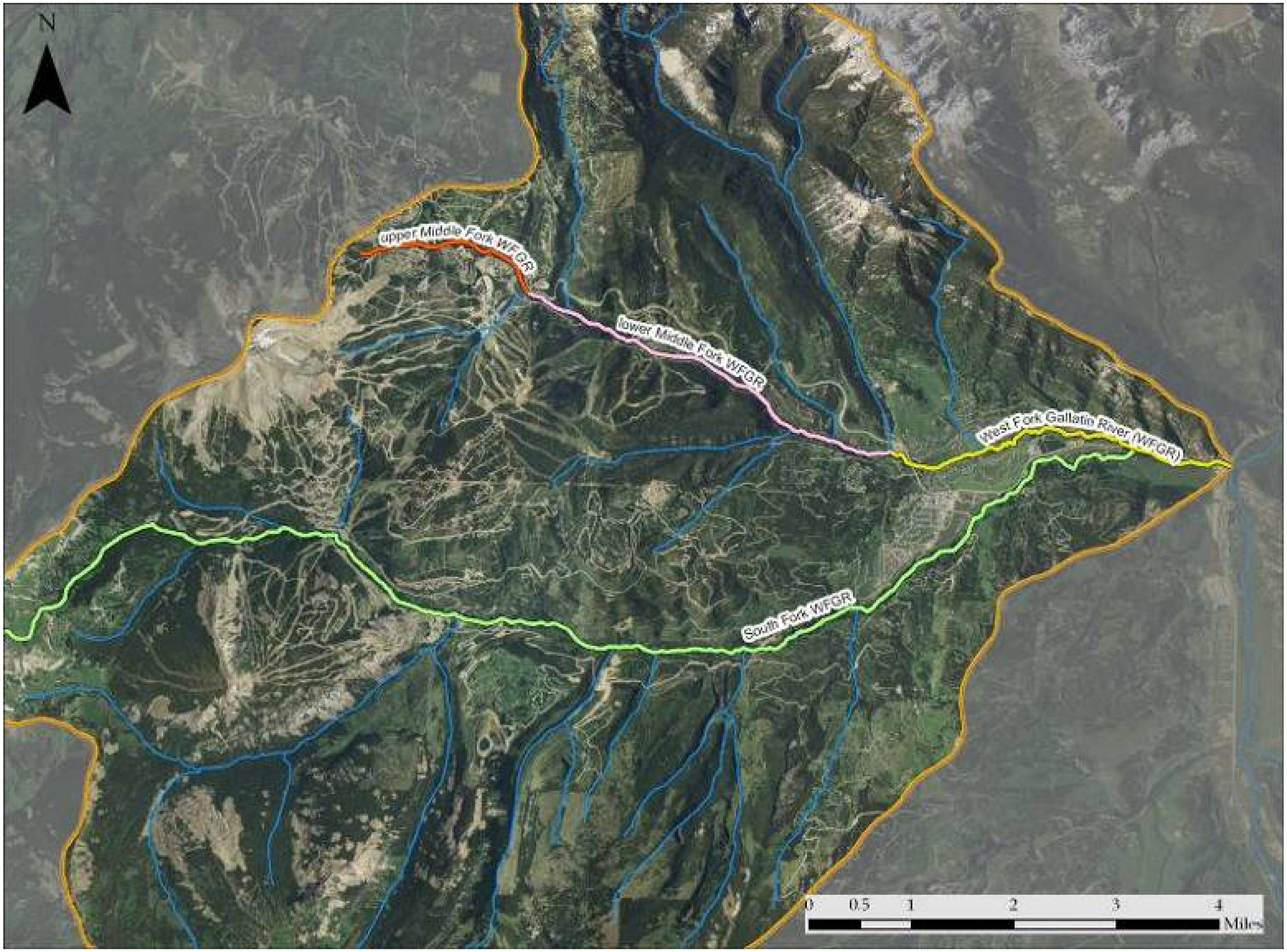


Figure 6-2. Nutrient Assessment Reaches

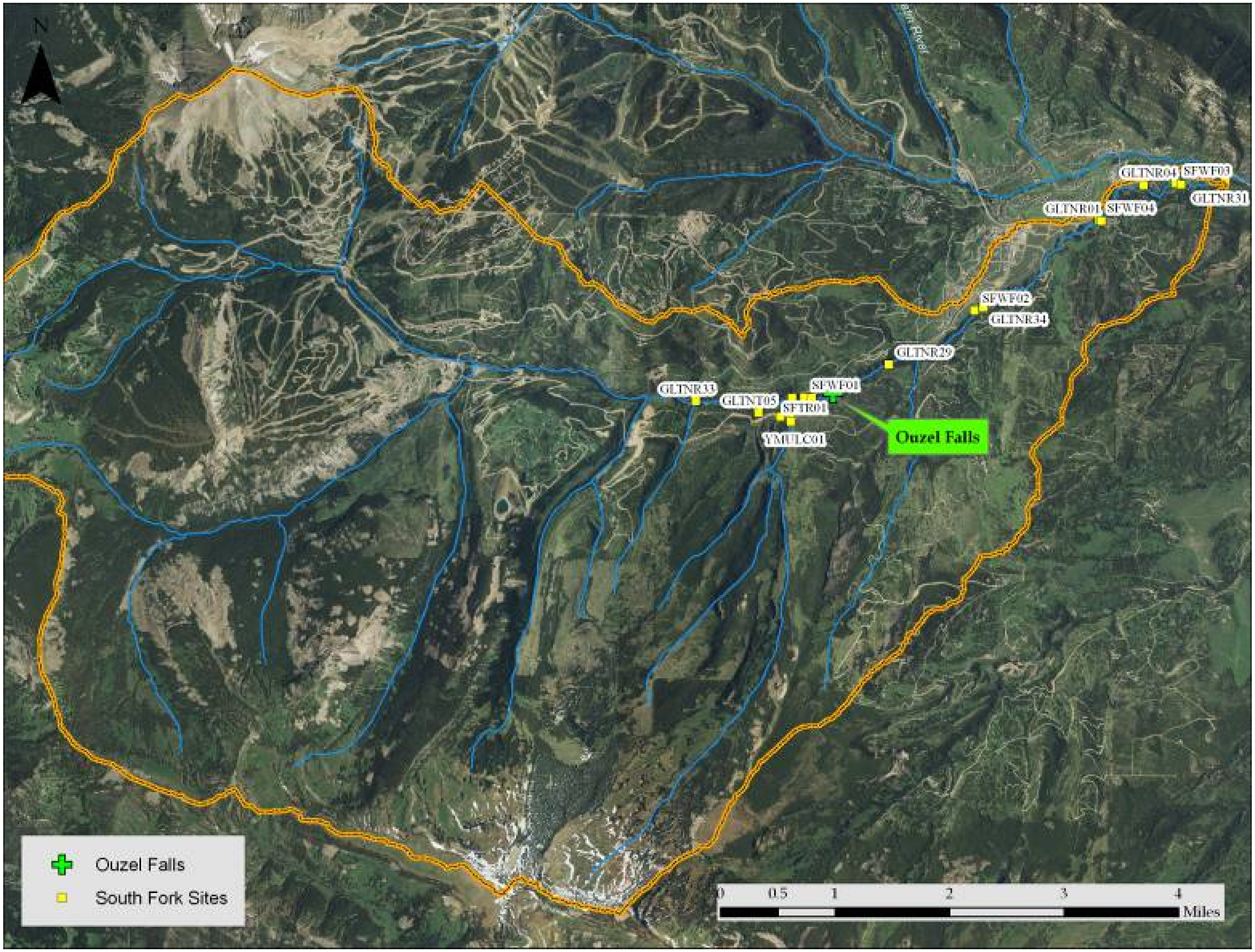


Figure 6-6. South Fork West Fork Gallatin River: Nutrient Sampling Sites

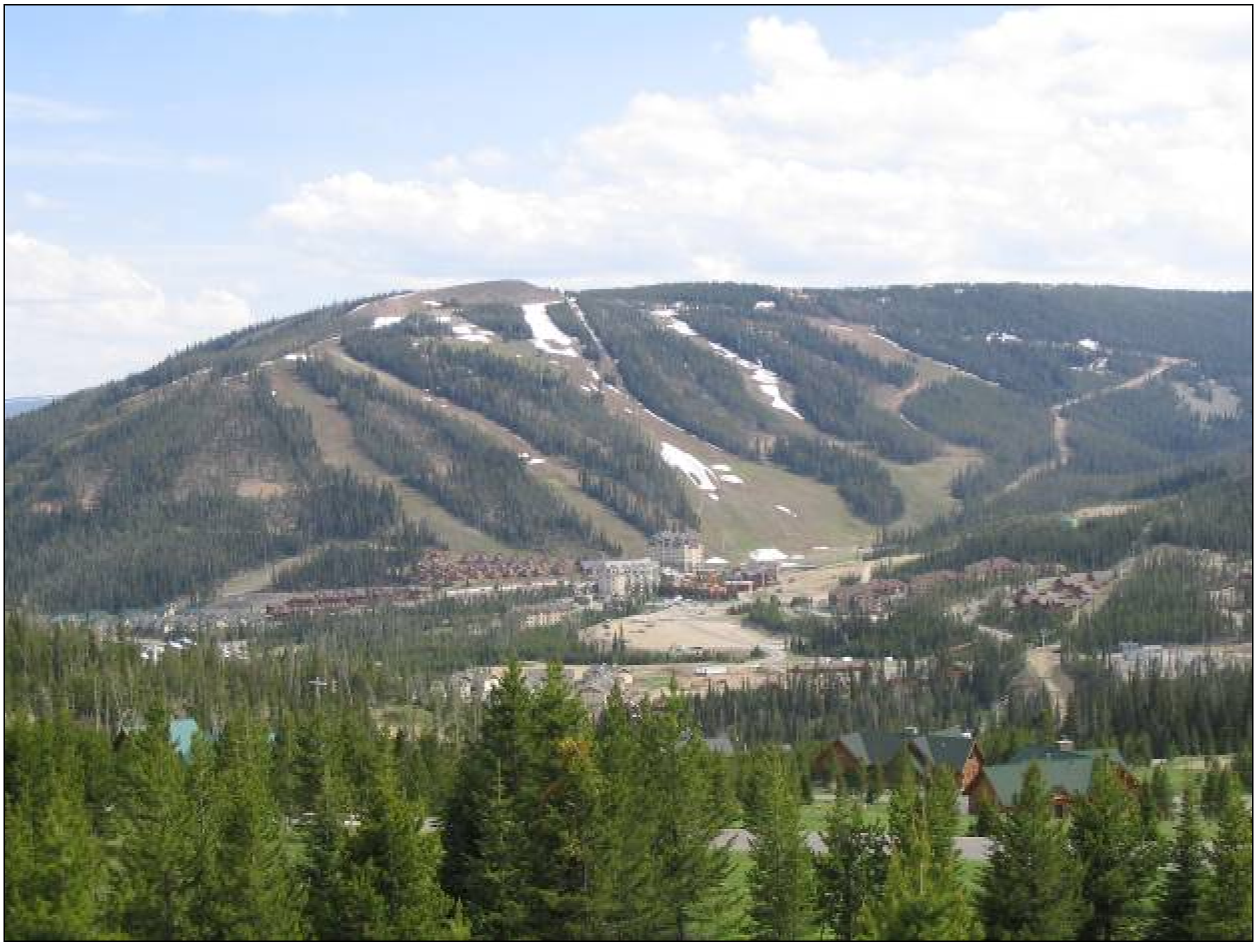


Figure 6-7. Upper Middle Fork West Fork Gallatin River watershed showing resort land use

Figure 6-8. Lake Levinsky, looking upstream. Upper Middle Fork West Fork Gallatin River watershed

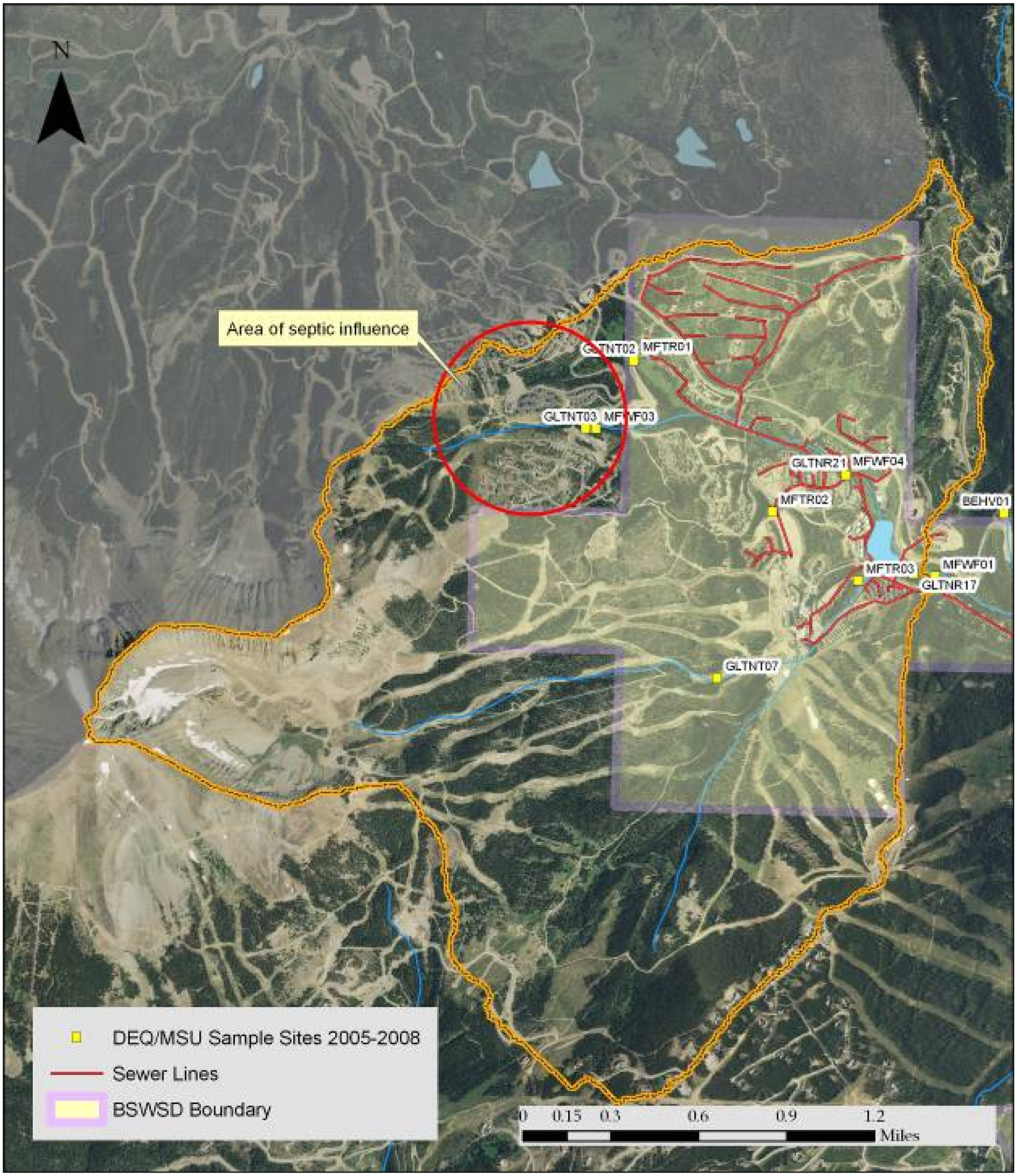


Figure 6-9a. Areas served by sewer and septic systems in the upper Middle Fork West Fork Gallatin River

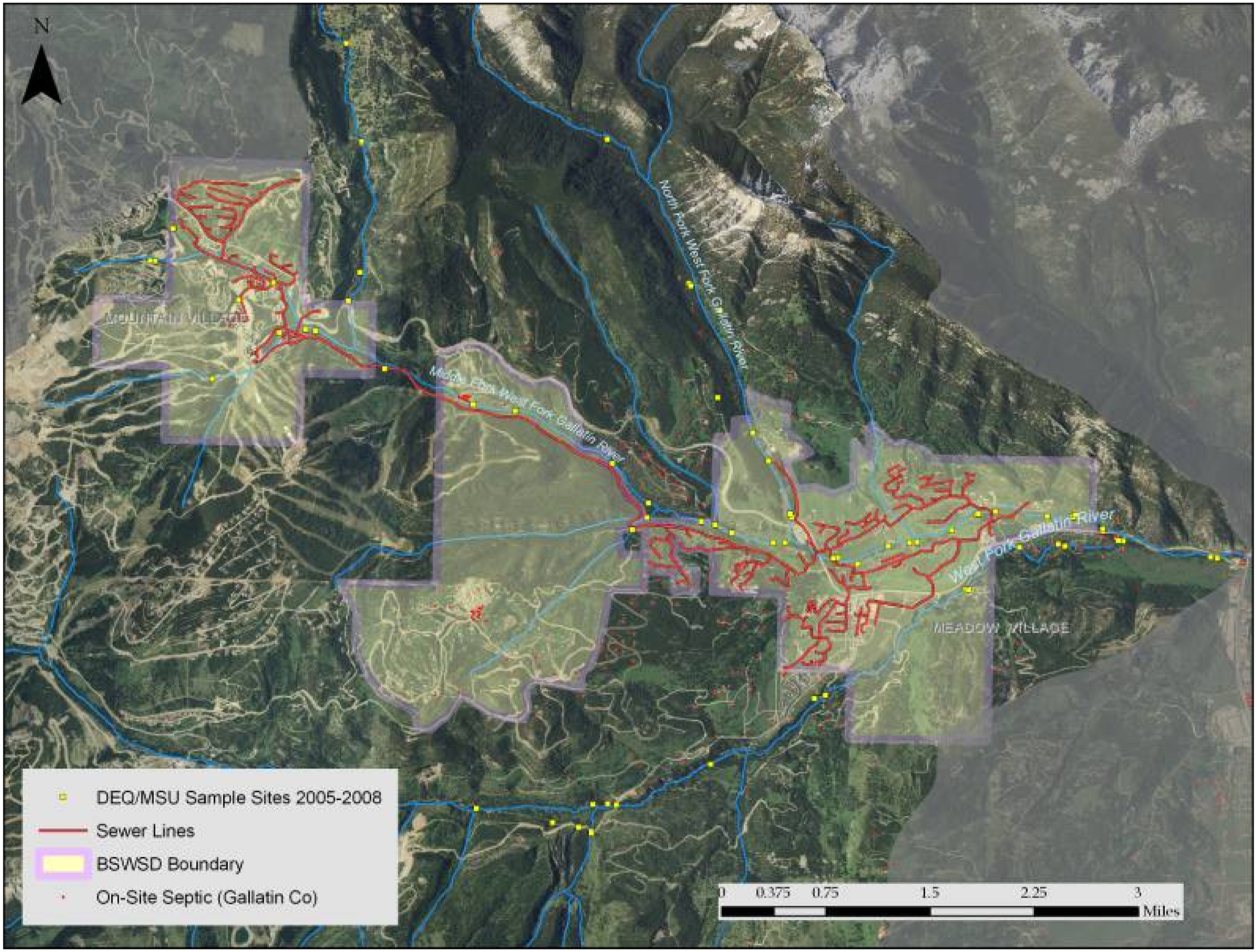


Figure 6-9b. Sewer and Septic coverage, West Fork Gallatin River watershed

Figure 6-17a. Substrate at site WFGR01 August 2008

Figure 6-17b. Stream cobbles at site WFGR01 August 2008

Figure 6-17c. Substrate at site WFGR04 August 2008

Figure 6-17d. Stream cobbles at site WFGR04 August 2008

Figure 6-17e. Substrate at site WFGR06 August 2008

Figure 6-17f. Stream cobbles at site WFGR06 August 2008

Figure 6-17g. Substrate at site WFGR03 August 2008

Figure 6-17h. Stream cobbles at site WFGR03 August 2008

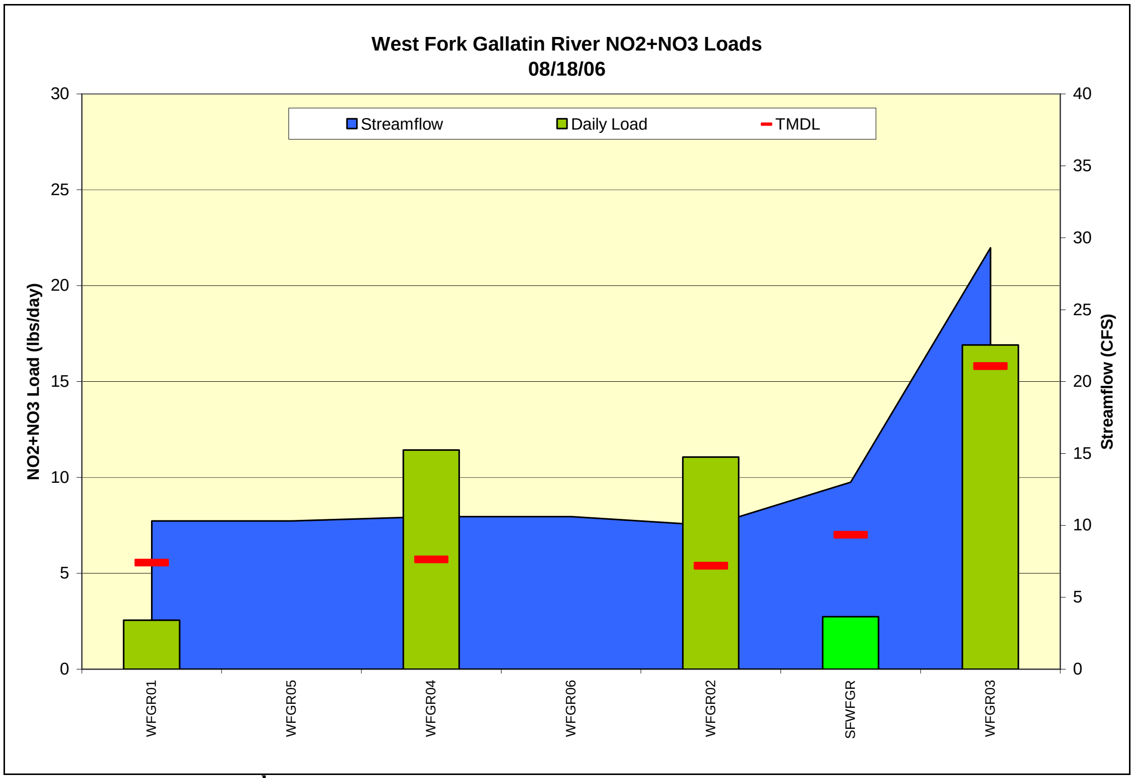


Figure 6-19. August 18th, 2006 NO_2+NO_3 Loads, West Fork Gallatin River

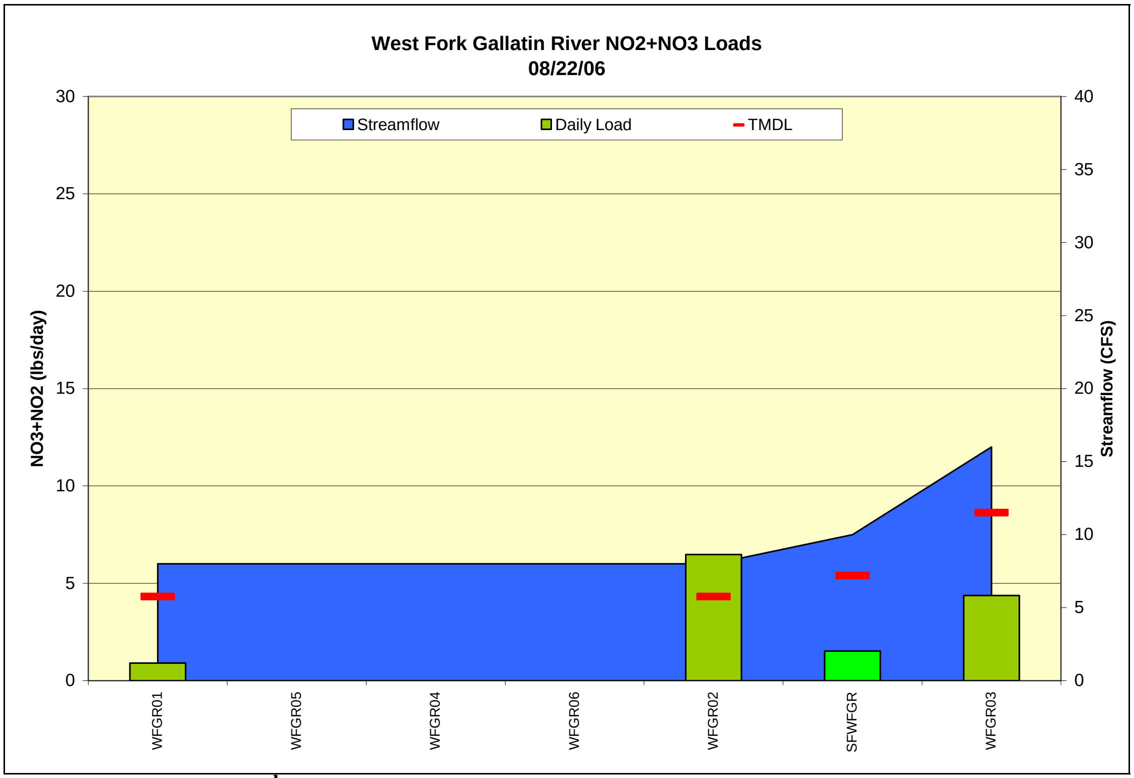


Figure 6-20. August 22nd 2006 NO_2+NO_3 Loads, West Fork Gallatin River

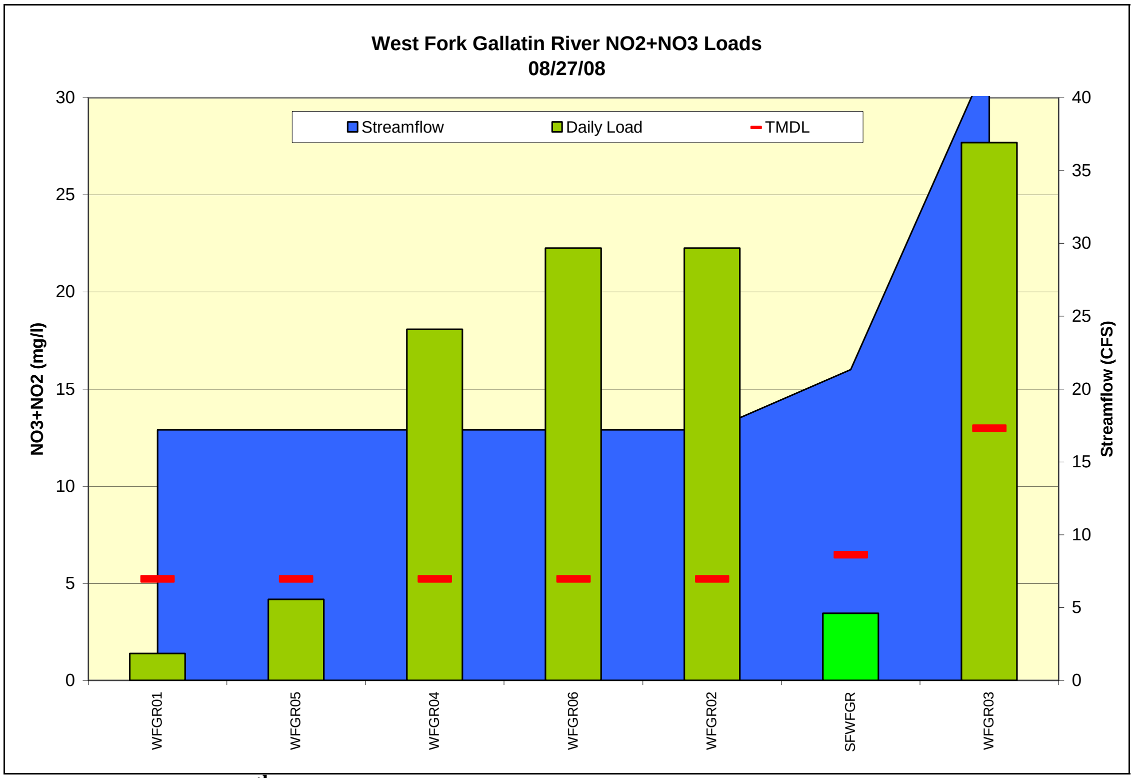


Figure 6-21. August 27th 2008 NO_2+NO_3 Loads, West Fork Gallatin River

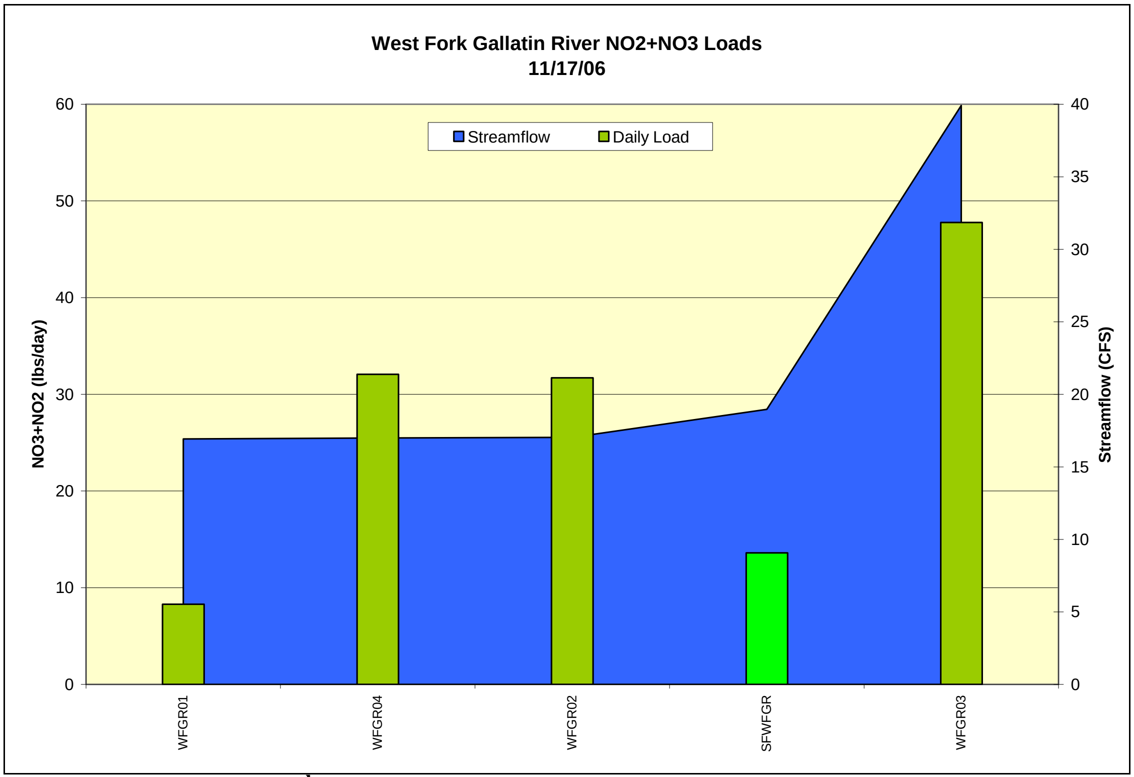


Figure 6-22. November 17th 2006 NO_2+NO_3 Loads, West Fork Gallatin River

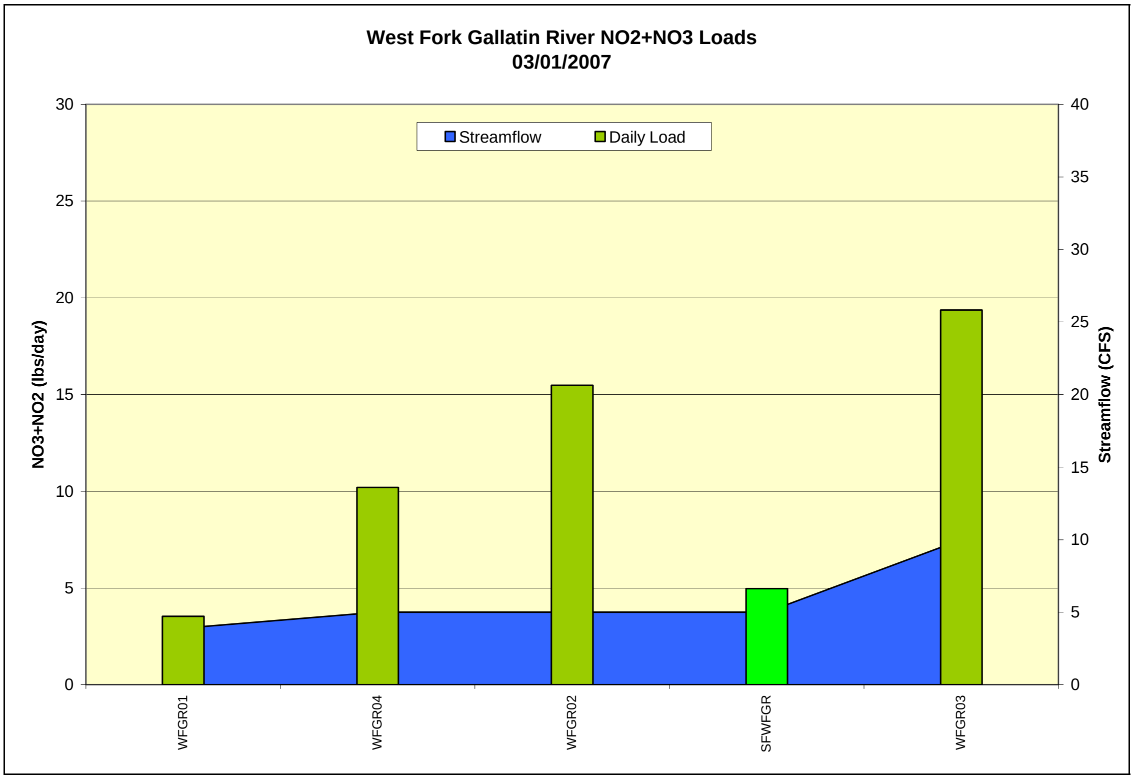


Figure 6-23. March 1st, 2007 NO_2+NO_3 Loads, West Fork Gallatin River

Figure 6-24. Cross-drain on the Big Sky Golf Course fairway

Figure 6-25. Cross-drain discharges to the West Fork Gallatin River

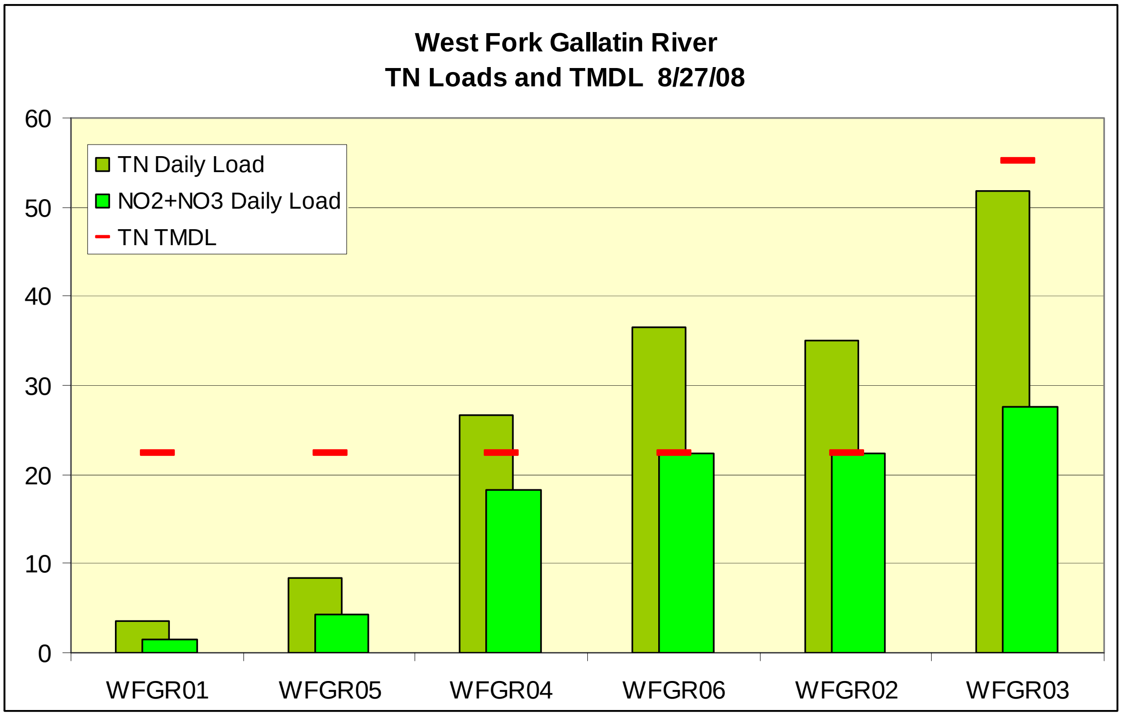


Figure 6-28. August 27th 2008 TN Loads, West Fork Gallatin River

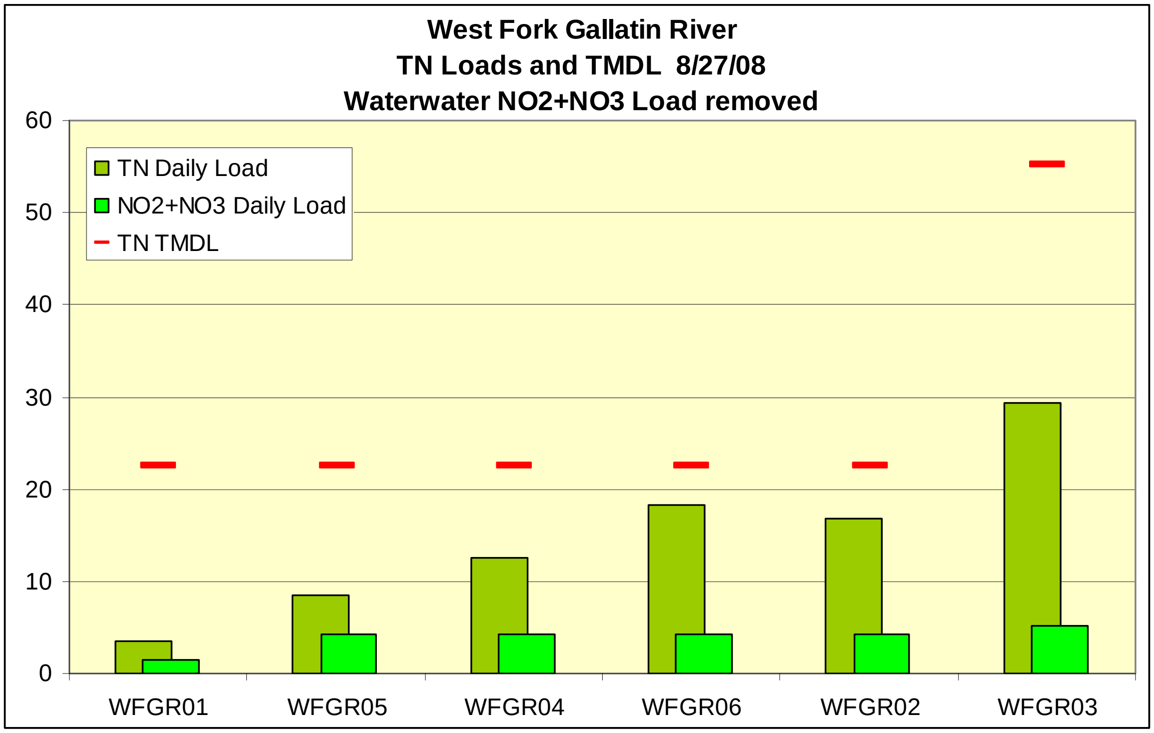


Figure 6-29. August 27th 2008 TN Loads with wastewater load removed

Figure 6-31. Algae-free substrate at site SFWF01 September 2005

Figure 6-32. Substrate at site SFWF01 August 2008

Figure 6-33. Stream cobbles at site SFWF01 August 2008

Figure 6-34. Substrate at site SFWF02 September 2005

Figure 6-35. Substrate at site SFWF02 August 2008

Figure 6-36. Stream cobbles at site SFWF02 August 2008

Figure 6-37. Substrate at site SFWF03 September 2005

Figure 6-38. Substrate at site SFWF03 August 2008

Figure 6-39. Stream cobbles at site SFWF03 August 2008

Figure 6-40. Substrate at site SFWF03 August 2010

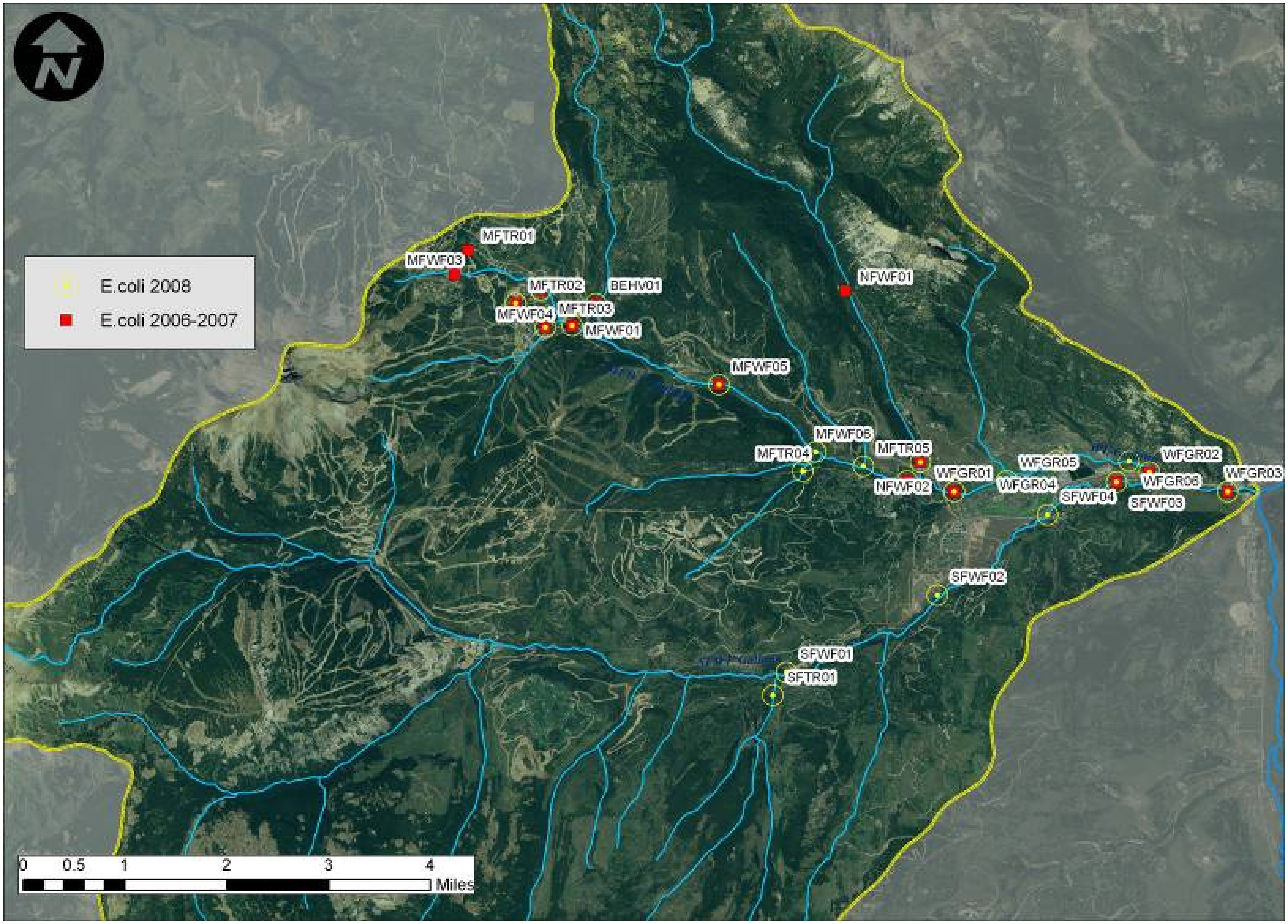


Figure 7-1. 2006-2008 E. coli sampling sites in the West Fork Gallatin watershed

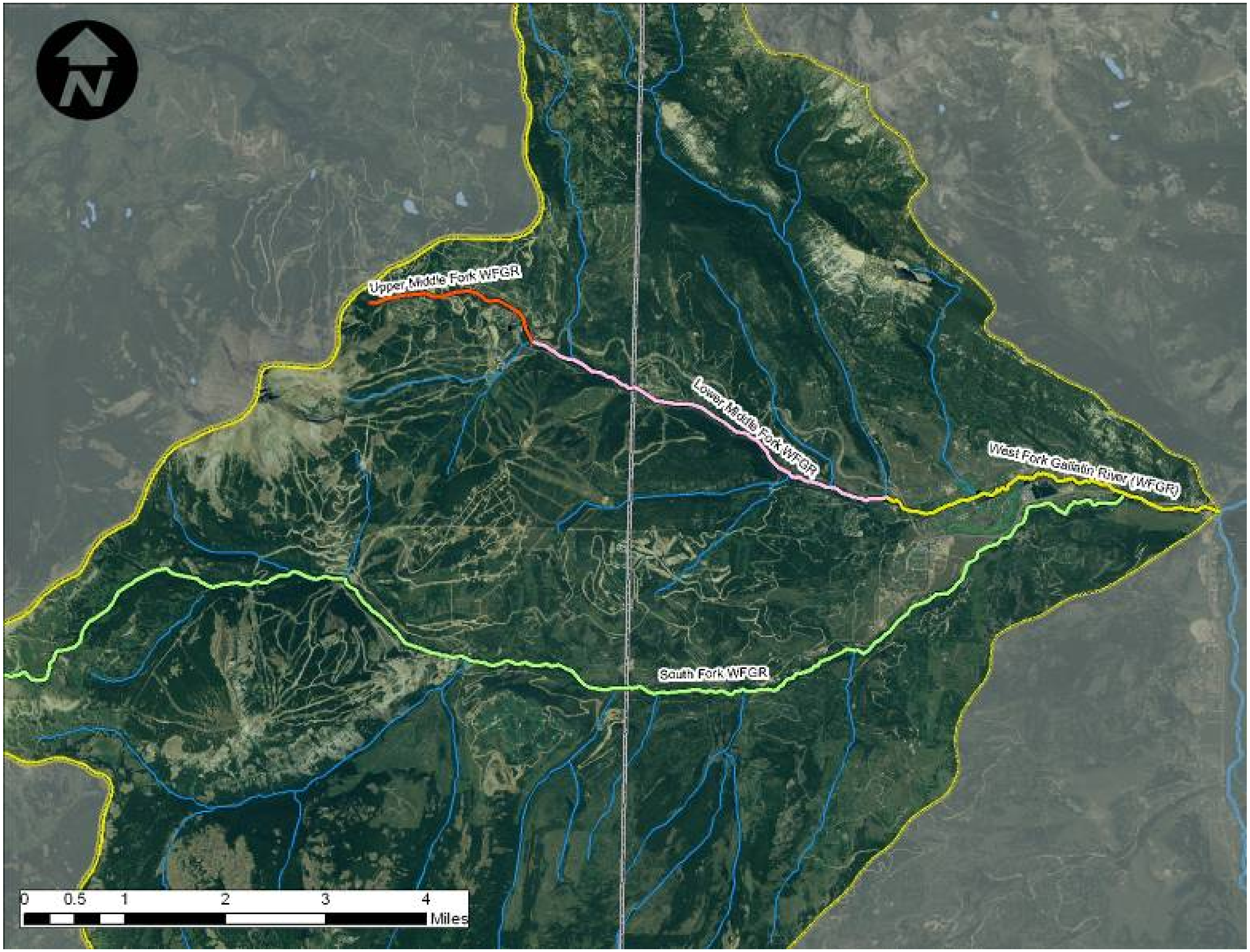


Figure 7-2. E. Coli Assessment Reaches

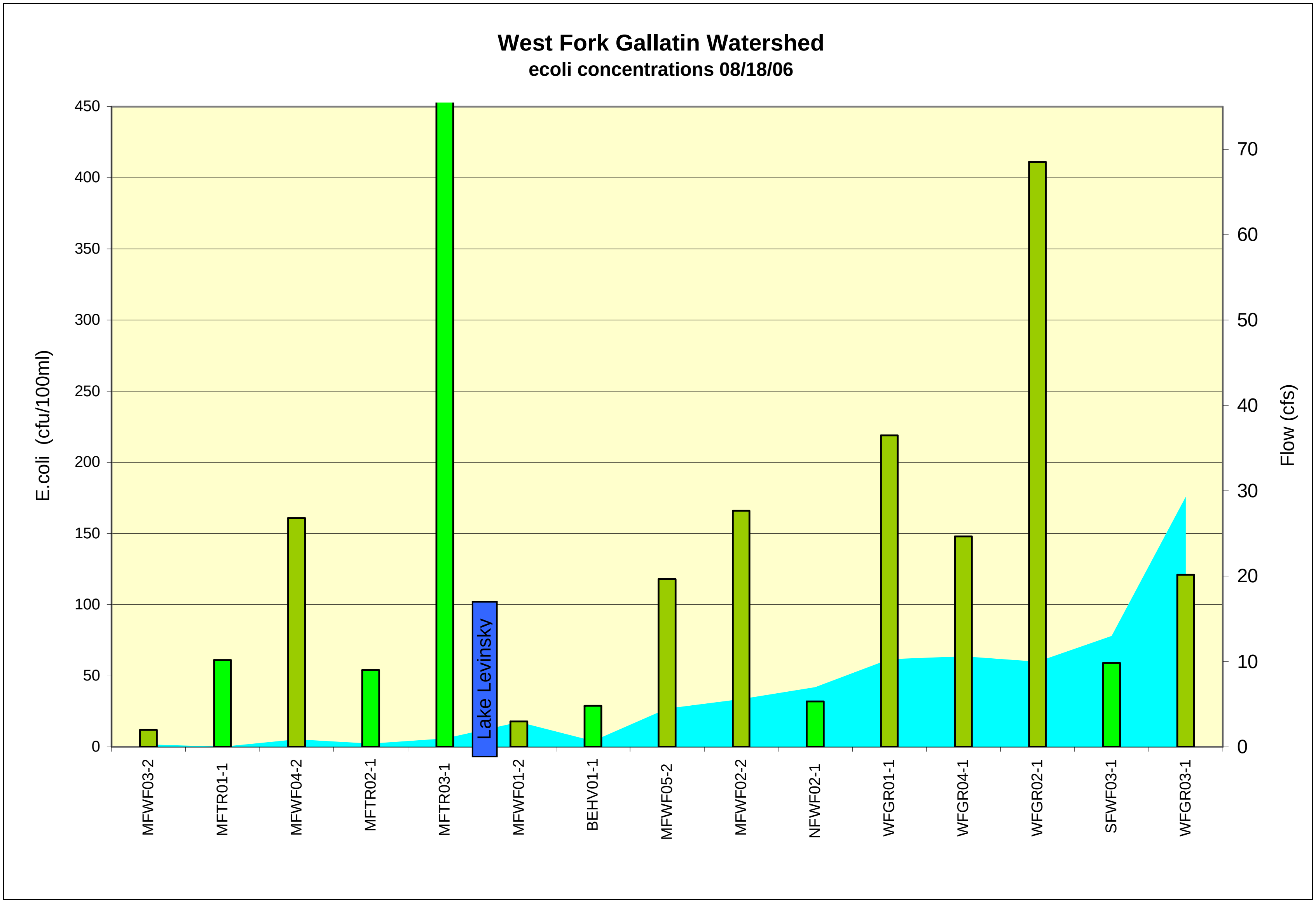


Figure 7-9. E. Coli concentrations on 08/18/06

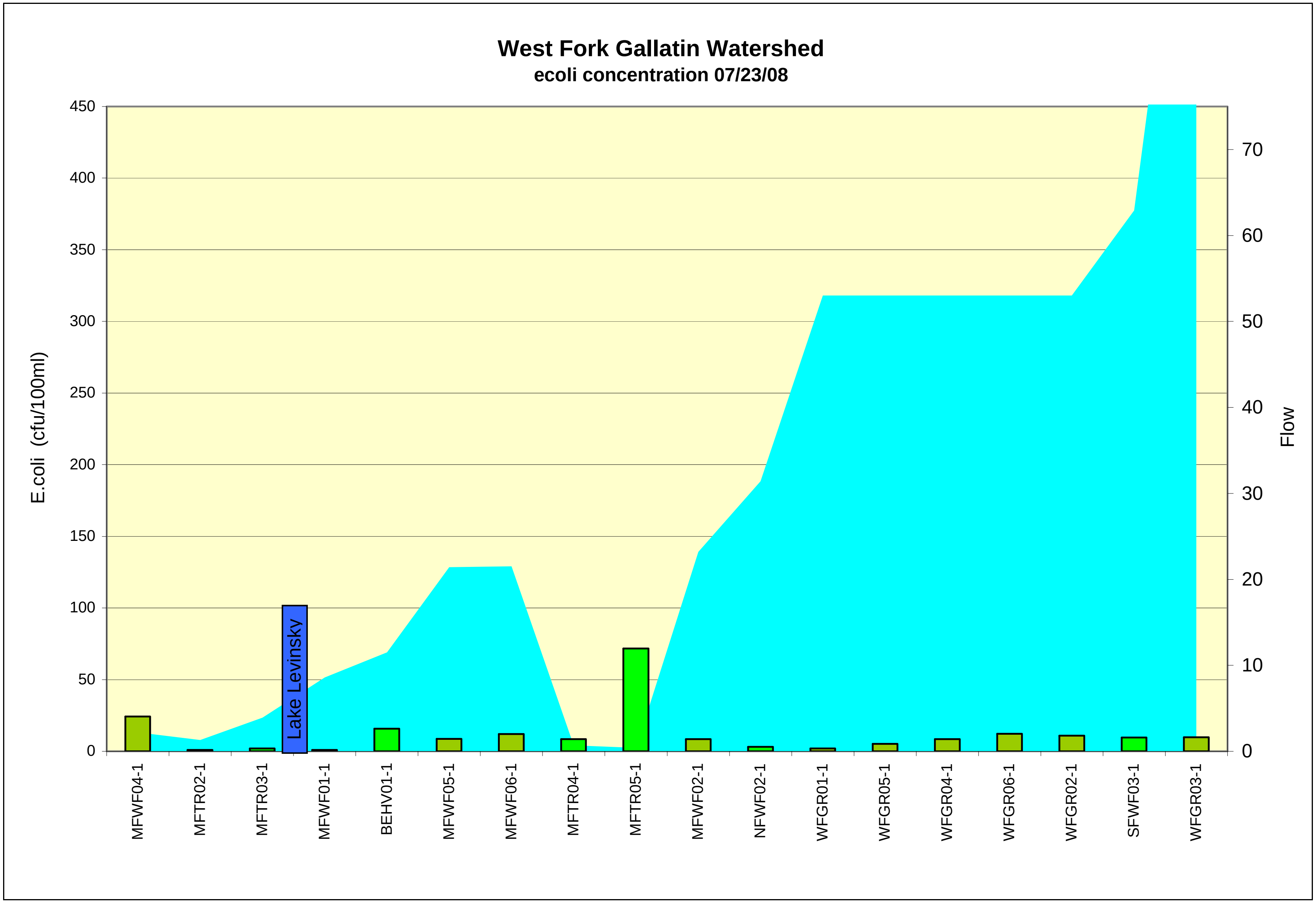


Figure 7-10. E. Coli concentrations on 07/23/08

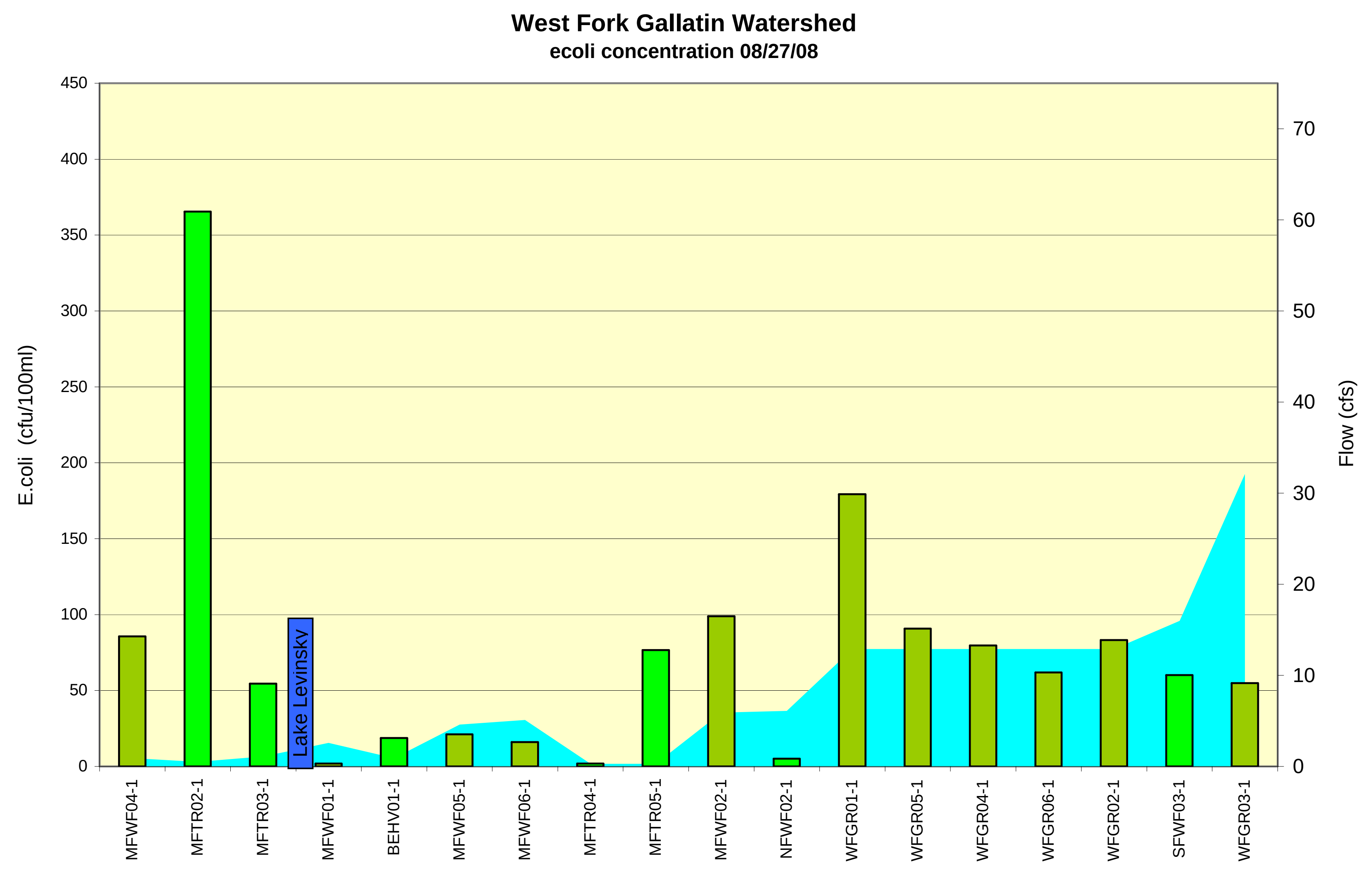


Figure 7-11. E. Coli concentrations on 08/27/08

APPENDIX B
REGULATORY FRAMEWORK AND REFERENCE CONDITION APPROACH

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

B1.0 TMDL DEVELOPMENT REQUIREMENTS

Section 303 of the Federal CWA and the Montana WQA (Section 75-5-703) requires development of TMDLs for impaired water bodies that do not meet Montana WQS. Although water bodies can become impaired from pollution (e.g. flow alterations and habitat degradation) and pollutants (e.g. nutrients, sediment, metals, pathogens, and temperature), the CWA and Montana State Law (75-5-703) both require TMDL development for waters impaired only by pollutants. Section 303 also requires states to submit a list of impaired water bodies to EPA every two years. Prior to 2004, EPA and DEQ referred to this list 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 problems (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 water body is used for consistency; the actual methodology is identified in DEQ's Water Quality Assessment Process and Methods (DEQ 2006b). This methodology was developed via a public process and was incorporated into the EPA-approved 2000 version of the 305(b) report (now also referred to as the Integrated Report).

Under Montana State Law, an "impaired water body" is defined as a water body or stream segment for which sufficient credible data show that the water body or stream segment is failing to achieve compliance with applicable WQS (Montana Water Quality Act; Section 75-5-103(11)). A "threatened water body" is defined as a water body or stream segment for which sufficient credible data and calculated increases in loads show that the water body or stream segment is fully supporting its designated uses, but threatened for a particular designated use because of either (a) proposed sources that are not subject to pollution prevention or control actions required by a discharge permit, the nondegradation provisions, or reasonable land, soil, and water conservation practices or (b) documented adverse pollution trends (Montana WQA; Section 75-5-103(31)). State Law and Section 303 of the CWA require states to develop all necessary TMDLs for impaired or threatened water bodies. There are no threatened water bodies within the Upper Gallatin TPA.

A TMDL is a pollutant budget for a water body identifying the maximum amount of the pollutant that a water body can assimilate without causing applicable WQS to be exceeded. 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.

To satisfy the Federal CWA and Montana State Law, TMDLs will be developed for each water body-pollutant combination identified on Montana's 2006 303(d) List of impaired waters in the Upper Gallatin TPA. 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 water bodies that are subject to a TMDL…" This is an important directive that is reflected in the overall TMDL development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing Federal, State, or local regulations.

B2.0 APPLICABLE WATER QUALITY STANDARDS

WQS include the uses designated for a water body, the legally enforceable standards that ensure that the uses are supported, and a non-degradation policy that protects the high quality of a water body. The ultimate goal of this TMDL document, once implemented, is to ensure that all designated beneficial uses are fully supported and all standards are met. Water quality standards form the basis for the targets described in **Section 5.4.1**. Pollutants addressed in this Water Quality Planning Framework include: sediment, nutrients and pathogens. This section provides a summary of the applicable water quality standards for these three pollutants.

B2.1 Classification and Beneficial Uses

Classification is the assignment (designation) of a single or group of uses to a water body based on the potential of the water body 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 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 water body 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 may not make the natural conditions worse.

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

Descriptions of Montana’s surface water classifications and designated beneficial uses are presented in **Table B2.1**. All water bodies within the Upper Gallatin TPA are classified as B-1 (see **Section 3.1, Table 3-1** for individual stream classifications).

Table B2.1. 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.

B2.2 Standards

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

Numeric surface WQS have been developed for many parameters to protect human health and aquatic life. These standards are in the Department Circular WQB-7 (DEQ 2006a). 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., life long) 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 Department. However, under no circumstance may standards be exceeded. It is important to note that waters that meet or are of better quality than a standard are high quality for that parameter, and nondegradation policies apply to new or increased discharges to that the water body.

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 water body. 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 Upper Gallatin 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, impacts from habitat modifications, or impacts from excess algae.

Sediment

Sediment (i.e., coarse and fine bed sediment) and suspended sediment are addressed via the narrative criteria identified in **Table B2-2**. 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 B2-2**).

Table B2-2. Applicable Rules for Sediment Related Pollutants.

Rule(s)	Standard
17.30.623(2)	No person may violate the following specific water quality standards for waters classified B-1.
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.
	The maximum allowable increase above naturally occurring turbidity is: 0 NTU for A-closed; 5 NTU for A-1, B-1, and C-1; 10 NTU for B-2, C-2, and C-3)
17.30.602(17)	"Naturally occurring" means conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil, and water conservation practices have been applied.
17.30.602(21)	"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.

Turbidity

The allowable changes in turbidity (above natural) is a rather small 5 or 10 nephelometric turbidity units (NTU), see **Table B2-2**. The likely direct effects of increased turbidity are on recreation and aesthetics and drinking water supplies. Indirectly increased turbidity can be linked to an increased pathogen potential, total recoverable metals concentration and increased total suspended sediment. Turbidity cannot be equated with other parameters. Turbidity is a measure of light scatter in water. Suspended or colloidal solids like phytoplankton, metal precipitates or clay may cause the light scatter. In some cases it may be a useful and easily measured surrogate for total suspended solids (TSS) but only after paired flow and seasonal (full hydrograph) turbidity and TSS data have been collected and a statistically significant correlation exists.

Nutrients

The narrative standards applicable to nutrients in Montana are contained in the General Prohibitions of the surface water quality standards (ARM 17.30.637 et. Seq.,). The prohibition against the creation of "*conditions which produce undesirable aquatic life*" is generally the most relevant to nutrients. Undesirable aquatic life includes bacteria, fungi, and algae. Montana has recently developed draft nutrient criteria for nitrate+nitrite nitrogen, total nitrogen, total phosphorus, and chlorophyll *a* based on the Level III ecoregion in which a stream is located (Suplee et al., 2008). For the Middle Rockies Level III ecoregion, draft water quality criteria for nitrate+nitrite nitrogen (NO_2+NO_3), total nitrogen (TN), total phosphorus (TP), and chlorophyll *a* are presented in **Table B2-3**. These criteria are growing season, or summer, values applied from July 1st through September 30th. Additionally, numeric human health standards exist for nitrogen (**Table B2-4**), but the narrative standard is most applicable to nutrients as the concentration in most water bodies in Montana is well below the human health standard and the nutrients contribute to undesirable aquatic life at much lower concentrations than the human health standard.

Table B2-3. Numeric Nutrient and Benthic Algae Criteria for the Middle Rockies Ecoregion.

Parameter	Criteria
Nitrate+Nitrite Nitrogen	≤ 0.100 mg/L
Total Nitrogen	≤ 0.320 mg/L
Total Phosphorus	≤ 0.030 mg/L
Benthic Algae	≤ 129 mg/m²

Table B2-4. Human Health Standards for Nitrogen for the State of Montana.

Parameter	Human Health Standard (µL)[1]
Nitrate as Nitrogen (NO3-N)	10,000
Nitrite as Nitrogen (NO2-N)	1,000
Nitrate plus Nitrite as N	10,000
[1]Maximum Allowable Concentration.	

Pathogens

For pathogen impairments, the Montana standard is based on concentrations of *Escherichia coli* (*E. coli*). The Montana standard for pathogen pollutants for B-1 water bodies specifies:

> *The geometric mean number of E. coli may not exceed 126 cfu/100mL and 10% of the total samples may not exceed 252 cfu/100mL during any 30-day period between April 1 through October 31* [ARM 17.30.623 (2)(i)] (**Table B2-5**). *From November 1 through March 31, the geometric mean number of E. coli may not exceed 630 cfu/100mL and 10% of the samples may not exceed 1,260 cfu/100mL during any 30-day period* [ARM 17.30.623 (2)(ii)]. *The E. coli bacteria standard is based on a minimum of five samples obtained during separate 24-hour periods during any consecutive 30-day period that are analyzed by the most probable number (MPN) or equivalent membrane filter method* [ARM 17.30.620(2)]. *The geometric mean is the value obtained by taking the Nth root of the product of the measured values where values below the detection limit are taken to be the detection limit* [ARM 17.30.602(13)].

Table B2-5. Montana Standards for Pathogen Pollutants for B-1 Water Bodies.

Applicable Period	Standard	Geometric mean of 5 samples collected over a 30-day time period	No more than 10% of the samples shall exceed:
April 1 - October 31	The geometric mean number of ***E-coli*** may not exceed 126 colony forming units per 100 milliliters and 10% of the total samples may not exceed 252 colony forming units per 100 milliliters during any 30-day period (ARM 17.30.623 (2)(i)).	<126 cfu/100mL	252 cfu/100mL
November 1 - March 31	The geometric mean number of ***E-coli*** may not exceed 630 colony forming units per 100 milliliters and 10% of the samples may not exceed 1,260 colony forming units per 100 milliliters during any 30-day period (ARM 17.30.623 (2)(ii)).	<630 cfu/100mL	1,260 cfu/100mL

B3.0 REFERENCE CONDITIONS

B3.1 Reference Conditions as Defined in DEQ's Standard Operating Procedure for Water Quality Assessment (2006b)

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 water body 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 water body's 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.

Water bodies 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 water body to reference water body 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 water body to baseline data from minimally impaired water bodies 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 water body in the past.
- Comparing conditions in a water body to conditions in another portion of the same water body, 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 water bodies that are least impaired.
- Seeking expert opinion (e.g. expert opinion from a regional fisheries biologist who has a good understanding of the water body'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.

B3.2 Use of Statistics for Developing Reference Values or Ranges

Reference value development must consider natural variability as well as variability that can occur as part of field measurement techniques. Statistical approaches are commonly used to help incorporate variability. One statistical approach is to compare stream conditions to the mean (average) value of a reference data set to see if the stream condition compares favorably to this value or falls within the range of one standard deviation around the reference mean. The use of these statistical values assumes a normal distribution; whereas, water resources data tend to have a non-normal distribution (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 25th and 75th percentiles of the reference data. This is a more realistic approach than using one standard deviation since water quality data often include observations considerably higher or lower than most of the data. Very high and low observations can have a misleading impact on the statistical summaries if a normal distribution is incorrectly assumed, whereas statistics based on non-normal distributions are far less influenced by such observations.

Figure B3-1 is an example boxplot type presentation of the median, 25th and 75th percentiles, and minimum and maximum values of a reference data set. In this example, the reference stream results are stratified by two different stream types. Typical stratifications for reference stream data may include Rosgen stream types, stream size ranges, or geology. If the parameter being measured is one where low values are undesirable and can cause harm to aquatic life, then measured values in the potentially impaired stream that fall below the 25th percentile of reference data are not desirable and can be used to indicate impairment. If the parameter being measured is one where high values are undesirable, then measured values above the 75th percentile can be used to indicate impairment.

The use of a non-parametric statistical distribution for interpreting narrative WQS or developing numeric criteria is consistent with EPA guidance for determining nutrient criteria (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.

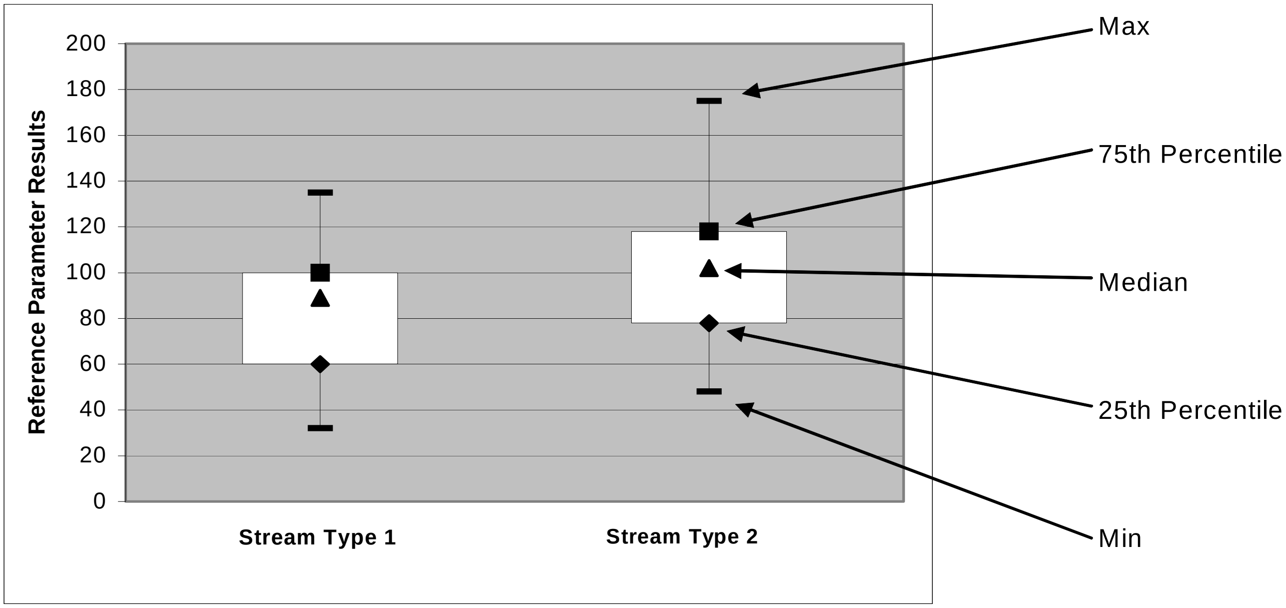


Figure B3-1. Boxplot Example for Reference Data.

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 water bodies 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 water bodies 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 B3-2**. 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 25th or 75th percentiles as potential target values, but you would use the 25th and 75th 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 B3-2** is an example statistical distribution where higher values represent better water quality. In **Figure B3-2**, the median and 25th percentiles represent potential target values versus the median and 75th 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.

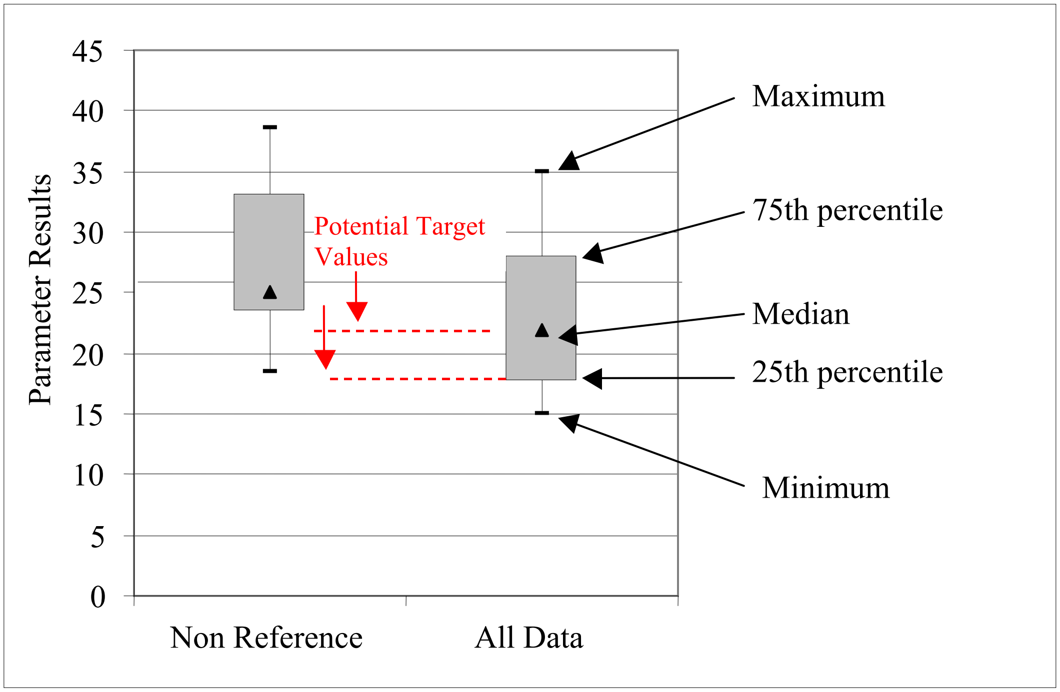


Figure B3-2. Boxplot example for the use of all data to set targets.

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APPENDIX C
SEDIMENT TOTAL MAXIMUM DAILY LOADS

C.1 Sediment

C.1.1 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. It is not expected that daily loads will drive implementation activities.

C.1.2 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 West Fork Gallatin River watershed, some limited monthly and short-term daily discharge measurements have been collected but there are no long-term daily discharge values. Within the entire Gallatin River watershed, there are several USGS gage stations with extensive discharge datasets but no gage stations with daily suspended sediment measurements. The closest gage to the West Fork Gallatin River is the Gallatin River near Gallatin Gateway (station #06043500) and it has discharge values dating back to 1889. The gage near Gallatin Gateway is downstream of the confluence with the West Fork and likely has similar hydrologic patterns to the West Fork (Van Voast 1972). Since sediment loading in the West Fork Gallatin River watershed is associated with nonpoint sources and storm water-related point sources, the hydrograph is assumed to be a reasonable surrogate for sediment loading to streams in the West Fork Gallatin River watershed (i.e. peak contributions during periods of runoff and high flow). Therefore, mean daily discharge values from 120 years of record (1889 - 2009) at the gage near Gallatin Gateway were used to calculate daily sediment values for TMDLs in the West Fork Gallatin 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 C-1**). For each TMDL, the daily percentages in **Table C-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 daily loads are shown graphically in **Figure C-1** and may be computed by using the daily percentages in **Table C-1** and the TMDLs expressed as an average annual load, which are discussed in **Section 5.7** and also provided in **Table C-2**. For instance, the total allowable annual sediment load for the Middle Fork West Fork Gallatin River is 6,125 tons. To determine the TMDL for January 1, 6,125 tons is multiplied by 0.10% which provides a daily load for the Middle Fork on January 1st of 6.125 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 C-1. USGS Stream Gage 06043500 (Gallatin River near Gallatin Gateway) – Percent of Mean Annual Discharge Based on Mean of Daily Mean Discharge Values for each Day of Record (Calculation Period 1889-08-01 -> 2009-09-30)

Day of Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.10%	0.10%	0.10%	0.12%	0.29%	1.00%	0.70%	0.25%	0.17%	0.16%	0.14%	0.12%
2	0.10%	0.10%	0.10%	0.12%	0.30%	1.03%	0.68%	0.25%	0.17%	0.16%	0.14%	0.12%
3	0.10%	0.10%	0.10%	0.12%	0.32%	1.04%	0.67%	0.24%	0.17%	0.16%	0.14%	0.12%
4	0.10%	0.10%	0.10%	0.12%	0.34%	1.06%	0.64%	0.24%	0.17%	0.16%	0.14%	0.11%
5	0.10%	0.10%	0.10%	0.12%	0.35%	1.09%	0.62%	0.24%	0.17%	0.16%	0.14%	0.11%
6	0.10%	0.10%	0.10%	0.12%	0.37%	1.12%	0.60%	0.23%	0.17%	0.16%	0.14%	0.11%
7	0.10%	0.10%	0.10%	0.13%	0.39%	1.13%	0.58%	0.22%	0.17%	0.16%	0.14%	0.11%
8	0.10%	0.10%	0.10%	0.13%	0.41%	1.11%	0.55%	0.22%	0.17%	0.16%	0.14%	0.11%
9	0.10%	0.10%	0.10%	0.13%	0.43%	1.09%	0.53%	0.22%	0.17%	0.16%	0.14%	0.11%
10	0.10%	0.10%	0.10%	0.13%	0.44%	1.08%	0.51%	0.22%	0.17%	0.16%	0.13%	0.11%
11	0.10%	0.10%	0.10%	0.14%	0.46%	1.06%	0.50%	0.21%	0.17%	0.16%	0.13%	0.11%
12	0.10%	0.10%	0.10%	0.14%	0.48%	1.06%	0.48%	0.21%	0.17%	0.16%	0.13%	0.11%
13	0.10%	0.10%	0.10%	0.14%	0.51%	1.06%	0.45%	0.21%	0.17%	0.15%	0.13%	0.11%
14	0.10%	0.10%	0.10%	0.15%	0.54%	1.05%	0.44%	0.21%	0.17%	0.15%	0.13%	0.11%
15	0.10%	0.10%	0.10%	0.16%	0.57%	1.05%	0.42%	0.20%	0.16%	0.15%	0.13%	0.11%
16	0.10%	0.10%	0.10%	0.16%	0.59%	1.05%	0.40%	0.20%	0.16%	0.16%	0.13%	0.11%
17	0.10%	0.10%	0.10%	0.17%	0.63%	1.04%	0.38%	0.20%	0.16%	0.15%	0.13%	0.11%
18	0.10%	0.10%	0.10%	0.17%	0.67%	1.02%	0.37%	0.19%	0.16%	0.15%	0.13%	0.11%
19	0.10%	0.10%	0.11%	0.18%	0.69%	1.02%	0.36%	0.19%	0.16%	0.15%	0.13%	0.11%
20	0.10%	0.10%	0.11%	0.19%	0.72%	1.01%	0.35%	0.19%	0.16%	0.15%	0.12%	0.10%
21	0.10%	0.10%	0.11%	0.19%	0.75%	0.97%	0.34%	0.19%	0.16%	0.15%	0.12%	0.11%
22	0.10%	0.10%	0.11%	0.20%	0.77%	0.95%	0.32%	0.19%	0.16%	0.15%	0.12%	0.11%
23	0.10%	0.10%	0.11%	0.21%	0.78%	0.92%	0.32%	0.19%	0.16%	0.15%	0.12%	0.10%
24	0.10%	0.10%	0.11%	0.22%	0.80%	0.91%	0.31%	0.19%	0.16%	0.15%	0.12%	0.11%
25	0.10%	0.10%	0.11%	0.22%	0.83%	0.89%	0.30%	0.18%	0.16%	0.15%	0.12%	0.11%
26	0.10%	0.10%	0.11%	0.22%	0.87%	0.87%	0.29%	0.18%	0.16%	0.15%	0.12%	0.10%
27	0.10%	0.10%	0.11%	0.23%	0.90%	0.83%	0.29%	0.18%	0.16%	0.14%	0.12%	0.10%
28	0.10%	0.10%	0.11%	0.24%	0.94%	0.79%	0.28%	0.18%	0.16%	0.15%	0.12%	0.10%
29	0.10%	0.10%	0.11%	0.25%	0.97%	0.76%	0.27%	0.18%	0.16%	0.14%	0.12%	0.10%
30	0.10%		0.11%	0.27%	0.98%	0.74%	0.27%	0.18%	0.16%	0.14%	0.12%	0.11%
31	0.10%		0.11%		0.98%		0.26%	0.17%		0.14%		0.11%

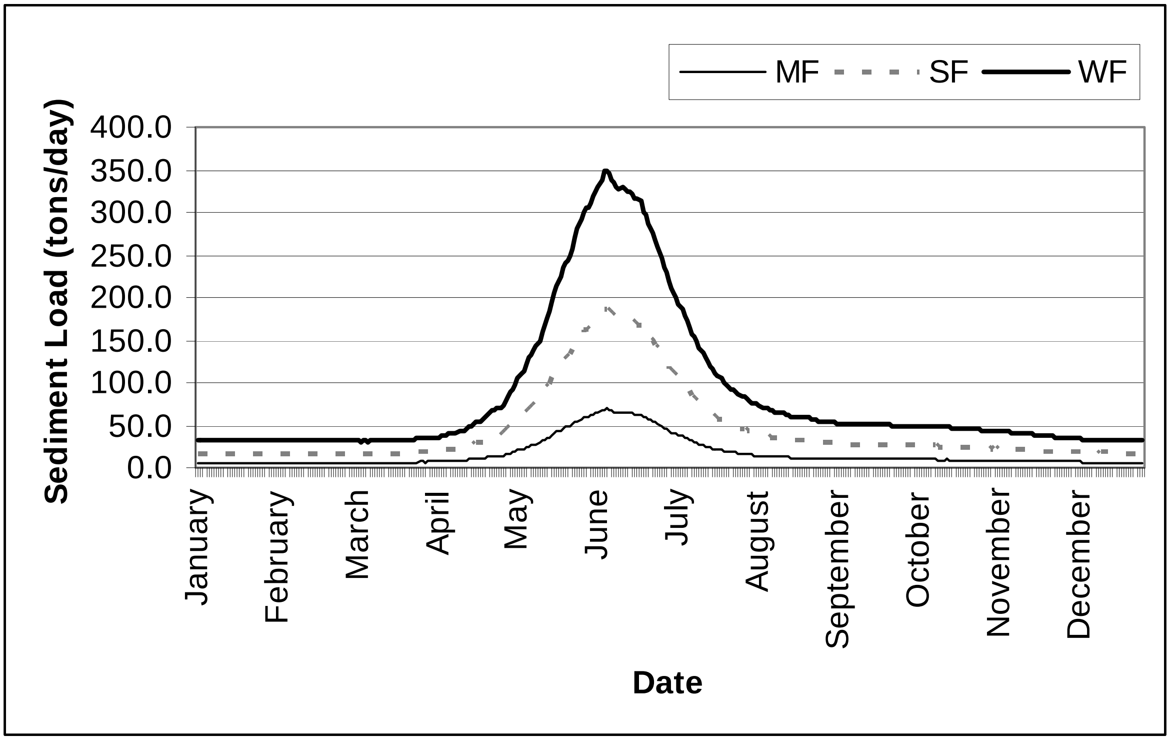

Figure C-1. Average Daily Sediment Load for the Middle Fork West Fork (MF), South Fork West Fork (SF), and the West Fork Gallatin River (WF).

Table C-2. TMDLs expressed as an average annual load and can be used in conjunction with the values in Table C-1 to compute daily loads.

Stream Segment	**Waterbody #**	**TMDL Expressed as Average Annual Load (tons/year)**
Middle Fork West Fork Gallatin River	MT41H005_050	6,125
South Fork West Fork Gallatin River	MT41H005_060	16,583
West Fork Gallatin River	MT41H005_040	31,038

REFERENCES

Van Voast, WA. 1972. *Hydrology of the West Fork Drainage of the Gallatin River, southwestern Montana, prior to commercial recreational development.* Special Publication 57. Montana Bureau of Mines and Geology.

APPENDIX D
STREAMBANK EROSION SOURCE ASSESSMENT

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FIGURES

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D1.0 INTRODUCTION

This report presents an assessment of sediment loading due to streambank erosion along several stream segments in the West Fork Gallatin River watershed of the Upper Gallatin Total Maximum Daily Load (TMDL) Planning Area (TPA) located in Gallatin and Madison Counties, Montana. Sediment loads due to streambank erosion were estimated based on field data collected at 30 monitoring sites covering 5.2 miles of stream between July and October of 2008. Streambank erosion data collected at field monitoring sites was extrapolated to the stream reach and stream segment scales based on reach type characteristics identified in the Aerial Assessment Database, which was compiled in a geographic information system (GIS) prior to field data collection. Streambank erosion data collected in the field were also used to estimate sediment loading at the watershed scale and to assess the potential to decrease sediment inputs due to anthropogenically accelerated streambank erosion.

D2.0 METHODS

The streambank erosion assessment involved stratifying streams into reaches in GIS, collecting streambank erosion data in the field, estimating sediment loads from streambank erosion, extrapolating streambank erosion sediment loads to the entire stream, and estimating the potential for reducing anthropogenically accelerated streambank erosion.

D2.1 Aerial Assessment Reach Stratification

Prior to field data collection, an aerial assessment of streams in the West Fork Gallatin River watershed was conducted using National Agricultural Imagery Program (NAIP) color imagery from 2005 in GIS along with other relevant data layers, including the National Hydrography Dataset (NHD) 1:100,000 stream layer and United States Geological Survey 1:24,000 Topographic Quadrangle Digital Raster Graphics. GIS data layers were used to stratify streams into distinct reaches based on landscape and land-use factors following techniques described in *Watershed Stratification Methodology for TMDL Sediment and Habitat Investigations* (MT DEQ 2008a) and *White Paper: A Watershed Stratification Approach for TMDL Sediment and Habitat Impairment Verification* (MT DEQ 2008b).

The Aerial Assessment reach stratification process was completed for the following sediment listed stream segments in the West Fork Gallatin River watershed: Middle Fork West Fork Gallatin River, South Fork West Fork Gallatin River, and West Fork Gallatin River. In addition to the sediment listed stream segments, several other streams in the West Fork Gallatin River watershed were assessed to provide supporting information, including: Muddy Creek, First Yellow Mule Creek, Second Yellow Mule Creek, Third Yellow Mule Creek, North Fork West Fork Gallatin River, Beehive Creek, “Stony” Creek (including the mainstem, “North Fork” and “South Fork”), and “Moose Tracks” Creek (including the mainstem, “North Fork” and “South Fork”). *Note that “ ” indicates stream names assigned to un-named streams for the purposes of this assessment.*

D2.1.1 Reach Types

The Aerial Assessment reach stratification process involved dividing each stream into distinct reaches based on four landscape factors: Ecoregion, valley gradient, Strahler stream order, and valley confinement. Each individual combination of the four landscape factors is referred to as a “**reach type**” in this report based on the following definition:

> *Reach Type - Unique combination of Ecoregion, gradient, Strahler stream order and confinement*

Reach types were described using the following naming convention based on the reach type identifiers presented in **Table D-1**:

> *Level III Ecoregion – Valley Gradient – Strahler Stream Order – Confinement*

Table D-1. Reach Type Identifiers.

Landscape Factor	Stratification Category	Reach Type Identifier
Level III Ecoregion	Middle Rockies	MR
Valley Gradient	0-<2%	0
	2-<4%	2
	4-<10%	4
	>10%	10
Strahler Stream Order	first order	1
	second order	2
	third order	3
	fourth order	4
Confinement	unconfined	U
	confined	C

Thus, a stream reach identified as MR-0-3-U is a low gradient (0-<2%), 3rd order, unconfined stream in the Middle Rockies Level III Ecoregion.

D2.2 Field Data Collection

Field data collection utilized the approach described the in *Longitudinal Field Methods for the Assessment of TMDL Sediment and Habitat Impairments* (MT DEQ 2008). Field assessment reaches were typically selected in relatively low-gradient portions of the study streams where sediment deposition is likely to occur. Other considerations in selecting field assessment reaches included representativeness of the reach to other reaches of the same slope, order, confinement and Ecoregion, as well of ease of access, as outlined in *Upper Gallatin River TMDL Planning Area Sediment Monitoring Sampling and Analysis Plan* (PBS&J 2008a). Within each field assessment reach, streambank erosion was evaluated at monitoring sites, which were typically 500, 1000, or 2000 feet long and varied based on bankfull width of the stream (MT DEQ 2008).

At each monitoring site, all streambanks were assessed for erosion severity and categorized as either “actively/visually eroding” or “slowly eroding/vegetated/undercut”. At each eroding bank, **Bank Erosion Hazard Index (BEHI)** measurements were performed and the **Near Bank Stress (NBS)** was evaluated (Rosgen 1996, 2004). Bank erosion severity was rated from “very low” to “extreme” based on the BEHI score, which was determined based on the following six parameters: bank height, bankfull height, root depth, root density, bank angle, and surface protection. Near Bank Stress was also rated from “very low” to “extreme” depending on the shape of the channel at the toe of the bank and the force of the water (i.e. “stream power”) along the bank. In addition, the source or underlying cause of streambank erosion was evaluated based on observed anthropogenic disturbances within the riparian corridor, as well as current or historic land-use practices within the surrounding landscape. The source of streambank instability was identified based on the following near-stream source categories: transportation, riparian grazing, cropland, mining, silviculture, irrigation, natural, and “other”. Naturally eroding streambanks were considered the result of “natural sources” while 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.

D2.3 Streambank Erosion Sediment Load Calculations

For each eroding streambank, the average annual sediment load was estimated based on the bank's length, mean height, and estimated 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. Annual retreat rates were estimated based on retreat rates from the Lamar River in Yellowstone National Park (Rosgen 1996) (**Table D-2**). The annual sediment load in cubic feet was then calculated from the field data (annual retreat rate x mean bank height x bank length), 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) (EPA 2006, Rosgen 2006). This process resulted in a sediment load for each eroding bank expressed in tons per year.

Table D-2. Annual Streambank Retreat Rates (Feet/Year), Lamar River, Yellowstone National Park (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

D2.4 Streambank Erosion Sediment Load Extrapolation

Streambank erosion data collected at **monitoring sites** were extrapolated to the **stream reach** and **stream segment** scales based on similar reach type 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 stream reach where field monitoring was conducted*
Stream Reach - *Subdivision of the stream segment based on Ecoregion, stream order, gradient and confinement as evaluated in GIS*
Stream Segment - *303(d) listed segment* (Note: several additional non-listed streams were included within this assessment)

D2.4.1 Sediment Load Extrapolation Criteria

The extrapolation of average annual stream reach sediment loads due to streambank erosion was based on the following criteria:

1. Monitoring site sediment loads were extrapolated directly to the stream reach in which the monitoring site was located.
2. For reaches not assessed in the field, the average sediment load for all monitoring sites within a given reach type was applied. This "reach type" sediment load is the foundation of the streambank erosion extrapolation process.
3. For reaches assessed in the field, the field identified sources replaced the sources identified during the aerial assessment.

Exceptions to these criteria were made in several instances based on a detailed review of color aerial imagery in GIS and extensive on-the ground experience within the West Fork Gallatin River watershed, including:

1. In select situations, the sediment load derived for a specific reach was extrapolated directly to another reach, often when the two reaches were adjacent or within close proximity.
2. For reaches in which no historic or current land-use practices were observed (i.e. assigned a source of "100% natural"), the average of the "slowly eroding" banks was often applied (see **Section D3.4.1.2**).
3. For many of the headwater reaches, the sediment load from the only assessed site with a valley gradient of >10% was applied (see **Section D3.4.1.2**).
4. When anthropogenic disturbances were evident at the stream reach scale but not directly observed at the monitoring site, the sources identified in the Aerial Assessment Database were retained.

D2.5 Streambank Erosion Sediment Load Reductions

The potential to decrease sediment loads from anthropogenically induced streambank erosion through the implementation of Best Management Practices (BMPs) was evaluated for each monitoring site and then extrapolated to the stream reach and stream segment scales.

D2.5.1 Sediment Load Reduction Criteria

The potential for annual streambank erosion sediment load reductions were evaluated using the following criteria:

1. Only reaches with an identified anthropogenic source of sediment were considered for load reduction.
2. For reaches with anthropogenic sources of streambank erosion, the potential to decrease sediment loads was assessed by reducing the BEHI rating for all streambanks with a BEHI score greater than "moderate" (i.e. "high", "very high" or "extreme") down to "moderate".

Bank erosion reductions are based on the Beaverhead-Deerlodge National Forest (BDNF) reference dataset, which includes data from streams throughout southwest Montana (Bengeyfield n.d.). The BDNF reference dataset indicates that a "moderate" BEHI score (20-29.5) can be expected on reference streams with the following stream types: A, C, (C3, C4) and E (E3, E4, E5, Ea) (**Table D-3**). Streams classified as B stream types are on the border of the "moderate" and "high" (30.0-39.5) BEHI categories, with B3 streams falling in "moderate" category and B4 streams falling in the “high” category. Based on the BDNF reference dataset, it was determined that functioning streams in the Upper Gallatin TPA would tend to have a “moderate” BEHI score. In addition, the sediment load reduction criteria is based on the assumption that the application of all reasonable land, soil and water conservation practices will result in the growth and preservation of sufficient streambank vegetation to minimize streambank erosion.

Table D-3. Expected BEHI Values for Various Stream Types based on the BDNF Reference Dataset.

A	B3	B4	B	C3	C4	C	E3	E4	E5	Ea	E
24.2	27.1	31.7	29.7	26.9	26.5	26.5	26.3	24.2	22	22.7	23.6

D3.0 RESULTS

This section provides estimated average annual sediment loads due to streambank erosion at the monitoring site, stream segment and watershed scales based on similar reach type characteristics as determined through the Aerial Assessment process. In addition, the potential to reduce streambank erosion was examined.

D3.1 Aerial Assessment Reach Stratification

During the Aerial Assessment, a total of 88.1 miles of stream were identified in the West Fork Gallatin River watershed and 60.7 miles of stream were included in the aerial assessment reach stratification process (PBS&J 2008b). The remaining 27.4 miles of stream not included in the aerial assessment are small 1st order headwater streams. A total of 157 reaches were delineated in GIS and reach specific data were compiled into an Aerial Assessment Database. A total of 14 reach types were identified in the West Fork Gallatin River watershed, 9 of which were assessed in the field. Possible reach type combinations based on the Level III Ecoregion identified in the West Fork Gallatin River watershed are presented in **Table D-4**, along with the number of reaches assessed in the field for each reach type. A complete discussion of this assessment can be found in *Aerial Assessment Reach Stratification Upper Gallatin TMDL Planning Area* (PBS&J 2008b).

Table D-4. Aerial Assessment Reach Stratification Spatial Representation.

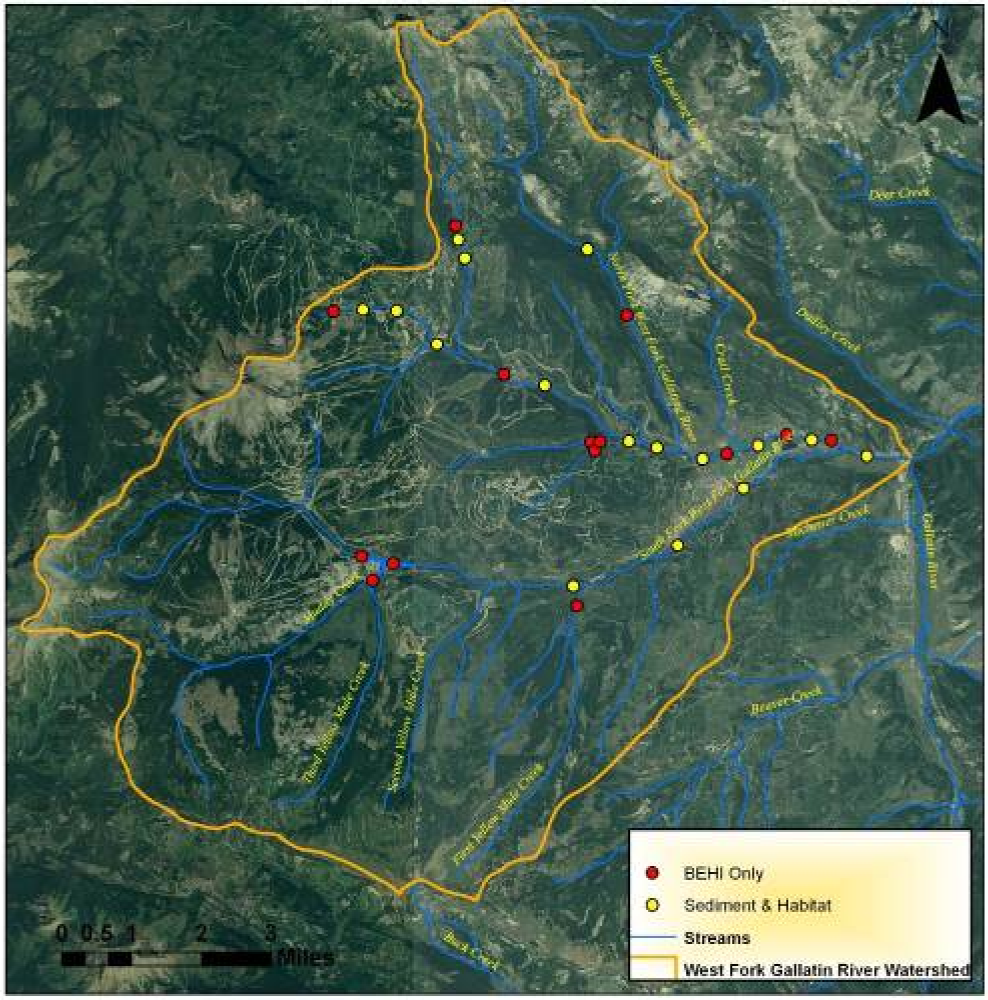
Reach Type	Number of Reaches	Number of Reaches Assessed
MR-0-3-U	12	5
MR-0-4-U	4	1
MR-2-1-U	2	1
MR-2-2-U	6	5
MR-2-3-C	2	0
MR-2-3-U	10	7
MR-4-1-C	10	2
MR-4-1-U	39	5
MR-4-2-C	2	0
MR-4-2-U	18	4
MR-4-3-C	2	0
MR-10-1-C	12	0
MR-10-1-U	36	1
MR-10-2-U	2	0

D3.2 Field Data Collection

A total of 30 sediment monitoring sites spatially distributed throughout the study tributaries in the West Fork Gallatin River watershed were assessed between July and October of 2008. Monitoring sites were identified through an assessment of aerial images and on-the-ground reconnaissance to capture the variability in land-use and watershed characteristics potentially contributing to sediment impairment issues in streams. At 16 of the monitoring sites, the complete sediment and habitat assessment methodology was performed (MT DEQ 2008), while the remaining 14 monitoring sites were assessed only for streambank erosion. A total of 204 individual streambanks were assessed. The following streams were assessed in the West Fork Gallatin River watershed in 2008 (**Figure D3-1**) (specific reaches identified in parenthesis):

- Middle Fork West Fork Gallatin River (1-01, 2-01, 4-01, 7-02, 8-01, 9-01, 9-02)
- North Fork West Fork Gallatin River (10-01, 11-01)
- South Fork West Fork Gallatin River (17-02, 18-01, 22-01, 28-01, 29-02)
- West Fork Gallatin River (1-02, 1-03, 1-04, 1-05, 2-01, 2-02, 3-03)
- Beehive Creek (11-01, 12-01, 13-01)
- Muddy Creek (8-01, 8-02)
- First Yellow Mule Creek (16-01)
- Stony Creek (1-01)
- North Fork Stony Creek (7-01)
- South Fork Stony Creek (4-01)

Figure D3-1. West Fork Gallatin River Watershed Sediment Monitoring Sites.



D3.3 Streambank Erosion Sediment Load Calculations

Sediment loads for each eroding streambank assessed in the field were summed to provide a sediment load for each monitoring site.

D3.3.1 Monitoring Site Sediment Loads

An average annual sediment load of 397 tons/year was attributed to the 204 assessed eroding streambanks within the 30 monitoring sites (**Table D-5**). Approximately 30% of the streambank erosion sediment load at the monitoring sites was attributed to accelerated streambank erosion caused by historic or current human activities, while approximately 70% was attributed to natural erosional processes and sources. Monitoring site assessments indicate that transportation (8%), silviculture (10%), and "other" (12%) are the main types of anthropogenic activities in the West Fork Gallatin River watershed of the Upper Gallatin TPA. The "other" category primarily describes impacts due to resort area development, including downhill ski runs and golf courses, along with residential and commercial structures. Riparian grazing, cropland, mining and irrigation were not observed within the West Fork Gallatin River watershed.

Table D-5. Summary of Monitoring Site Sediment Loads.

Source	Sediment Load (Tons/Year)	Sediment Load (Percent)
Transportation	30	8
Riparian Grazing	0	0
Cropland	0	0
Mining	0	0
Silviculture	41	10
Irrigation	0	0
Natural Sources	278	70
Other	48	12
Total	**397**	**100**
Anthropogenic	**119**	**30**
Natural	**278**	**70**

Average annual 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 D-6** by stream segment, while sediment loads for each monitoring site are presented by source in **Table D-7**. Length of eroding bank, percent of eroding bank, and the estimated potential Rosgen stream type are also presented for each monitoring site in **Table D-6**.

Table D-6. Monitoring Site Estimated Average Annual Sediment Loads due to Streambank Erosion.

Stream Segment	ReachID	Reach Type	Estimated Potential Rosgen Stream Type	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)
Middle Fork West Fork Gallatin River	MFWF01-01	MR-10-1-U	E4b	14	250	3	0.1	0.3
	MFWF02-01-1	MR-4-1-U	E4b	26	400	3	0.2	0.4
	MFWF02-01-2	MR-4-1-U	E4a	75	500	8	0.5	1.0
	MFWF04-01	MR-4-1-C	B4	41	600	3	0.8	1.3
	MFWF07-02	MR-4-2-U	B3/4	212	500	21	2.2	4.4
	MFWF08-01	MR-2-2-U	B3	97	1000	5	1.9	1.9
	MFWF09-01	MR-2-3-U	C3b	526	1000	26	26.2	26.2
	MFWF09-02	MR-2-3-U	C4	473	1000	24	24.5	24.5
North Fork West Fork Gallatin River	NFWF10-01	MR-2-2-U	C4b	191	1000	10	3.8	3.8
	NFWF12-01	MR-4-2-U	B3	310	500	31	1.0	2.1
Muddy Creek	MUDD08-01/02	MR-2-2-U	B4	1086	2050	26	30.9	15.1
South Fork West Fork Gallatin River	SFWF17-02	MR-2-2-U	B4	145	800	9	1.1	1.4
	SFWF18-01	MR-0-3-U	C4	222	900	12	5.8	6.4
	SFWF22-01	MR-0-3-U	C4	413	1000	21	24.5	24.5
	SFWF28-01	MR-2-3-U	B3	432	2000	11	12.0	6.0
	SFWF29-02	MR-0-3-U	C3	785	2000	20	57.3	28.6
West Fork Gallatin River	WFGR01-02	MR-2-3-U	C3b	436	1000	22	16.2	16.2
	WFGR01-03	MR-2-3-U	F3/4, B3/4	301	1000	15	7.0	7.0
	WFGR01-04	MR-2-3-U	C3	58	1000	3	2.9	2.9
	WFGR01-05	MR-2-3-U	C4	543	1000	27	29.2	29.2
	WFGR02-01	MR-0-3-U	C3	364	1000	18	25.1	25.1
	WFGR02-02	MR-0-3-U	B3/4	212	500	21	2.3	4.7
	WFGR03-03	MR-0-4-U	B3c	421	2000	11	2.7	1.3
Beehive Creek	BEEH11-01	MR-4-1-U	B4	275	500	28	4.4	8.8
	BEEH12-01	MR-2-1-U	E4	698	1000	35	84.5	84.5
	BEEH13-01	MR-4-1-U	B3a	404	1000	20	23.3	23.3
First Yellow Mule Creek	FYMC16-01	MR-4-2-U	B3/4	100	500	10	2.8	5.6
Stony Creek	STON01-01	MR-4-2-U	B3/4	108	500	11	2.1	4.1
North Fork Stony Creek	NFST07-01	MR-4-1-C	A3/4	88	500	9	0.9	1.9
South Fork Stony Creek	SFSC04-01	MR-4-1-U	A3/4	66	500	7	1.1	2.2

Table D-7. Monitoring Site Estimated Average Annual Sediment Loads from Individual Sources due to Streambank Erosion.

Stream Segment	ReachID	Monitoring Site Length (Feet)	Sediment Load	Transportation Load (Tons/Year)	Silviculture Load (Tons/Year)	Natural Load (Tons/Year)	"Other" Load (Tons/Year)	Sediment Loading from Monitoring Site (Tons/Year)
Middle Fork West Fork Gallatin River	MFWF01-01	250	**Total**	0.0	0.01	0.1	0.01	0.1
			Percent	0	10	80	10	
	MFWF02-01-1	400	**Total**	0.0	0.0	0.2	0.0	0.2
			Percent	0	0	100	0	
	MFWF02-01-2	500	**Total**	0.0	0.0	0.5	0.0	0.5
			Percent	0	0	100	0	
	MFWF04-01	600	**Total**	0.0	0.0	0.8	0.0	0.8
			Percent	0	0	100	0	
	MFWF07-02	500	**Total**	0.0	1.8	0.4	0.0	2.2
			Percent	0	83	17	0	
	MFWF08-01	1000	**Total**	0.0	1.2	0.7	0.0	1.9
			Percent	0	62	38	0	
	MFWF09-01	1000	**Total**	0.0	13.0	2.7	10.4	26.2
			Percent	0	50	10	40	
	MFWF09-02	1000	**Total**	0.0	0.0	24.5	0.0	24.5
			Percent	0	0	100	0	
North Fork West Fork Gallatin River	NFWF10-01	1000	**Total**	0.0	0.0	2.6	1.2	3.8
			Percent	0	0	68	32	
	NFWF12-01	500	**Total**	0.0	0.01	1.0	0.0	1.0
			Percent	0	1	99	0	
Muddy Creek	MUDD08-01/02	2050	**Total**	21.1	4.8	5.0	0.0	30.9
			Percent	68	15	16	0	
South Fork West Fork Gallatin River	SFWF17-02	800	**Total**	0.0	0.0	1.1	0.0	1.1
			Percent	0	0	100	0	
	SFWF18-01	900	**Total**	0.0	3.9	1.9	0.0	5.8
			Percent	0	67	33	0	
	SFWF22-01	1000	**Total**	0.0	13.3	11.2	0.0	24.5
			Percent	0	54	46	0	
	SFWF28-01	2000	**Total**	0.0	1.5	10.5	0.0	12.0
			Percent	0	13	87	0	
	SFWF29-02	2000	**Total**	0.0	0.0	57.3	0.0	57.3
			Percent	0	0	100	0	
West Fork Gallatin River	WFGR01-02	1000	**Total**	1.3	0.0	10.7	4.2	16.2
			Percent	8	0	66	26	
	WFGR01-03	1000	**Total**	0.6	0.0	2.7	3.7	7.0
			Percent	9	0	38	53	
	WFGR01-04	1000	**Total**	0.0	0.0	0.4	2.5	2.9
			Percent	0	0	14	86	
	WFGR01-05	1000	**Total**	5.9	0.0	2.2	21.1	29.2
			Percent	20	0	8	72	
	WFGR02-01	1000	**Total**	0.0	0.0	20.3	4.8	25.1
			Percent	0	0	81	19	
	WFGR02-02	500	**Total**	0.0	0.0	2.3	0.0	2.3
			Percent	0	0	100	0	
	WFGR03-03	2000	**Total**	0.3	0.0	2.4	0.0	2.7
			Percent	10	0	90	0	
Beehive Creek	BEEH11-01	500	**Total**	0.0	0.0	4.4	0.0	4.4
			Percent	0	0	100	0	
	BEEH12-01	1000	**Total**	0.0	0.0	84.5	0.0	84.5
			Percent	0	0	100	0	
	BEEH13-01	1000	**Total**	0.0	0.0	22.8	0.5	23.3
			Percent	0	0	98	2	
First Yellow Mule Creek	FYMC16-01	500	**Total**	0.0	0.8	2.0	0.0	2.8
			Percent	0	28	72	0	
Stony Creek	STON01-01	500	**Total**	0.4	0.4	1.3	0.0	2.1
			Percent	17	20	63	0	
North Fork Stony Creek	NFST07-01	500	**Total**	0.0	0.0	0.9	0.0	0.9
			Percent	0	0	100	0	
South Fork Stony Creek	SFSC04-01	500	**Total**	0.0	0.0	1.1	0.0	1.1
			Percent	0	0	100	0	

D3.4 Streambank Erosion Sediment Load Extrapolation

Sediment loads derived from the monitoring sites were extrapolated to the stream reach, stream segment and watershed scales based on the Aerial Assessment reach type analysis. The annual sediment load of all assessed monitoring sites of the same reach type was averaged to derive a reach type sediment load. The reach type sediment load was then extrapolated to all un-assessed reaches within the same reach type. This resulted in a sediment load for the entire stream segment, which, when combined with sediment loads from tributary streams, was used to derive a sediment load for each streams watershed.

D3.4.1 Reach Type Sediment Loads

Monitoring site sediment loads were averaged within a specific reach type to derive a reach type sediment load. The following sections present individual discussions for each reach type. Discussions are broken up between reach types with valley slopes <4%, which are generally the focus of this assessment methodology, and reach types with valley slopes >4%, which comprise the majority of the West Fork Gallatin River watershed. A summary of reach type sediment loads is presented in **Table D-8**.

Table D-8. Reach Type Sediment Loads.

Reach Type	Description	Average Streambank Erosion Sediment Load per 1000 Feet (Tons/Year)
MR-10-1-U	very steep 1st order streams	0.3
MR-4-1-C	steep 1st order streams, confined	1.6
MR-4-1-U	steep 1st order streams, unconfined	3.1
MR-4-2-U	steep 2nd order streams	4.1
MR-2-2-U	moderate gradient 2nd order streams	5.6
MR-2-3-U	moderate gradient 3rd order streams	16.0
MR-0-3-U	low gradient 3rd order streams	17.9
MR-0-4-U	low gradient 4th order streams	1.3

D3.4.1.1 Valley Gradient <4%

MR-0-3-U - Low gradient and unconfined 3rd order streams
A total of five reaches were assessed in this reach type out of a total of twelve reaches delineated in the Aerial Assessment. Three monitoring sites were on the South Fork West Fork Gallatin River (SFWF18-1, 22-1 and 29-2) and two monitoring sites were on the West Fork Gallatin River (WFGR02-01 and 02-02). Annual sediment loads ranged from 4.7 to 28.6 tons/1000 feet and averaged 17.9 tons/1000 feet. Out of the seven un-assessed reaches, six were on the South Fork West Fork Gallatin River and one was on the West Fork Gallatin River. The reach type average sediment load was applied to all un-assessed reaches on the South Fork West Fork Gallatin River within this reach type. For the West Fork Gallatin River, an annual sediment load of 4.7 tons/1000 feet measured in WFGR02-02 was applied directly to WFGR02-03 based on the similarity of their conditions as observed in the field.

MR-0-4-U - Low gradient and unconfined 4th order streams

The lowermost portion of the West Fork Gallatin River downstream of the confluence with the South Fork West Fork Gallatin River is the only stream that falls within this reach type category and included four reaches in the aerial assessment, one of which (WFGR03-03) was assessed in the field. Within this reach, an annual sediment load of 1.3 tons/1000 feet was identified. The low sediment load at the assessed monitoring site is primarily due to the large cobble substrate that dominates this portion of river and naturally armors the streambed and streambanks. This load was extrapolated directly to the other three reaches within this reach type.

MR-2-1-U – Moderate gradient and unconfined 1st order streams

There were only two reaches within this reach type and one was assessed in the field. At the BEEH12-01 monitoring site on Beehive Creek, extensive bank erosion was occurring in what appeared to have once been a beaver dominated meadow or former mountain lake. A perched culvert downstream of this reach appears to be at least partially responsible for the accelerated bank erosion. An annual sediment load of 84.5 tons/year was identified from this reach. This sediment load was not applied to the other reach (SFWF15-01) within this type. Instead, the sediment load for SFWF15-01 was based on the assessed value at SFWF17-02 (1.4 tons/1000 feet), which has similar reach type characteristics.

MR-2-2-U – Moderate gradient and unconfined 2nd order streams

A total of six reaches were identified within this reach type during the Aerial Assessment and five reaches were assessed in the field. However, only four reach specific sediment loads were derived for this reach type since reaches MUDD08-01 and MUDD08-02 were assessed in the field as one continuous monitoring site. Field monitoring sites were located on Muddy Creek, Middle Fork West Fork Gallatin River, North Fork West Fork Gallatin River and South Fork West Fork Gallatin River. Sediment loads ranged from 1.4 to 15.1 tons/1000 feet, with an average annual streambank sediment load of 5.6 tons/1000 feet. The mean sediment load was not extrapolated to the only un-assessed reach (SFWF17-01) within this reach type. Instead, the measured sediment load at SFWF17-02 (1.4 tons/1000 feet) was applied directly to SFWF17-01 based on the similarity in their conditions.

MR-2-3-C – Moderate gradient and confined 3rd order streams

There were only two reaches within this reach type and neither was assessed on the ground. Both reaches were located on the South Fork West Fork Gallatin River (SFWF20-01 and 27-01). The reach average annual streambank sediment load (16.0 tons/1000 feet) for the MR-2-3-U reach type was applied to these two reaches, with the only difference being the amount of confinement.

MR-2-3-U – Moderate gradient and unconfined 3rd order streams

A total of nine reaches were identified during the initial Aerial Assessment, but MFWF09 was split into two sub-reaches following site reconnaissance, so there are a total of ten reaches within this reach type. Stream reaches assessed in the field include sites on the Middle Fork West Fork Gallatin River, South Fork West Gallatin River and West Fork Gallatin River. A total of 7 reaches were assessed at field monitoring sites and the annual sediment load ranged from 2.9 to 26.2 tons/1000 feet, with a reach type average of 16.0 tons/1000 feet. The reach type annual average streambank sediment load was extrapolated directly to un-assessed reaches SFWF25-01 and WFGR01-01. For un-assessed reach SFWF28-02, the sediment load for SFWF28-01 (6.0 tons/year) was extrapolated directly based on the similarity in their conditions.

D3.4.1.2 Valley Gradient >4%

In the West Fork Gallatin River watershed, the vast majority of stream length is comprised of smaller and steeper streams. A total of 121 out of the 157 reaches included in the Aerial Assessment had a stream gradient of >4%, with seven distinct reach types. Out of these seven reach types, four reach types were assessed at twelve monitoring sites in the field. Sediment loads from streambank erosion within these reach types were relatively low. Since these reach types comprise the majority of the watershed and many of the reaches were not observed on the ground, streambank erosion rates were extrapolated to un-assessed reaches based on several factors, including:

1. Average reach type sediment load
2. On-the-ground knowledge
3. Observations from the 2005 color aerial imagery
4. Annual average streambank sediment loading on the same stream or in a similar landscape setting

In addition, the annual average streambank sediment load from “slowly eroding/vegetated/undercut” streambanks was evaluated for the entire dataset to estimate a background rate of erosion for streams in the West Fork Gallatin River watershed. In general, it is expected that the “slowly eroding” streambanks observed along a monitoring site are due to natural sources and are likely found along all streams, including ones in which no anthropogenic disturbance has occurred. The annual average sediment load from “slowly eroding” streambanks was reviewed for all monitoring sites and resulted in a sediment load of 1.1 tons/1000 feet of stream (5.6 tons/mile of stream). This was applied to several of the reaches with slopes >4% when other loads appeared to be either too high or too low.

MR-4-1-C – High gradient and confined 1st order streams

A total of ten reaches were delineated in the Aerial Assessment and two were assessed in the field. At MFWF04-01 on the Middle Fork West Fork Gallatin River, an average annual sediment load of 1.3 tons/1000 feet was estimated, while at NFST07-01 on “Stony” Creek, an average annual sediment load of 1.9 tons/1000 feet was estimated, for a reach type average of 1.6 tons/1000 feet. This value was applied to all un-assessed reaches within this reach type and included the following streams: “North Fork Stony” Creek and South Fork West Fork Gallatin River, along with First, Second and Third Yellow Mule creeks.

MR-4-1-U – High gradient and unconfined 1st order streams

Thirty-nine reaches were delineated in the Aerial Assessment and five were assessed in the field within this reach type, including monitoring sites on Middle Fork West Fork Gallatin River, Beehive Creek and “South Fork Stony” Creek. On the Middle Fork West Fork Gallatin River, two monitoring sites were assessed within reach MFWF02-01. For MFWF02-1, these two values were averaged to derive a reach load of 0.7 tons/1000 feet. At the five monitoring sites within this reach type, annual streambank sediment loads ranged from 0.4 to 23.3 tons/1000 feet. However, a sediment load of 23.3 tons/1000 feet, which was recorded at BEEH13-01 was thought to be an outlier for this reach type and was removed from the dataset. Large eroding hillslopes along this reach on Beehive Creek are infrequent within the watershed. Thus, the data from four monitoring was used to develop a reach type average annual streambank sediment load of 3.1 tons/1000 feet, with a range of 0.4 to 8.8 tons/1000 feet. The reach type average was extrapolated to many of the un-assessed reaches, particularly to reaches lower in a particular stream's watershed. The "slowly eroding" streambank annual sediment load of 1.1 tons/1000 feet was applied to seven sites, generally in the upper watershed of a particular stream segment, while an annual sediment load of 0.3 tons/1000 feet, which was measured in a 1st order stream with a slope >10%, was applied to several of the most headwater reaches, particularly when a review of aerial imagery indicated a sub-alpine landscape and/or surrounding reaches had slopes >10%.

MR-4-2-C – High gradient and confined 2nd order streams

There were only two reaches within this reach type and no assessments were performed. The average sediment load for the MR-4-2-U reach type (4.1 tons/year) was extrapolated to MUDD06-01 and NFWF07-01.

MR-4-2-U – High gradient and unconfined 2nd order streams

Eighteen reaches were delineated in the Aerial Assessment for this reach type and four were assessed in the field, including monitoring sites on Middle Fork West Fork Gallatin River, North Fork West Fork Gallatin River, First Yellow Mule Creek and "Stony" Creek. Annual sediment loads ranged from 2.1 to 5.6 tons/1000 feet, with an average annual streambank sediment load of 4.1 tons/1000 feet, which is similar to their 1st order counterparts (3.1 tons/1000 feet). Un-assessed reaches were all applied this sediment load, except for MUDD07-01, which was applied the same sediment load as measured in MUDD08-01/02. In addition, five reaches on the North Fork West Fork Gallatin River were assigned the load measured at NFWF12-01, while MOOS01-01 was assigned a load of 0 tons/1000 feet since it appears to be in a culvert under Huntley Lodge.

MR-4-3-C – High gradient and confined 3rd order streams

There were two reaches within this reach type, neither of which was assessed in the field. An average annual streambank sediment load of 6.1 tons/1000 feet was applied to SFWF19-01 based on the estimated value at the SFWF18-01 monitoring site. An annual sediment load of 17.9 tons/1000 feet was applied to SFWF24-01 based on the reach type average for MR-0-3-U.

MR-10-1-C – Very high gradient and confined 1st order streams

There are twelve reaches within this reach type, none of which were assessed in the field. All but two reaches were assigned a value of 0.3 tons/1000 feet based on a measurement in MFWF01-01, which was unconfined. Reaches SFWF10-01 and TYMC08-01 were assigned a value of 3.1 tons/1000 feet based on the reach type average for MR-4-1-U.

MR-10-1-U – Very high gradient and unconfined 1st order streams

There are thirty six reaches within this reach type, one of which was assessed in the field with an annual streambank sediment load of 0.3 tons/1000 feet at MFWF01-01. This value was extrapolated to all reaches, except SFWF11-01, MUDD04-01, and BEEH10-01, 14-01, and 16-01, which were assigned the "slowly eroding" streambank sediment load (1.1 tons/1000 feet).

MR-10-2-U – Very high gradient and confined 2nd order streams
Two reaches were delineated within this reach type, neither of which was assessed in the field. The annual streambank sediment load for FYMC15-01 was based on the estimated results for FYMC16-01. The annual streambank sediment load for MFWF06-01 was based on the estimated results for MFWF07-02.

D3.4.2 Stream Segment Sediment Loads

Stream segment streambank sediment loads were estimated based on the cumulative sediment load of the stream reaches within each stream segment (**Attachment A**). These sediment loads were estimated for a total of 60.7 miles. An average annual sediment load of 1,778 tons/year was attributed to eroding streambanks at the stream segment scale (**Table D-9**). Approximately 33% of the sediment load due to streambank erosion at the stream segment scale was attributed to anthropogenic sources, while approximately 67% was attributed to natural sources. This assessment indicates that transportation (9%), silviculture (13%) and “other” (11%) are the greatest anthropogenic contributors of sediment loads due to streambank erosion in the Upper Gallatin TPA. The “other” category primarily describes impacts due to resort area development, including downhill ski runs and golf courses, along with residential and commercial structures. Sediment loads due to streambank erosion for each stream segment are provided for each source in **Table D-10**.

Table D-9. Summary of Stream Segment Sediment Loads.

Source	Sediment Load (Tons/Year)	Sediment Load (Percent)
Transportation	161	9
Silviculture	224	13
Natural Sources	1,190	67
Other	203	11
Total	**1,778**	**100**
Anthropogenic	**588**	**33**
Natural	**1,190**	**67**

Table D-10. Stream Segment Sediment Loads from Individual Sources due to Streambank Erosion.

Stream Segment	Stream Length (Miles)	Sediment Load	Transportation Load (Tons/Year)	Silviculture Load (Tons/Year)	Natural Load (Tons/Year)	"Other" Load (Tons/Year)	Total Load (Tons/Year)	Total Load per Mile (Tons/Year)	Total Load per 1000 Feet (Tons/Year)
Beehive Creek	4.78	**Tons/Year**	31.9	0.0	232.5	2.1	**266.5**	**55.8**	**10.6**
		Percent	12%	0%	87%	1%			
First Yellow Mule Creek	4.95	**Tons/Year**	2.2	4.2	49.1	0.0	**55.5**	**11.2**	**2.1**
		Percent	4%	8%	88%	0%			
Middle Fork West Fork Gallatin River	5.82	**Tons/Year**	3.8	58.4	92.5	34.9	**189.5**	**32.6**	**6.2**
		Percent	2%	31%	49%	18%			
Moose Tracks Creek	0.41	**Tons/Year**	2.3	0.0	0.6	2.9	**5.7**	**14.0**	**2.7**
		Percent	40%	0%	10%	50%			
Muddy Creek	5.22	**Tons/Year**	25.0	24.2	69.2	2.3	**120.7**	**23.1**	**4.4**
		Percent	21%	20%	57%	2%			
North Fork Moose Tracks Creek	1.62	**Tons/Year**	0.4	0.0	1.3	1.2	**2.8**	**1.7**	**0.3**
		Percent	14%	0%	45%	41%			
North Fork Stony Creek	2.38	**Tons/Year**	0.3	0.0	7.8	0.7	**8.8**	**3.7**	**0.7**
		Percent	3%	0%	89%	8%			
North Fork West Fork Gallatin River	7.37	**Tons/Year**	0.5	0.3	62.9	3.2	**66.9**	**9.1**	**1.7**
		Percent	1%	0%	94%	5%			
South Fork Moose Tracks Creek	1.14	**Tons/Year**	1.0	0.0	3.5	0.0	**4.5**	**3.9**	**0.7**
		Percent	22%	0%	78%	0%			
South Fork Stony Creek	1.70	**Tons/Year**	1.9	0.0	5.4	0.0	**7.3**	**4.3**	**0.8**
		Percent	26%	0%	74%	0%			
South Fork West Fork Gallatin River	13.78	**Tons/Year**	62.3	126.1	545.0	64.5	**798.0**	**57.9**	**11.0**
		Percent	8%	16%	68%	8%			
Stony Creek	0.20	**Tons/Year**	0.7	0.9	2.7	0.0	**4.3**	**21.7**	**4.1**
		Percent	17%	20%	63%	0%			
Second Yellow Mule Creek	3.82	**Tons/Year**	4.3	4.5	9.2	0.1	**18.1**	**4.7**	**0.9**
		Percent	24%	25%	51%	1%			
Third Yellow Mule Creek	3.88	**Tons/Year**	0.5	5.8	20.8	0.0	**27.1**	**7.0**	**1.3**
		Percent	2%	22%	77%	0%			
West Fork Gallatin River	3.61	**Tons/Year**	24.1	0.0	87.5	90.9	**202.5**	**56.1**	**10.6**
		Percent	12%	0%	43%	45%			

D3.4.3 Watershed Sediment Loads

Watershed average annual streambank sediment loads were estimated for the Upper Gallatin TPA based on the total length of stream within the watershed. These watershed sediment loads were estimated from the sum of the average annual streambank sediment loads at the stream segment scale combined with an estimate of streambank sediment loads from un-assessed streams. Assessed streams include 60.7 miles of stream segments described in the Aerial Assessment Database, while un-assessed streams include 27.4 miles of 1st order headwater tributaries. For the purposes of estimating an annual average watershed streambank sediment load, streambank erosion sediment inputs from un-assessed streams was assumed to be 0.3 tons/year for 1000 feet of stream (1.6 tons/year for a mile of stream) based on estimates from the headwater monitoring site in the West Fork Gallatin River watershed (MFWF01-01). Un-assessed streams were reviewed in GIS and assigned sources. This assessment results in an estimated average annual sediment load due to streambank erosion in the West Fork Gallatin River watershed of 1,821 tons/year (**Table D-11**). Note that actual stream length in the West Fork Gallatin River watershed likely exceeds the 88.1 miles measured from the 1:100,000 NHD stream layer.

Table D-11. Summary of Sediment Loads due to Streambank Erosion at the Watershed Scale.

Stream Length (Miles)	Length of Stream included in Aerial Assessment Database (Miles)	Length of Stream Un-assessed (Miles)	Estimated Sediment Load for Streams included in Aerial Assessment Database (Tons/Year)	Sediment Load applied to Un-assessed 1st Order Streams (1.6 Tons/Mile/Year)	Total Existing Sediment Load (Tons/Year)
88.1	60.7	27.4	1,778	43	1,821

Sediment loads due to streambank erosion for each stream segment are provided for each source in **Table D-12**.

Table D-12. Watershed Sediment Loads from Individual Sources due to Streambank Erosion.

Watershed	Stream Segment	Stream Length (Miles)	Sediment Load	Transportation Load (Tons/Year)	Silviculture Load (Tons/Year)	Natural Load (Tons/Year)	"Other" Load (Tons/Year)	Total Load (Tons/Year)
Middle Fork West Fork Gallatin River	Middle Fork West Fork Gallatin River	5.82	**Tons/Year**	3.8	58.4	92.5	34.9	**189.5**
			Percent	2%	31%	49%	18%	
	Moose Tracks Creek	0.41	**Tons/Year**	2.3	0.0	0.6	2.9	**5.7**
			Percent	40%	0%	10%	50%	
	North Fork Moose Tracks Creek	1.62	**Tons/Year**	0.4	0.0	1.3	1.2	**2.8**
			Percent	14%	0%	45%	41%	
	South Fork Moose Tracks Creek	1.14	**Tons/Year**	1.0	0.0	3.5	0.0	**4.5**
			Percent	22%	0%	78%	0%	
	Beehive Creek	4.78	**Tons/Year**	31.9	0.0	232.5	2.1	**266.5**
			Percent	12%	0%	87%	1%	
	Stony Creek	0.20	**Tons/Year**	0.7	0.9	2.7	0.0	**4.3**
			Percent	17%	20%	63%	0%	
	North Fork Stony Creek	2.38	**Tons/Year**	0.3	0.0	7.8	0.7	**8.8**
			Percent	3%	0%	89%	8%	
	South Fork Stony Creek	1.70	**Tons/Year**	1.9	0.0	5.4	0.0	**7.3**
			Percent	26%	0%	74%	0%	
	MF1	2.81	**Tons/Year**	0.9	0.9	2.7	0.0	**4.4**
			Percent	20%	20%	60%	0%	
North Fork West Fork Gallatin River	North Fork West Fork Gallatin River	7.37	**Tons/Year**	0.5	0.3	62.9	3.2	**66.9**
			Percent	1%	0%	94%	5%	
	NF1	1.27	**Tons/Year**	0.0	0.0	2.0	0.0	**2.0**
			Percent	0%	0%	100%	0%	
	NF2	1.66	**Tons/Year**	0.0	0.0	2.6	0.0	**2.6**
			Percent	0%	0%	100%	0%	
South Fork West Fork Gallatin River	South Fork West Fork Gallatin River	13.78	**Tons/Year**	62.3	126.1	545.0	64.5	**798.0**
			Percent	8%	16%	68%	8%	
	SF1	1.56	**Tons/Year**	0.0	0.0	2.5	0.0	**2.5**
			Percent	0%	0%	100%	0%	
	SF2	1.70	**Tons/Year**	0.3	0.0	2.4	0.0	**2.7**
			Percent	10%	0%	90%	0%	
	SF3	1.37	**Tons/Year**	0.4	0.0	1.3	0.4	**2.2**
			Percent	20%	0%	60%	20%	
	SF4	1.87	**Tons/Year**	0.3	2.1	0.6	0.0	**3.0**
			Percent	10%	70%	20%	0%	
	SF5	3.19	**Tons/Year**	0.5	3.5	1.0	0.0	**5.0**
			Percent	10%	70%	20%	0%	
	Muddy Creek	5.22	**Tons/Year**	25.0	24.2	69.2	2.3	**120.7**
			Percent	21%	20%	57%	2%	
	M1	2.31	**Tons/Year**	0.0	0.0	3.6	0.0	**3.6**
			Percent	0%	0%	100%	0%	
	M2	1.36	**Tons/Year**	0.0	0.0	2.1	0.0	**2.1**
			Percent	0%	0%	100%	0%	
	First Yellow Mule Creek	4.95	**Tons/Year**	2.2	4.2	49.1	0.0	**55.5**
			Percent	4%	8%	88%	0%	
	1YM1	2.46	**Tons/Year**	0.4	1.6	1.9	0.0	**3.9**
			Percent	10%	40%	50%	0%	
	1YM2	1.61	**Tons/Year**	0.3	1.0	1.3	0.0	**2.5**
			Percent	10%	40%	50%	0%	
	Second Yellow Mule Creek	3.82	**Tons/Year**	4.3	4.5	9.2	0.1	**18.1**
			Percent	24%	25%	51%	1%	
	2YM1	1.28	**Tons/Year**	0.2	1.4	0.4	0.0	**2.0**
			Percent	10%	70%	20%	0%	
	Third Yellow Mule Creek	3.88	**Tons/Year**	0.5	5.8	20.8	0.0	**27.1**
			Percent	2%	22%	77%	0%	
West Fork Gallatin River*	West Fork Gallatin River	3.61	**Tons/Year**	24.1	0.0	87.5	90.9	**202.5**
			Percent	12%	0%	43%	45%	
	Crail Creek	2.92	**Tons/Year**	0.5	0.0	3.2	0.9	**4.6**
			Percent	10%	0%	70%	20%	

*Remaining portion of watershed excluding South Fork West Fork, Middle Fork West Fork and North Fork West Fork.

D3.5 Streambank Erosion Sediment Load Reductions

The potential for streambank erosion sediment load reductions was evaluated in order to provide technical guidance in determining sediment allocations for human activities that cause accelerated streambank erosion. Determining a potential overall load reduction from streambank erosion will also help define how much sediment production from streambank erosion is likely derived from natural conditions. The results are only one of a number of components that will be considered during the TMDL sediment allocation process. The allocation process will also consider economic feasibility of restoration from each significant source and regional BMP effectiveness studies.

To estimate a potential decrease in sediment loading due to improved streambank stability, BEHI values in the existing dataset for each streambank within a monitoring site with an identified anthropogenic source that exceeded the “moderate” category were reduced to “moderate”. The results of this model are presented in **Table D-13** for the individual monitoring sites and in **Table D-14** for each reach type. No potential reduction was identified for the reach types of 1st order streams, which is likely due to the small size of these streams and the generally large substrate. For 2nd order streams, moderate gradient reach types tended to have a greater potential for reduction than steeper reach types. For 3rd order streams, moderate gradient reach types tended to have a greater potential for streambank sediment load reductions than low gradient reach types. This appears to be due to the different levels of anthropogenic disturbance between the lesser developed South Fork West Fork Gallatin River, on which three out of the five monitoring sites in the MR-0-3-U reach type were located, and the West Fork Gallatin River, around which extensive development has occurred and along which four out of the seven monitoring sites in the MR-2-3-U reach type were located. The only 4th order stream assessed in the West Fork Gallatin River watershed was the West Fork Gallatin River downstream of the confluence with the South Fork West Fork Gallatin River. This section of stream had zero potential for streambank erosion load reductions since the banks are naturally armored with large cobbles.

Reductions calculated at the monitoring site scale were extrapolated to the stream segment scale and the watershed scale using the Aerial Assessment Database (**Attachment A**). This assessment indicates that anthropogenically induced streambank sediment loads at the stream segment scale could be reduced by 40% along the Middle Fork West Fork Gallatin River, 20% along the South Fork West Fork Gallatin River and 47% along the West Fork Gallatin River through the application of BMPs. Through BMPs, the actual length and height of eroding bank could also be reduced, which would lead to further reductions in sediment loading.

Table D-13. Monitoring Site Sediment Loads with BEHI Reduced to "Moderate".

Reach Type	Reach ID	Field Assessed Sediment Load per 1000 Feet (Tons/Year)	Number of Banks with "High" BEHI Rating	Anthropogenic Sources Identified Along Reach	Sediment Load per 1000 Feet with "High" BEHI Ratings Reduced to "Moderate" (Tons/Year)*
MR-0-3-U	SFWF 18-01	6.4	1	yes	2.6
MR-0-3-U	SFWF 22-01	24.5	1	yes	22.0
MR-0-3-U	SFWF 29-02	28.6	5	no	28.6
MR-0-3-U	WFGR 02-01	25.1	3	yes	12.1
MR-0-3-U	WFGR 02-02	4.7	0	no	4.7
MR-0-4-U	WFGR 03-03	1.3	0	yes	1.3
MR-2-1-U	BEEH 12-01	84.5	13	yes	29.4
MR-2-2-U	MFWF 08-01	1.9	0	yes	1.9
MR-2-2-U	MUDD 08-01/02	15.1	2	yes	9.0
MR-2-2-U	NFWF 10-01	3.8	0	yes	3.8
MR-2-2-U	SFWF 17-02	1.4	0	no	1.4
MR-2-3-U	MFWF 09-01	26.2	2	yes	12.1
MR-2-3-U	MFWF 09-02	24.5	1	no	24.5
MR-2-3-U	SFWF 28-01	6.0	1	yes	3.4
MR-2-3-U	WFGR 01-02	16.2	2	yes	6.3
MR-2-3-U	WFGR 01-03	7.0	1	yes	5.8
MR-2-3-U	WFGR 01-04	2.9	2	yes	1.1
MR-2-3-U	WFGR 01-05	29.2	2	yes	13.0
MR-4-1-C	MFWF 04-01	1.3	0	no	1.3
MR-4-1-C	NFST 07-01	1.9	0	no	1.9
MR-4-1-U	BEEH 11-01	8.8	4	no	8.8
MR-4-1-U	BEEH 13-01	23.3	4	yes	9.1
MR-4-1-U	MFWF 02-01	0.4	0	yes	0.4
MR-4-1-U	MFWF 02-01	1.0	0	yes	1.0
MR-4-1-U	SFSC 04-01	2.2	0	yes	2.2
MR-4-2-U	FYMC 16-01	5.6	2	yes	3.8
MR-4-2-U	MFWF 07-02	4.4	0	yes	4.4
MR-4-2-U	NFWF 12-01	2.1	0	yes	2.1
MR-4-2-U	STON 01-01	4.1	1	yes	2.9
MR-10-1-U	MFWF 01-01	0.3	0	yes	0.3

*If no "high" BEHI banks, then no reduction.

*If no anthopogenic sources within assessed reach, then no reduction.

Table D-14. Reach Type Sediment Load Reductions.

Reach Type	Description	Average Streambank Erosion Sediment Load per 1000 Feet (Tons/Year)	BEHI Reduced to Moderate (Tons/Year)	Potential Reduction (Tons/Year)	Percent Reduction	Sample Size
MR-10-1-U	very steep 1st order streams	0.3	0.3	0.0	0.0	1
MR-4-1-C	steep 1st order streams, confined	1.6	1.6	0.0	0.0	2
MR-4-1-U	steep 1st order streams, unconfined	3.1	3.1	0.0	0.0	5
MR-4-2-U	steep 2nd order streams	4.1	3.3	0.8	19.5	4
MR-2-2-U	moderate gradient 2nd order streams	5.6	4.0	1.6	28.6	4
MR-2-3-U	moderate gradient 3rd order streams	16.0	9.5	6.5	40.6	7
MR-0-3-U	low gradient 3rd order streams	17.9	14.0	3.9	21.8	5
MR-0-4-U	low gradient 4th order streams	1.3	1.3	0.0	0.0	1

Table D-15. Potential Reduction in Anthropogenic Sediment Load from Stream Segments with BEHI Reduced to "Moderate".

Stream Segment	Existing Sediment Load (Tons/Year)	Existing Load due to Anthropogenic Sources (Tons/Year)	Reduced Load with "Moderate" BEHI for Anthropogenically Induced Streambank Erosion (Tons/Year)	Reduced Load due to Anthropogenic Sources (Tons/Year)	Potential Reduction in Anthropogenic Sediment Load (Existing-Reduced) (Tons/Year)	Percent Reduction in Anthropogenic Sediment Load (Existing/Potential Reduction)
Beehive Creek	266.5	34.0	247.4	14.9	19.1	56%
First Yellow Mule Creek	55.5	6.4	54.2	5.1	1.3	20%
Middle Fork West Fork Gallatin River	189.5	97.0	150.8	58.3	38.7	40%
Moose Tracks Creek	5.7	5.2	4.6	4.2	1.0	19%
Muddy Creek	120.7	51.5	101.9	32.7	18.8	37%
North Fork Moose Tracks Creek	2.8	1.5	2.8	1.5	0.0	0%
North Fork Stony Creek	8.8	1.0	8.8	1.0	0.0	0%
North Fork West Fork Gallatin River	66.9	4.0	66.9	4.0	0.0	0%
South Fork Moose Tracks Creek	4.5	1.0	4.5	1.0	0.0	0%
South Fork Stony Creek	7.3	1.9	7.3	1.9	0.0	0%
South Fork West Fork Gallatin River	798.0	252.9	746.5	201.5	51.4	20%
Stony Creek	4.3	1.6	3.8	1.1	0.5	31%
Second Yellow Mule Creek	18.1	8.9	18.1	8.9	0.0	0%
Third Yellow Mule Creek	27.1	6.3	27.1	6.3	0.0	0%
West Fork Gallatin River	202.5	115.0	147.9	60.4	54.6	47%

Table D-16. Watershed Sediment Load Reductions from Individual Sources.

Watershed	Stream Segment	Stream Length (Miles)	Sediment Load	Transportation Load (Tons/Year)	Silviculture Load (Tons/Year)	Natural Load (Tons/Year)	"Other" Load (Tons/Year)	Total Load (Tons/Year)
Middle Fork West Fork Gallatin River	Middle Fork West Fork Gallatin River	5.82	**Tons/Year**	3.6	36.9	92.5	17.8	**150.8**
			Percent	2%	24%	61%	12%	
	Moose Tracks Creek	0.41	**Tons/Year**	1.8	0.0	0.6	2.3	**4.6**
			Percent	40%	0%	13%	50%	
	North Fork Moose Tracks Creek	1.62	**Tons/Year**	0.4	0.0	1.3	1.2	**2.8**
			Percent	14%	0%	45%	41%	
	South Fork Moose Tracks Creek	1.14	**Tons/Year**	1.0	0.0	3.5	0.0	**4.5**
			Percent	22%	0%	78%	0%	
	Beehive Creek	4.78	**Tons/Year**	14.0	0.0	232.5	0.9	**247.4**
			Percent	6%	0%	94%	0%	
	Stony Creek	0.20	**Tons/Year**	0.5	0.6	2.7	0.0	**3.8**
			Percent	14%	16%	70%	0%	
	North Fork Stony Creek	2.38	**Tons/Year**	0.3	0.0	7.8	0.7	**8.8**
			Percent	3%	0%	89%	8%	
	South Fork Stony Creek	1.70	**Tons/Year**	1.9	0.0	5.4	0.0	**7.3**
			Percent	26%	0%	74%	0%	
	MF1	2.81	**Tons/Year**	0.9	0.9	2.7	0.0	**4.4**
			Percent	20%	20%	60%	0%	
North Fork West Fork Gallatin River	North Fork West Fork Gallatin River	7.37	**Tons/Year**	0.5	0.3	62.9	3.2	**66.9**
			Percent	1%	0%	94%	5%	
	NF1	1.27	**Tons/Year**	0.0	0.0	2.0	0.0	**2.0**
			Percent	0%	0%	100%	0%	
	NF2	1.66	**Tons/Year**	0.0	0.0	2.6	0.0	**2.6**
			Percent	0%	0%	100%	0%	
South Fork West Fork Gallatin River	South Fork West Fork Gallatin River	13.78	**Tons/Year**	48.1	104.9	545.0	48.5	**746.5**
			Percent	6%	14%	73%	6%	
	SF1	1.56	**Tons/Year**	0.0	0.0	2.5	0.0	**2.5**
			Percent	0%	0%	100%	0%	
	SF2	1.70	**Tons/Year**	0.3	0.0	2.4	0.0	**2.7**
			Percent	10%	0%	90%	0%	
	SF3	1.37	**Tons/Year**	0.4	0.0	1.3	0.4	**2.2**
			Percent	20%	0%	60%	20%	
	SF4	1.87	**Tons/Year**	0.3	2.1	0.6	0.0	**3.0**
			Percent	10%	70%	20%	0%	
	SF5	3.19	**Tons/Year**	0.5	3.5	1.0	0.0	**5.0**
			Percent	10%	70%	20%	0%	
	Muddy Creek	5.22	**Tons/Year**	14.9	16.0	69.2	1.8	**101.9**
			Percent	15%	16%	68%	2%	
	M1	2.31	**Tons/Year**	0.0	0.0	3.6	0.0	**3.6**
			Percent	0%	0%	100%	0%	
	M2	1.36	**Tons/Year**	0.0	0.0	2.1	0.0	**2.1**
			Percent	0%	0%	100%	0%	
	First Yellow Mule Creek	4.95	**Tons/Year**	2.2	2.8	49.1	0.0	**54.2**
			Percent	4%	5%	91%	0%	
	1YM1	2.46	**Tons/Year**	0.4	1.6	1.9	0.0	**3.9**
			Percent	10%	40%	50%	0%	
	1YM2	1.61	**Tons/Year**	0.3	1.0	1.3	0.0	**2.5**
			Percent	10%	40%	50%	0%	
	Second Yellow Mule Creek	3.82	**Tons/Year**	4.3	4.5	9.2	0.1	**18.1**
			Percent	24%	25%	51%	1%	
	2YM1	1.28	**Tons/Year**	0.2	1.4	0.4	0.0	**2.0**
			Percent	10%	70%	20%	0%	
	Third Yellow Mule Creek	3.88	**Tons/Year**	0.5	5.8	20.8	0.0	**27.1**
			Percent	2%	22%	77%	0%	
West Fork Gallatin River*	West Fork Gallatin River	3.61	**Tons/Year**	13.5	0.0	87.5	46.9	**147.9**
			Percent	9%	0%	59%	32%	
	Crail Creek	2.92	**Tons/Year**	0.5	0.0	3.2	0.9	**4.6**
			Percent	10%	0%	70%	20%	

*Remaining portion of watershed excluding South Fork West Fork, Middle Fork West Fork and North Fork West Fork.

D4.0 DISCUSSION AND CONCLUSIONS

The results of this assessment indicate that historic timber harvest activities, the road network, and resort area development have increased streambank erosion sediment loads in the West Fork Gallatin River watershed. It is estimated that an annual average of 1,821 tons of streambank sediment are delivered to streams in the West Fork Gallatin River watershed and that 33% (604 tons) of this streambank sediment load is due to anthropogenic disturbances (**Table D-17**). Through the implementation of BMPs, it is estimated that the total sediment load from anthropogenically accelerated streambank erosion in the West Fork Gallatin River watershed can be reduced by 31% (186 tons/year), which is a 10% reduction in the overall sediment load associated with bank erosion.

Table D-17. Watershed Sediment Load Reduction Summary.

Watershed	Existing Sediment Load (Tons/Yr)	Existing Load due to Anthropogenic Sources (Tons/Yr)	Desired Reduced Load (Tons/Yr)	Potential Reduction in Anthropogenic Sediment Load (Existing-Reduced) (Tons/Yr)	Percent Reduction in Anthropogenic Sediment Load (Existing/Potential Reduction)	Percent Reduction Overall
Middle Fork	**494**	145	**435**	59	41%	**12%**
South Fork	**1049**	338	**977**	72	21%	**7%**
North Fork	**72**	4	**72**	0	0%	**0%**
West Fork	**207**	116	**153**	55	47%	**26%**
West Fork Total	**1821**	604	**1636**	186	31%	**10%**

D4.1 Streambank Erosion Results by Particle Size Class

During the Upper Gallatin sediment and habitat assessment in 2008, a total of 204 eroding streambanks were examined and streambank composition was recorded as a percentage for the following particle size classes: coarse gravel (>6mm), fine gravel (<6mm and >2mm) and sand/silt (<2mm). One streambank in BEEH12-01 lacked composition data and was excluded from the dataset, resulting in a total of 203 eroding streambanks in the West Fork Gallatin River watershed. Using this data, the average streambank composition within each particle size class was calculated based on the entire dataset for the West Fork Gallatin River watershed, while data from streams within the Middle Fork West Fork Gallatin River watershed and South Fork West Fork Gallatin River watershed were used to calculate the average streambank composition at the sub-watershed scale. Sediment loads due to streambank erosion were also calculated for each stream segment to facilitate the development of sediment TMDLs.

Based on the entire dataset, streambank composition averaged 33% coarse gravel, 12% fine gravel and 55% sand/silt in the West Fork Gallatin River watershed (**Table D-18**). The results for the Middle Fork West Fork Gallatin River watershed, which includes data from Middle Fork West Fork Gallatin River, Beehive Creek and Stony Creek (including tributaries), mirror the results for the entire West Fork Gallatin River watershed, with 32% coarse gravel, 11% fine gravel and 57% sand/silt. In the South Fork West Fork Gallatin River watershed, which includes data from South Fork West Fork Gallatin River, Muddy Creek and First Yellow Mule Creek, streambank composition averaged 41% coarse gravel, 12% fine gravel and 47% sand/silt, indicating that streambanks in the South Fork West Fork Gallatin watershed contain a slightly greater component of coarse gravel and a slightly smaller component of sand/silt than is found in the rest of the West Fork Gallatin River watershed.

Table D-18. Mean Streambank Composition for Selected Watersheds.

Watershed	Sample Size	Coarse Gravel >6mm (Percent)	Fine Gravel <6mm & >2mm (Percent)	Sand/Silt <2mm (Percent)
Middle Fork West Fork Gallatin River	88	32	11	57
South Fork West Fork Gallatin River	46	41	12	47
West Fork Gallatin River	203	33	12	55

Streambank composition data for individual stream segments is presented in **Table D-19**. This data was used to amend **Table D-10** to include the sediment load for each particle size class, which is presented in **Table D-20**.

Table D-19. Mean Streambank Composition for Assessed Stream Segments.

Stream Segment	Sample Size	Coarse Gravel >6mm (Percent)	Fine Gravel <6mm & >2mm (Percent)	Sand/Silt <2mm (Percent)
Beehive Creek	27	18	11	71
First Yellow Mule Creek	5	32	10	58
Middle Fork West Fork Gallatin River	34	30	12	58
Muddy Creek	11	50	13	37
North Fork Stony Creek	11	45	10	45
North Fork West Fork Gallatin River	22	20	16	64
South Fork Stony Creek	7	46	10	44
South Fork West Fork Gallatin River	30	39	12	49
Stony Creek	9	57	12	31
West Fork Gallatin River	47	34	11	55

Table D-20. Stream Segment Sediment Loads due to Streambank Erosion.

Stream Segment	Stream Length (Miles)	Coarse Gravel >6mm Load (Tons/Year)	Fine Gravel <6mm & >2mm Load (Tons/Year)	Sand/Silt <2mm Load (Tons/Year)	Total Load (Tons/Year)
Beehive Creek	4.78	48.4	28.1	190.0	266.5
First Yellow Mule Creek	4.95	17.8	5.6	32.2	55.5
Middle Fork West Fork Gallatin River	5.82	56.9	22.3	110.4	189.5
Moose Tracks Creek*	0.41	1.9	0.7	3.2	5.7
Muddy Creek	5.22	60.3	15.4	45.0	120.7
North Fork Moose Tracks Creek*	1.62	0.9	0.3	1.5	2.8
North Fork Stony Creek	2.38	4.0	0.9	3.9	8.8

Table D-20. Stream Segment Sediment Loads due to Streambank Erosion.

Stream Segment	Stream Length (Miles)	Coarse Gravel >6mm Load (Tons/Year)	Fine Gravel <6mm & >2mm Load (Tons/Year)	Sand/Silt <2mm Load (Tons/Year)	Total Load (Tons/Year)
North Fork West Fork Gallatin River	7.37	13.4	10.6	42.9	66.9
South Fork Moose Tracks Creek*	1.14	1.5	0.5	2.5	4.5
South Fork Stony Creek	1.70	3.3	0.7	3.2	7.3
South Fork West Fork Gallatin River	13.78	313.9	95.8	388.3	798.0
Stony Creek	0.20	2.5	0.5	1.4	4.3
Second Yellow Mule Creek*	3.82	6.0	2.1	9.9	18.1
Third Yellow Mule Creek*	3.88	9.0	3.2	14.9	27.1
West Fork Gallatin River	3.61	68.1	23.3	111.2	202.5

*Streambank composition based on average for entire dataset.

D5.0 REFERENCES

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ATTACHMENT A

AERIAL ASSESSMENT DATABASE – STREAM REACH SEDIMENT LOADS, UPPER GALLATIN TMDL PLANNING AREA

STREAM NAME	REACH ID	REACH TYPE III	SUBREACH	REACH	ASSESSED Bank Erosion Sediment Load (Tons/1000 Feet)	BEHI Reduced to MODERATE for ASSESSED Sites (Tons/1000 feet)	EXTRAPOLATED Bank Erosion Sediment Load (Tons/1000 Feet)	EXTRAPOLATED BEHI Reduced to MODERATE (Tons/1000 feet)	TRANSPORTATION	GRAZING	CROPS	MINING	TIMBER	IRRIGATION	NATURAL	OTHER	LENGTH (ft)
Beehive Creek	BEEH 01-01	MR-10-1-U	1	1			0.3	0.3	0	0	0	0	0	0	100	0	2648
Beehive Creek	BEEH 02-01	MR-10-1-U	1	2			0.3	0.3	0	0	0	0	0	0	100	0	582
Beehive Creek	BEEH 03-01	MR-4-1-U	1	3			0.3	0.3	0	0	0	0	0	0	100	0	641
Beehive Creek	BEEH 04-01	MR-10-1-U	1	4			0.3	0.3	0	0	0	0	0	0	100	0	507
Beehive Creek	BEEH 05-01	MR-4-1-U	1	5			0.3	0.3	0	0	0	0	0	0	100	0	497
Beehive Creek	BEEH 06-01	MR-10-1-U	1	6			0.3	0.3	0	0	0	0	0	0	100	0	586
Beehive Creek	BEEH 07-01	MR-4-1-U	1	7			0.3	0.3	0	0	0	0	0	0	100	0	5251
Beehive Creek	BEEH 08-01	MR-10-1-U	1	8			0.3	0.3	0	0	0	0	0	0	100	0	1394
Beehive Creek	BEEH 09-01	MR-10-1-C	1	9			0.3	0.3	0	0	0	0	0	0	100	0	280
Beehive Creek	BEEH 10-01	MR-10-1-U	1	10			1.1	1.1	0	0	0	0	0	0	100	0	368
Beehive Creek	BEEH 11-01	MR-4-1-U	1	11	8.8	8.8	8.8	8.8	0	0	0	0	0	0	100	0	2896
Beehive Creek	BEEH 12-01	MR-2-1-U	1	12	84.5	29.4	84.5	29.4	20	0	0	0	0	0	80	0	1629
Beehive Creek	BEEH 13-01	MR-4-1-U	1	13	23.3	9.1	23.3	9.1	0	0	0	0	0	0	98	2	3899
Beehive Creek	BEEH 14-01	MR-10-1-U	1	14			1.1	1.1	35	0	0	0	0	0	45	20	760
Beehive Creek	BEEH 15-01	MR-4-1-U	1	15			3.1	3.1	55	0	0	0	0	0	45	0	2350
Beehive Creek	BEEH 16-01	MR-10-1-U	1	16			1.1	1.1	10	0	0	0	0	0	90	0	927
First Yellow Mule Creek	FYMC 01-01	MR-4-1-U	1	1			0.3	0.3	0	0	0	0	0	0	100	0	1657
First Yellow Mule Creek	FYMC 02-01	MR-10-1-U	1	2			0.3	0.3	0	0	0	0	0	0	100	0	1494
First Yellow Mule Creek	FYMC 03-01	MR-4-1-U	1	3			0.3	0.3	0	0	0	0	0	0	100	0	1052
First Yellow Mule Creek	FYMC 04-01	MR-10-1-U	1	4			0.3	0.3	0	0	0	0	0	0	100	0	837
First Yellow Mule Creek	FYMC 05-01	MR-4-1-U	1	5			0.3	0.3	0	0	0	0	0	0	100	0	1514
First Yellow Mule Creek	FYMC 06-01	MR-10-1-U	1	6			0.3	0.3	50	0	0	0	0	0	50	0	4147

STREAM NAME	REACH ID	REACH TYPE III	SUBREACH	REACH	ASSESSED Bank Erosion Sediment Load (Tons/1000 Feet)	BEHI Reduced to MODERATE for ASSESSED Sites (Tons/1000 feet)	EXTRAPOLATED Bank Erosion Sediment Load (Tons/1000 Feet)	EXTRAPOLATED BEHI Reduced to MODERATE (Tons/1000 feet)	TRANSPORTATION	GRAZING	CROPS	MINING	TIMBER	IRRIGATION	NATURAL	OTHER	LENGTH (ft)
First Yellow Mule Creek	FYMC 07-01	MR-4-1-U	1	7			3.1	3.1	0	0	0	0	0	0	100	0	3409
First Yellow Mule Creek	FYMC 08-01	MR-10-1-U	1	8			0.3	0.3	0	0	0	0	0	0	100	0	820
First Yellow Mule Creek	FYMC 09-01	MR-4-1-U	1	9			3.1	3.1	20	0	0	0	0	0	80	0	1606
First Yellow Mule Creek	FYMC 10-01	MR-4-1-C	1	10			1.6	1.6	0	0	0	0	0	0	100	0	437
First Yellow Mule Creek	FYMC 11-01	MR-4-1-U	1	11			3.1	3.1	0	0	0	0	0	0	100	0	482
First Yellow Mule Creek	FYMC 12-01	MR-10-1-U	1	12			0.3	0.3	0	0	0	0	0	0	100	0	527
First Yellow Mule Creek	FYMC 13-01	MR-10-1-C	1	13			0.3	0.3	0	0	0	0	0	0	100	0	295
First Yellow Mule Creek	FYMC 14-01	MR-4-1-U	1	14			3.1	3.1	5	0	0	0	0	0	95	0	3926
First Yellow Mule Creek	FYMC 15-01	MR-10-2-U	1	15			5.6	5.6	0	0	0	0	0	0	100	0	1280
First Yellow Mule Creek	FYMC 16-01	MR-4-2-U	1	16	5.6	3.8	5.6	3.8	0	0	0	0	28	0	72	0	2632
MFWF Gallatin River	MFWF 01-01	MR-10-1-U	1	1	0.3	0.3	0.3	0.3	0	0	0	0	10	0	80	10	1665
MFWF Gallatin River	MFWF 02-01	MR-4-1-U	1	2	0.4	0.4	0.7	0.7	30	0	0	0	0	0	15	55	7623
MFWF Gallatin River	MFWF 02-01	MR-4-1-U	2	2	1.0	1.0			30	0	0	0	0	0	15	55	
MFWF Gallatin River	MFWF 03-01	MR-4-1-U	1	3			1.1	1.1	50	0	0	0	0	0	25	25	399
MFWF Gallatin River	MFWF 04-01	MR-4-1-C	1	4	1.3	1.3	1.3	1.3	0	0	0	0	0	0	100	0	1221
MFWF Gallatin River	MFWF 05-01	MR-10-1-U	1	5			0.3	0.3	10	0	0	0	0	0	60	30	722
MFWF Gallatin River	MFWF 06-01	MR-10-2-U	1	6			4.4	4.4	15	0	0	0	0	0	85	0	1637
MFWF Gallatin River	MFWF 07-01	MR-4-2-U	1	7			4.1	3.3	10	0	0	0	0	0	90	0	2102
MFWF Gallatin River	MFWF 07-02	MR-4-2-U	2	7	4.4	4.4	4.4	4.4	0	0	0	0	83	0	17	0	2741
MFWF Gallatin River	MFWF 08-01	MR-2-2-U	1	8	1.9	1.9	1.9	1.9	0	0	0	0	62	0	38	0	7109
MFWF Gallatin River	MFWF 09-01	MR-2-3-U	1	9	26.2	12.1	26.2	12.1	0	0	0	0	50	0	10	40	3052
MFWF Gallatin River	MFWF09-02	MR-2-3-U	2	9	24.5	24.5	24.5	24.5	0	0	0	0	0	0	100	0	2453

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Moose Tracks	MOOS 01-01	MR-4-2-U	1	1			0.0	0.0	0	0	0	0	0	0	0	100	754
Moose Tracks	MOOS 01-02	MR-4-2-U	2	1			4.1	3.3	40	0	0	0	0	0	10	50	1401
Muddy Creek	MUDD 01-01	MR-10-1-U	1	1			0.3	0.3	0	0	0	0	0	0	100	0	3643
Muddy Creek	MUDD 02-01	MR-4-1-U	1	2			1.1	1.1	0	0	0	0	0	0	100	0	4134
Muddy Creek	MUDD 03-01	MR-4-1-U	1	3			1.1	1.1	0	0	0	0	0	0	100	0	1637
Muddy Creek	MUDD 04-01	MR-10-1-U	1	4			1.1	1.1	0	0	0	0	0	0	100	0	1757
Muddy Creek	MUDD 05-01	MR-4-2-U	1	5			4.1	4.1	0	0	0	0	0	0	100	0	7781
Muddy Creek	MUDD 05-02	MR-4-2-U	2	5			4.1	3.3	0	0	0	0	30	0	70	0	2944
Muddy Creek	MUDD 05-03	MR-4-2-U	3	5			4.1	3.3	0	0	0	0	40	0	10	50	1100
Muddy Creek	MUDD 06-01	MR-4-2-C	1	6			4.1	4.1	0	0	0	0	50	0	50	0	530
Muddy Creek	MUDD 07-01	MR-4-2-U	1	7			15.1	9.0	0	0	0	0	50	0	50	0	1591
Muddy Creek	MUDD 08-01	MR-2-2-U	1	8	15.1	9.0	15.1	9.0	68	0	0	0	15	0	16	0	1480
Muddy Creek	MUDD 08-02	MR-2-2-U	2	8			15.1	9.0	68	0	0	0	15	0	16	0	945
North Fork Moose Tracks	NFMT 01-01	MR-10-1-U	1	1			0.3	0.3	95	0	0	0	0	0	5	0	302
North Fork Moose Tracks	NFMT 02-01	MR-10-1-U	1	2			0.3	0.3	0	0	0	0	0	0	50	50	3890
North Fork Moose Tracks	NFMT 03-01	MR-4-1-U	1	3			1.1	1.1	0	0	0	0	0	0	50	50	523
North Fork Moose Tracks	NFMT 04-01	MR-10-1-U	1	4			0.3	0.3	10	0	0	0	0	0	50	40	1260
North Fork Moose Tracks	NFMT 05-01	MR-10-1-C	1	5			0.3	0.3	25	0	0	0	0	0	50	25	456
North Fork Moose Tracks	NFMT 06-01	MR-10-1-U	1	6			0.3	0.3	50	0	0	0	0	0	30	20	1578
North Fork Moose Tracks	NFMT 07-01	MR-4-1-U	1	7			0.0	0.0	10	0	0	0	0	0	5	85	527

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North Fork Stony Creek	NFST 01-01	MR-10-1-U	1	1			0.3	0.3	10	0	0	0	0	0	60	30	3872
North Fork Stony Creek	NFST 02-01	MR-4-1-U	1	2			1.1	1.1	10	0	0	0	0	0	65	25	1224
North Fork Stony Creek	NFST 03-01	MR-10-1-C	1	3			0.3	0.3	5	0	0	0	0	0	95	0	2960
North Fork Stony Creek	NFST 04-01	MR-4-1-C	1	4			1.6	1.6	0	0	0	0	0	0	100	0	1038
North Fork Stony Creek	NFST 05-01	MR-10-1-C	1	5			0.3	0.3	0	0	0	0	0	0	100	0	1296
North Fork Stony Creek	NFST 06-01	MR-10-1-U	1	6			0.3	0.3	0	0	0	0	0	0	100	0	495
North Fork Stony Creek	NFST 07-01	MR-4-1-C	1	7	1.9	1.9	1.9	1.9	0	0	0	0	0	0	100	0	1661
NFWF Gallatin River	NFWF 01-01	MR-10-1-U	1	1			0.3	0.3	0	0	0	0	0	0	100	0	1784
NFWF Gallatin River	NFWF 02-01	MR-4-1-U	1	2			0.3	0.3	0	0	0	0	0	0	100	0	3947
NFWF Gallatin River	NFWF 03-01	MR-10-1-U	1	3			0.3	0.3	0	0	0	0	0	0	100	0	5443
NFWF Gallatin River	NFWF 04-01	MR-4-1-U	1	4			1.1	1.1	0	0	0	0	0	0	100	0	1024
NFWF Gallatin River	NFWF 05-01	MR-4-2-U	1	5			2.1	2.1	0	0	0	0	0	0	100	0	1588
NFWF Gallatin River	NFWF 06-01	MR-4-2-U	1	6			2.1	2.1	0	0	0	0	0	0	100	0	1220
NFWF Gallatin River	NFWF 07-01	MR-4-2-C	1	7			4.1	4.1	0	0	0	0	0	0	100	0	965
NFWF Gallatin River	NFWF 08-01	MR-4-2-U	1	8			2.1	2.1	0	0	0	0	0	0	100	0	2192
NFWF Gallatin River	NFWF 09-01	MR-4-2-U	1	9			2.1	2.1	0	0	0	0	0	0	100	0	2054
NFWF Gallatin River	NFWF 10-01	MR-2-2-U	1	10	3.8	3.8	3.8	3.8	0	0	0	0	0	0	68	32	2576
NFWF Gallatin River	NFWF 11-01	MR-4-2-U	1	11			2.1	2.1	5	0	0	0	0	0	95	0	4758
NFWF Gallatin River	NFWF 12-01	MR-4-2-U	1	12	2.1	2.1	2.1	2.1	0	0	0	0	1	0	99	0	11365
South Fork Moose Tracks	SFMT 01-01	MR-10-1-U	1	1			0.3	0.3	10	0	0	0	0	0	90	0	2661
South Fork Moose Tracks	SFMT 02-01	MR-4-1-U	1	2			1.1	1.1	25	0	0	0	0	0	75	0	3363

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South Fork Stony Creek	SFSC 01-01	MR-10-1-U	1	1			0.3	0.3	40	0	0	0	0	0	60	0	3939
South Fork Stony Creek	SFSC 02-01	MR-4-1-U	1	2			1.1	1.1	10	0	0	0	0	0	90	0	3620
South Fork Stony Creek	SFSC 03-01	MR-10-1-U	1	3			0.3	0.3	0	0	0	0	0	0	100	0	487
South Fork Stony Creek	SFSC 04-01	MR-4-1-U	1	4	2.2	2.2	2.2	2.2	50	0	0	0	0	0	50	0	908
SFWF Gallatin River	SFWF 01-01	MR-10-1-U	1	1			0.3	0.3	0	0	0	0	0	0	100	0	2592
SFWF Gallatin River	SFWF 02-01	MR-4-1-U	1	2			0.3	0.3	0	0	0	0	0	0	100	0	2420
SFWF Gallatin River	SFWF 03-01	MR-10-1-C	1	3			0.3	0.3	0	0	0	0	0	0	100	0	480
SFWF Gallatin River	SFWF 04-01	MR-10-1-U	1	4			0.3	0.3	0	0	0	0	0	0	100	0	869
SFWF Gallatin River	SFWF 05-01	MR-10-1-U	1	5			0.3	0.3	0	0	0	0	0	0	100	0	1365
SFWF Gallatin River	SFWF 06-01	MR-10-1-C	1	6			0.3	0.3	0	0	0	0	0	0	100	0	417
SFWF Gallatin River	SFWF 07-01	MR-4-1-U	1	7			3.1	3.1	0	0	0	0	0	0	100	0	3279
SFWF Gallatin River	SFWF 08-01	MR-4-1-C	1	8			1.6	1.6	0	0	0	0	0	0	100	0	2212
SFWF Gallatin River	SFWF 09-01	MR-4-1-U	1	9			3.1	3.1	0	0	0	0	0	0	100	0	1426
SFWF Gallatin River	SFWF 10-01	MR-10-1-C	1	10			3.1	3.1	0	0	0	0	0	0	100	0	473
SFWF Gallatin River	SFWF 11-01	MR-10-1-U	1	11			1.1	1.1	0	0	0	0	0	0	100	0	404
SFWF Gallatin River	SFWF 12-01	MR-4-1-U	1	12			3.1	3.1	0	0	0	0	0	0	100	0	550
SFWF Gallatin River	SFWF 13-01	MR-4-1-C	1	13			1.6	1.6	0	0	0	0	0	0	100	0	1127
SFWF Gallatin River	SFWF 14-01	MR-4-1-U	1	14			3.1	3.1	0	0	0	0	0	0	100	0	776
SFWF Gallatin River	SFWF 15-01	MR-2-1-U	1	15			1.4	1.4	10	0	0	0	0	0	90	0	1948
SFWF Gallatin River	SFWF 16-01	MR-4-2-U	1	16			4.1	4.1	0	0	0	0	0	0	100	0	1869
SFWF Gallatin River	SFWF 16-02	MR-4-2-U	2	16			4.1	3.3	20	0	0	0	35	0	45	0	3619
SFWF Gallatin River	SFWF 17-01	MR-2-2-U	1	17			1.4	1.4	35	0	0	0	0	0	65	0	3294

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SFWF Gallatin River	SFWF 17-02	MR-2-2-U	2	17	1.4	1.4	1.4	1.4	0	0	0	0	0	0	100	0	2418
SFWF Gallatin River	SFWF 18-01	MR-0-3-U	1	18	6.4	2.6	6.4	2.6	0	0	0	0	67	0	33	0	2894
SFWF Gallatin River	SFWF 19-01	MR-4-3-C	1	19			6.4	6.4	0	0	0	0	0	0	100	0	1965
SFWF Gallatin River	SFWF 20-01	MR-2-3-C	1	20			16.0	16.0	0	0	0	0	0	0	100	0	1630
SFWF Gallatin River	SFWF 21-01	MR-0-3-U	1	21			17.9	14.0	0	0	0	0	30	0	70	0	2077
SFWF Gallatin River	SFWF 22-01	MR-0-3-U	1	22	24.5	22.0	24.5	22.0	0	0	0	0	54	0	46	0	7218
SFWF Gallatin River	SFWF 23-01	MR-0-3-U	1	23			17.9	14.0	35	0	0	0	0	0	65	0	1248
SFWF Gallatin River	SFWF 24-01	MR-4-3-C	1	24			17.9	14.0	25	0	0	0	0	0	60	15	2530
SFWF Gallatin River	SFWF 25-01	MR-2-3-U	1	25			16.0	9.5	0	0	0	0	0	0	75	25	1173
SFWF Gallatin River	SFWF 26-01	MR-0-3-U	1	26			17.9	14.0	10	0	0	0	0	0	90	0	2486
SFWF Gallatin River	SFWF 27-01	MR-2-3-C	1	27			16.0	9.5	25	0	0	0	0	0	50	25	1338
SFWF Gallatin River	SFWF 28-01	MR-2-3-U	1	28	6.0	3.4	6.0	3.4	0	0	0	0	13	0	87	0	1589
SFWF Gallatin River	SFWF 28-02	MR-2-3-U	2	28			6.0	3.4	10	0	0	0	0	0	80	10	834
SFWF Gallatin River	SFWF 29-01	MR-0-3-U	1	29			17.9	14.0	10	0	0	0	0	0	90	0	2459
SFWF Gallatin River	SFWF 29-02	MR-0-3-U	2	29	28.6	28.6	28.6	28.6	0	0	0	0	0	0	100	0	4080
SFWF Gallatin River	SFWF 29-03	MR-0-3-U	3	29			17.9	14.0	60	0	0	0	0	0	40	0	1097
SFWF Gallatin River	SFWF 29-04	MR-0-3-U	4	29			17.9	14.0	10	0	0	0	0	0	50	40	6591
Stony Creek	STON 01-01	MR-4-2-U	1	1	4.1	2.9	4.1	2.9	17	0	0	0	20	0	63	0	1060
Second Yellow Mule Creek	SYMC 01-01	MR-10-1-U	1	1			0.3	0.3	0	0	0	0	0	0	100	0	2553
Second Yellow Mule Creek	SYMC 02-01	MR-4-1-U	1	2			0.3	0.3	0	0	0	0	0	0	100	0	1966

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Second Yellow Mule Creek	SYMC 03-01	MR-10-1-C	1	3			0.3	0.3	0	0	0	0	0	0	100	0	868
Second Yellow Mule Creek	SYMC 04-01	MR-4-1-U	1	4			0.3	0.3	0	0	0	0	50	0	50	0	3151
Second Yellow Mule Creek	SYMC 05-01	MR-10-1-C	1	5			0.3	0.3	0	0	0	0	50	0	50	0	2333
Second Yellow Mule Creek	SYMC 06-01	MR-4-1-U	1	6			3.1	3.1	50	0	0	0	0	0	50	0	495
Second Yellow Mule Creek	SYMC 07-01	MR-10-1-C	1	7			0.3	0.3	0	0	0	0	35	0	50	15	2457
Second Yellow Mule Creek	SYMC 08-01	MR-4-1-C	1	8			1.6	1.6	5	0	0	0	45	0	50	0	2945
Second Yellow Mule Creek	SYMC 09-01	MR-4-1-U	1	9			3.1	3.1	0	0	0	0	0	0	100	0	550
Second Yellow Mule Creek	SYMC 10-01	MR-4-1-C	1	10			1.6	1.6	80	0	0	0	0	0	20	0	1839
Second Yellow Mule Creek	SYMC 11-01	MR-4-1-U	1	11			3.1	3.1	30	0	0	0	40	0	30	0	1018
Third Yellow Mule Creek	TYMC 01-01	MR-10-1-U	1	1			0.3	0.3	0	0	0	0	0	0	100	0	1615
Third Yellow Mule Creek	TYMC 02-01	MR-4-1-U	1	2			0.3	0.3	0	0	0	0	0	0	100	0	1687
Third Yellow Mule Creek	TYMC 03-01	MR-10-1-U	1	3			0.3	0.3	0	0	0	0	0	0	100	0	1608
Third Yellow Mule Creek	TYMC 04-01	MR-4-1-U	1	4			0.3	0.3	0	0	0	0	0	0	100	0	6323
Third Yellow Mule Creek	TYMC 05-01	MR-10-1-U	1	5			0.3	0.3	0	0	0	0	0	0	100	0	769
Third Yellow Mule Creek	TYMC 06-01	MR-4-1-U	1	6			3.1	3.1	0	0	0	0	30	0	70	0	4336

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Third Yellow Mule Creek	TYMC 07-01	MR-4-1-C	1	7			1.6	1.6	0	0	0	0	50	0	50	0	1058
Third Yellow Mule Creek	TYMC 08-01	MR-10-1-C	1	8			3.1	3.1	0	0	0	0	0	0	100	0	1631
Third Yellow Mule Creek	TYMC 09-01	MR-4-1-C	1	9			1.6	1.6	0	0	0	0	0	0	100	0	859
Third Yellow Mule Creek	TYMC 10-01	MR-4-1-U	1	10			3.1	3.1	25	0	0	0	50	0	25	0	623
WF Gallatin River	WFGR 01-01	MR-2-3-U	1	1			16.0	9.5	20	0	0	0	0	0	40	40	1407
WF Gallatin River	WFGR 01-02	MR-2-3-U	2	1	16.2	6.3	16.2	6.3	8	0	0	0	0	0	66	26	1426
WF Gallatin River	WFGR 01-03	MR-2-3-U	3	1	7.0	5.8	7.0	5.8	9	0	0	0	0	0	38	53	3043
WF Gallatin River	WFGR 01-04	MR-2-3-U	4	1	2.9	1.1	2.9	1.1	0	0	0	0	0	0	14	86	2342
WF Gallatin River	WFGR 01-05	MR-2-3-U	5	1	29.2	13.0	29.2	13.0	20	0	0	0	0	0	8	72	2227
WF Gallatin River	WFGR 02-01	MR-0-3-U	1	2	25.1	12.1	25.1	12.1	0	0	0	0	0	0	81	19	2042
WF Gallatin River	WFGR 02-02	MR-0-3-U	2	2	4.7	4.7	4.7	4.7	0	0	0	0	0	0	100	0	617
WF Gallatin River	WFGR 02-03	MR-0-3-U	3	2			4.7	4.7	40	0	0	0	0	0	40	20	558
WF Gallatin River	WFGR 03-01	MR-0-4-U	1	3			1.3	1.3	50	0	0	0	0	0	30	20	1150
WF Gallatin River	WFGR 03-02	MR-0-4-U	2	3			1.3	1.3	50	0	0	0	0	0	50	0	602
WF Gallatin River	WFGR 03-03	MR-0-4-U	3	3	1.3	1.3	1.3	1.3	10	0	0	0	0	0	90	0	2367
WF Gallatin River	WFGR 04-01	MR-0-4-U	1	4			1.3	1.3	10	0	0	0	0	0	20	70	1284

APPENDIX E
HILLSLOPE SEDIMENT MODEL AND RIPARIAN HEALTH ADDENDUM

Erosion is the main source of nonpoint source sediment that results in siltation and habitat impairments. In addition, eroded sediment can carry nutrients, particularly phosphates, and contribute to eutrophication of lakes and streams. The two major types of erosion are geological erosion and erosion from human and animal activities (Ward and Trimble, 2004). Geological erosion results in the long-term development of topographic features such as stream channels, valleys, and canyons and contributes to soil formation. Residential and recreational development, tillage, road drainage and vegetation removal by humans and grazing animals may cause accelerated erosion. Other variables affecting erosion include climate, geology, soil properties, vegetation and topography.

Sources of sediment delivered to streams in the West Fork Gallatin River watershed include hillslope erosion, road disturbances, and stream bank erosion; each having some degree of human influence. This appendix describes development and application of a GIS-based computational model that predicts sediment eroded from hillslopes and delivered to streams.

Model Selection

Watershed models are a representation of physical processes in the natural environment. They depict, to the best of our knowledge, how these processes interact and result in landscape change. In this case, the processes are sediment erosion and deposition. The models chosen to assist with sediment TMDL development often utilize the Universal Soil Loss Equation (USLE – USDA, 1981). The USDA Soil Conservation Service (now the Natural Resources Conservation Service – NRCS) first developed the USLE in the 1960s. The USLE has evolved over time and its application has expanded. The evolution of GIS and associated spatial datasets in the last decade has allowed application of the USLE over large, watershed scale areas.

The model developed for this project is a modified version of the USLE (Universal Soil Loss Equation) model referred to as USPED (Unit Stream Power - based Erosion Deposition). This model was developed at the University of Illinois Geographic Modeling Systems Laboratory (Mitasova, et al., 2003). The model was constructed within ArcGIS, and uses the Spatial Analyst extension. The USPED model accounts for both sediment erosion and deposition in the hillslope erosion processes.

The USPED model is similar to the USLE model and is represented by the following equations.

Sediment Transport Capacity $T=R*K*C*P*LS$

T=Transport Capacity
R= rainfall erosivity index
K= soil erodibility index
C= soil cover factor
P= management factor
$LS=A^m \sin(\beta)^n$ (note: LS is slope length in the USLE)

Where:

A=upslope contributing area
β=Slope angle
$m=1.6$ (rill erosion dominant)
$n=1.3$ (rill erosion dominant)
$m=n=1$ (sheet erosion dominant)

Net erosion/deposition (ED) is then the divergence of transport capacity, T in both the downstream and perpendicular directions.

$$ED=\frac{d(T\cos a)}{dx}+\frac{d(T\sin a)}{dy}$$

ED= Net Erosion/Deposition
a= Aspect angle of terrain surface
dx, dy= Terrain Curvature (profile and tangential)

Model Construction

Model construction required identification of appropriate data sources, converting these data to a series of ESRI grid datasets with the same resolution and extent, and assembling the model grid datasets within an ArcGIS project. For this model, all grids were re-sampled to five-meter resolution.

Model construction also included segmentation of the West Fork Gallatin River watershed into sub-watersheds. Segmentation was based on the presence of major tributary streams or breaks in the 303(d) List streams. **Table E-1** below lists the sub-watersheds delineated.

Data Development

The West Fork Gallatin River was segmented into 14 sub-watersheds for load allocation purposes. Watershed breaks are based on 303(d) streams, major tributary streams, and natural and man-made breaks in watershed hydrology. The following table (**Table E-1**) lists the sub-watersheds, and **Figure E-1** shows their locations.

Table E-1. Sub-watershed delineation (upstream to downstream), West Fork Gallatin River.

ID	Sub-Watershed Name	Area (acres)	303(d) Watershed Name	Area (acres)
5	Uppermost Middle Fork West Fork Gallatin River	3,236	Middle Fork West Fork Gallatin River	11,505
1	Beehive Creek	2,065		
8	Middle Fork West Fork Gallatin River	6,204		
9	Upper South Fork West Fork Gallatin River	6,530	South Fork West Fork Gallatin River	29,654
11	Muddy Creek	5,772		
12	Third Yellow Mule Creek	2,306		
13	Second Yellow Mule Creek	2,887		
14	First Yellow Mule Creek	3,511		
10	South Fork West Fork Gallatin River	8,648		
2	North Fork West Fork Gallatin River	6,223	West Fork Gallatin River	10,078
6	Upper West Fork Gallatin River	553		
3	Crail Creek	1,366		
4	Lower West Fork Gallatin River	1,143		
7	Lowermost West Fork Gallatin River	792		

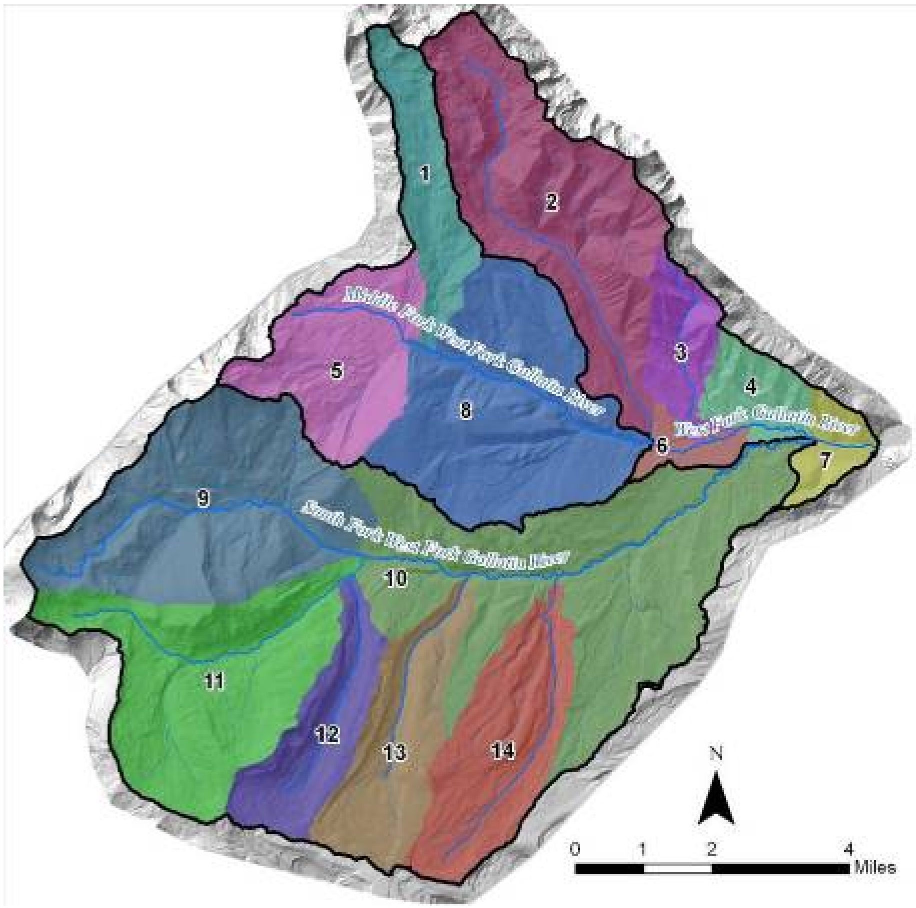


Figure E-1. Watershed segmentation.

Land Use and Land Cover

Developing the C-factor parameter for the USPED sediment model required a detailed data layer of land cover. This was derived from a 2008 MSU study (Campos, et al., 2008) that interpreted 13 land cover categories in the West Fork Gallatin River watershed using Quickbird satellite imagery and LIDAR elevation data. For this study, the MSU land cover data was simplified into six land cover categories as follows:

- Grass,
- Bare soil/sparse vegetation,
- Forest,
- Urban,
- Water, and
- Rock.

In order to determine the source of sediment loading, we developed a simple land use data layer using aerial photo interpretation, cadastral (land parcel) data from Montana Department of Revenue, and roads data. The resultant land use layer consists of three land use classes, residential, ski area, and none. None refers to no significant human land uses and is considered the naturally occurring condition. **Table E-2** summarizes land cover and land use in the three 303(d) List sub-watersheds and the entire project area. **Figures E-2** through **E-5** illustrates the distribution of land uses and land cover in the 303(d) watersheds.

Table E-2. Summary of land cover and land use data in the West Fork Gallatin River Watershed.

Land Use	Land Cover	Middle Fork West Fork Gallatin River (acres)	South Fork West Fork Gallatin River (acres)	West Fork Gallatin River (acres)	Project Area (acres)	Land Cover Percent of Project Area
Residential	Grass	974	1,602	880	3,457	43.5%
	Soil/Sparse Veg	498	348	150	995	12.5%
	Forest	1,437	1,049	492	2,979	37.4%
	Urban	132	82	58	272	3.4%
	Water	3	32	30	65	0.8%
	Rock	96	85	6	188	2.4%
	TOTAL	3,140	3,198	1,617	7,956	100.0%
Ski Area	Grass	660	299	0	959	18.5%
	Soil/Sparse Veg	115	141	0	255	4.9%
	Forest	1,702	1,564	0	3,265	62.9%
	Urban	5	4	0	9	0.2%
	Rock	232	469	0	701	13.5%
	TOTAL	2,713	2,476	0	5,189	100.0%
None (Naturally Occurring)	Grass	1,546	8,568	1,804	11,919	31.3%
	Soil/Sparse Veg	289	693	85	1,067	2.8%
	Forest	3,166	12,137	5,093	20,396	53.5%
	Water	10	0	0	11	0.0%
	Rock	640	2,581	1,479	4,699	12.3%
	TOTAL	5,652	23,979	8,460	38,092	100.0%

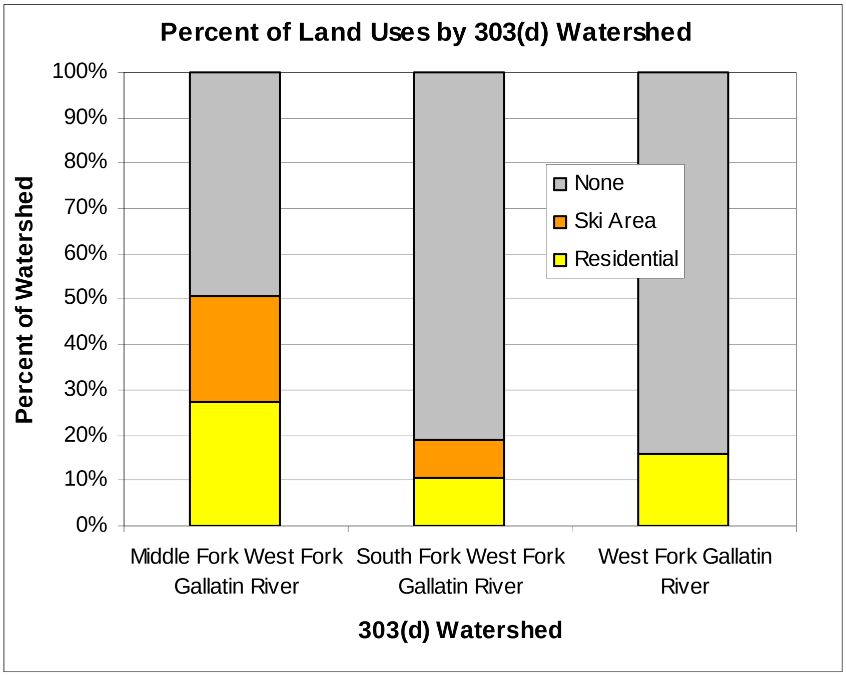


Figure E-2. Percent of land uses in the 303(d) watersheds.

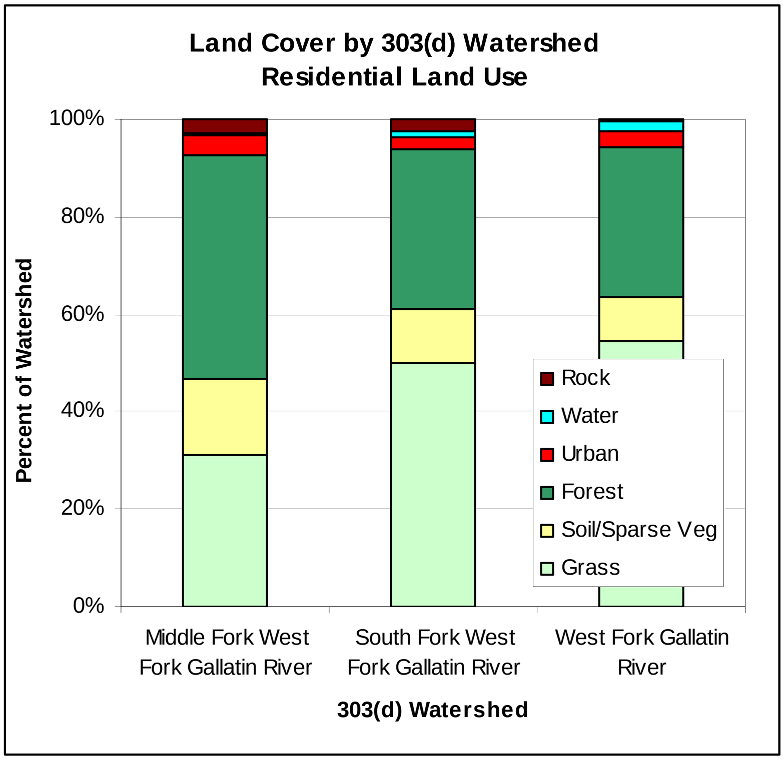


Figure E-3. Distribution of land cover in areas with residential land use in the 303(d) watersheds.

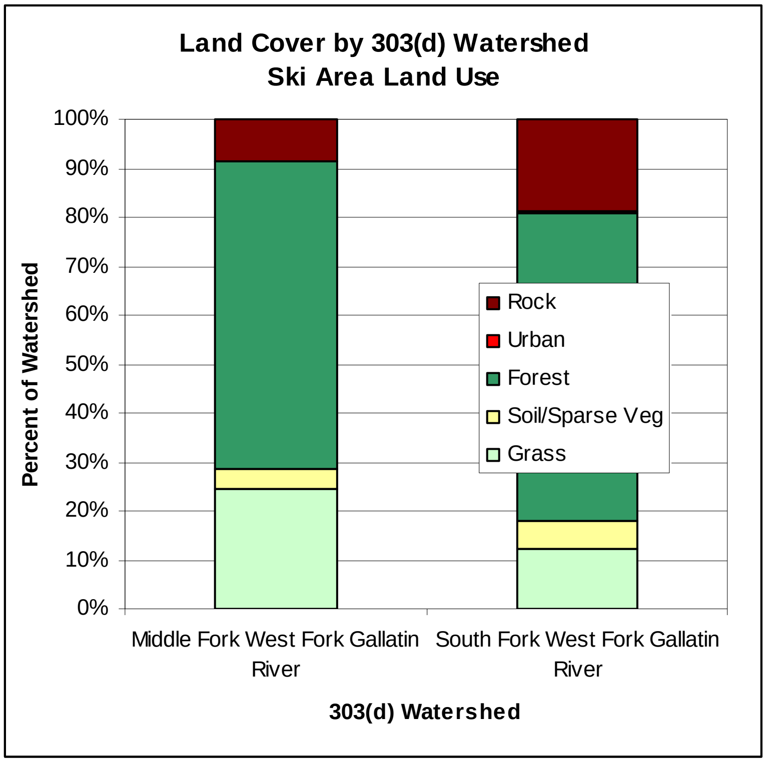


Figure E-4. Distribution of land cover in areas with ski area land use in the 303(d) watersheds.

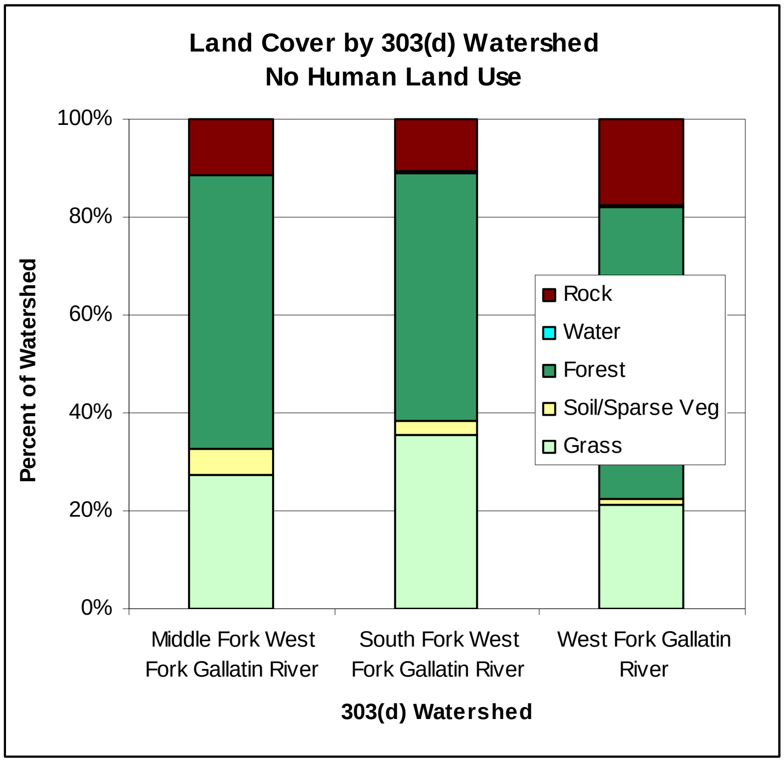


Figure E-3. Distribution of land cover in areas with no significant human land use in the 303(d) watersheds.

Table E-3 summarizes the data sources utilized for each of the model input parameters, the data processing steps, and related comments. All input datasets were downsampled to five-meter resolution and converted to ESRI grid format for use within an ArcGIS model. In hindsight, the high resolution of these datasets increased computation time and data storage requirements. A maximum resolution of ten meters for future similar modeling efforts would be sufficient.

Table E-3. Summary of data sources used to construct the West Fork Gallatin River watershed USPED hillslope erosion model.

Model Input	Source Data	Processing Steps	Comments
R- Rainfall Erosivity Index	USDA, 1981	Insert constant value (R=20) into grid calculations	USDA, 1981 indicates that the rainfall erosivity constant is equal to 20 for the region including the watershed
K – Soil Erodibility Index	K factor from NRCS digital soil surveys (Gallatin County, Madison County, and Gallatin National Forest).	Merge shapefiles, convert shapefile into 5m grid using K factor as the cell value	Some inconsistencies where datasets edge match.
C – Cover Soil Factor	MSU Land Use Land Cover (LULC) Dataset (Campos, et al. 2008)	Classification scheme simplified, data downsampled from 1m to 5m and converted to grid.	Combinations of MSU LULC simplified cover classes and major land uses for categories for C-factor determination. C-factors assigned through literature review and collaboration with MDEQ.
	Major land uses interpreted from imagery (this study).	Interpretation and heads up digitizing of major land uses (residential and ski area)	
P – Management Factor	Collaborative efforts with MDEQ to develop P-factors that represent the two model scenarios (current and desired conditions)	Reclassify the C-factor grid to create the two P-factor grids	See Table X-4 below for more detail on P-factor development.
A – Upslope contributing areas	Flow accumulation grids derived from 1m resolution LiDAR elevation dataset (Campos et al., 2008)	Downsample 1m LiDAR to 5m resolution. Fill sinks, calculate flow direction, and flow accumulation grids.	
β – Slope Angle	LiDAR elevation data	Slope function in ArcGIS	
m, n	The values for rill dominated systems were used. Sheet flow is characteristic of tilled agricultural settings and is not relevant for this setting.	m=1.6 and n=1.3 were incorporated in the raster calculations of the model.	
A – aspect angle	LiDAR elevation data	Aspect function in ArcGIS	

Figures E-6 and **E-7** below illustrate some of the critical input ESRI grid data sets for the USPED model for the West Fork Gallatin River watershed.

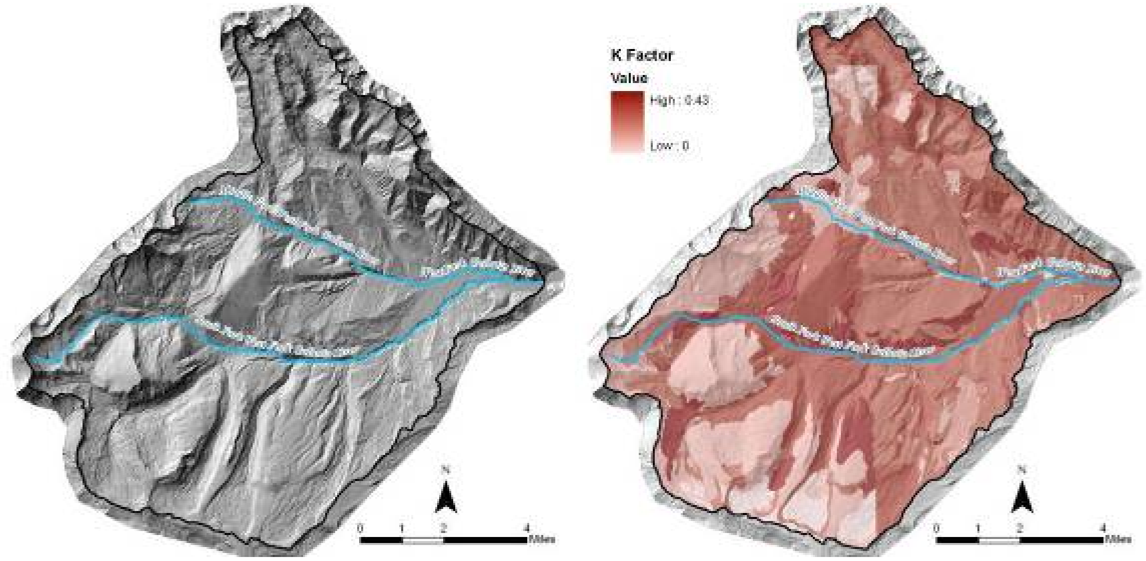


Figure E-6. Hillshade of LiDAR 5 meter DEM (left) and K factor derived from SSURGO soils (right) for the West Fork Gallatin River watershed. Examples of grid dataset inputs.

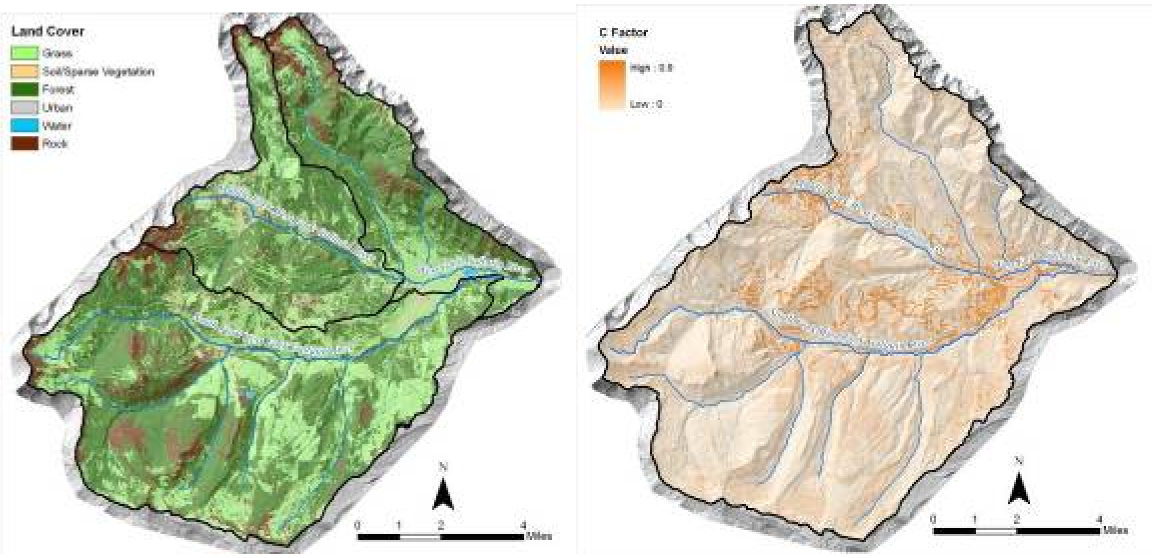


Figure E-7. Simplified land cover dataset derived from the Quickbird-LIDAR interpretation (Campos et al., 2008) (left) and C-factor dataset (right).

C-Factor

C factor in the USPED (and USLE) model is the cover and management factor. It is the ratio of soil loss from land use under specified conditions to that from continuously fallow and tilled land. In the model developed for this project, C-factor represents the vegetative land cover and its ability to retain sediment. For this project, the project team and Montana DEQ personnel developed C factors for the land uses and cover types in the watershed using field observations and literature values (Engel, 2001) for guidance. **Table E-4** illustrates the correlation between canopy cover, ground cover, and vegetation type with C factor from Engel, 2001, and **Table E-4** lists the C factors used for the West Fork model for both the existing condition and desired condition scenarios. These C-factors are based on estimated canopy covers for grass and bare ground dominated areas with various land uses. These values reflect expected values for areas without any BMPs or re-vegetation and are essentially a worst-case scenario.

Areas with “grass” land cover have the same C factor regardless of land use. This is because the “grass” land cover category contains areas with substantial grass cover and good sediment retention capabilities. Areas with these higher levels of grass cover should have similar sediment yields regardless of land use. Forest, urban, rock, and water land cover categories have low C-factors of 0.004, 0.03, 0.001, and 0.0 respectively, based on literature values (Ma, 2001). These are the same for both the current conditions and desired conditions scenarios. The soil/sparse vegetation land cover category can vary from completely bare soil to areas with some grass cover. The C factor for soil/sparse vegetation with a residential land use is high (0.9), and reflects ground clearing associated with construction. By comparison, the C factor for soil/sparse vegetation within ski areas is more moderate (0.3) and reflects construction and maintenance to ski areas, which is less likely to leave as much bare ground as residential/resort development.

Table E-4. C factor table for various levels of ground and canopy cover from Engel, 2001.

Vegetal Canopy			Cover That Contacts the Surface					
Type and Height	Canopy		Percent Ground Cover					
of Raised Canopy[2]	Covers[3] %	Type[4]	0	20	40	60	80	95-100
No appreciable canopy		G	0.45	0.2	0.1	0.042	0.013	0.003
		W	0.45	0.24	0.15	0.09	0.043	0.011
Canopy of tall weeds or short brush, 0.5 m (1.6 ft.) fall ht.	25	G	0.36	0.17	0.09	0.038	0.012	0.003
		W	0.36	0.2	0.13	0.082	0.041	0.011
	50	G	0.26	0.13	0.07	0.035	0.012	0.003
		W	0.26	0.16	0.11	0.075	0.039	0.011
	75	G	0.17	0.1	0.06	0.031	0.011	0.003
		W	0.17	0.12	0.09	0.068	0.038	0.011
Appreciable brush or bushes, 2 m 6.6 ft. fall ht.	25	G	0.4	0.18	0.09	0.04	0.013	0.003
		W	0.4	0.22	0.14	0.085	0.042	0.011
	50	G	0.34	0.16	0.085	0.038	0.012	0.003
		W	0.34	0.19	0.13	0.081	0.041	0.011
	75	G	0.28	0.14	0.08	0.036	0.012	0.003
		W	0.28	0.17	0.12	0.077	0.04	0.011
Trees but no appreciable low brush , 4 m (13.1 ft.) fall ht.	25	G	0.42	0.19	0.1	0.041	0.013	0.003
		W	0.42	0.23	0.14	0.087	0.042	0.011
	50	G	0.39	0.18	0.09	0.04	0.013	0.003
		W	0.39	0.21	0.14	0.085	0.042	0.011
	75	G	0.36	0.17	0.09	0.039	0.012	0.003
		W	0.36	0.2	0.13	0.083	0.041	0.011

[1] All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists. Idle land refers to land with undisturbed profiles for at least a period of three consecutive years.

[2] Average fall height of waterdrops from canopy to soil surface.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a birds’s-eye view).

[4] G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep. W: Cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface, and/or undecayed residue).

Table E-5. C factors developed for land use and land cover types in the West Fork Gallatin River watershed.

		Land Use		
		Residential	**Ski Area**	**None**
Land Cover	**Grass**	0.05	0.05	0.05
	Soil/Sparse Veg	0.9	0.3	0.1
	Rock	0.001	0.001	0.001
	Forest	0.004	0.004	0.004
	Urban	0.03	0.03	N/A
	Water	0	0	0

Existing BMP Implementation

Field observations indicate that residential and ski development areas have varying levels of BMPs installed to mitigation sediment runoff. In general, more recent construction has a higher level of BMPs than older development. However, recent development has taken place in steeper areas with more erosive soils that require more actions to mitigate sediment. Prior to model development, a coarse field review of existing BMPs was conducted. Observed BMPs include:

- Fiber wattles and straw bales at stream crossings and in drainage ditches,
- Rock lined storm water conveyance ditches,
- Storm water retention ponds with rock armored inlet and outlet channels,
- Storm water diversion channel with erosion blankets,
- Silt fencing at road crossings and active construction sites,
- Log terracing on hillslopes, and
- Inlet and outlet protection at culverts.

Photographs of these BMPs are included at the end of this appendix. (Photos 1-6)

Association Between BMPs and Desired Load Reductions

BMP efficiencies vary by the type of BMP implemented. Literature values suggest 85 percent sediment reduction is achievable with full implementation of vegetated buffer BMPs and is therefore used as the reduction capacity for the desired conditions scenario within the model. The following studies support the 85 percent BMP reduction factor:

- Oat buffer strips, six meters long, reduced sediment by 76 percent (Hall et al.., 1983).
- Mickelson et al. (2003) determined that the first few meters of the buffer strip trapped the majority of deposited sediment. Buffer strips 4.6 meters long and with a drainage area to buffer strip area ratio of 10:1 reduced sediment by 71 percent while the 9.1 meters long buffer strip with a ratio of 5:1 reduced sediment delivery by 87 percent.
- Grassed waterways reduced suspended sediment concentrations by 94 and 98 percent in wet and dry antecedent moisture conditions, respectively (Asmussen et al., 1977).
- Han et al. (2005) determined that vegetative filter strips, 10 meters in length, were effective at removing more than 85 percent of the incoming total suspended sediment from highway runoff.

P-Factor

P factor is the conservation or support practice factor. Within the USPED model used for this project, P factor is used as a coefficient that represents the level of change in C-factor associated with improvement in land condition or BMPs. Therefore, two separate sets of P factors were used for the two model scenarios: current conditions and that associated with the use of all reasonable land, soil, and water conservation practices (i.e. desired conditions). This recognizes the general level of BMP implementation currently in place and also the potential for reductions in loading associated with additional BMP usage. Because the C factor is multiplied by the P factor within the model, values within **Table E-4** were also used during the development of P factors. As shown in **Tables E-6** and **E-7**, which contain the P factors for each scenario, all P factor values are equal to one with the exception of "Soil/Sparse Vegetation" land cover located in residential or ski area land uses. Therefore, these are the only areas that will have appreciable differences in sediment production between the two model scenarios.

Table E-6. P factors developed for land use and land cover types in the west Fork Gallatin River watershed, current conditions model scenario.

		Land Use		
		Residential	**Ski Area**	**Other**
Land Cover	**Grass**	1	1	1
	Soil/Sparse Veg	0.22	0.67	1
	Rock	1	1	1
	Forest	1	1	1
	Urban	1	1	1
	Water	1	1	1

Table E-7. P factors developed for land use and land cover types in the west Fork Gallatin River watershed, desired conditions model scenario.

		Land Use		
		Residential	**Ski Area**	**Other**
Land Cover	**Grass**	1	1	1
	Soil/Sparse Veg	0.14	0.4	1
	Rock	1	1	1
	Forest	1	1	1
	Urban	1	1	1
	Water	1	1	1

Effective C-Factor

The effective C factor is the product of the C and P factors and is a result of the baseline condition modified by the use of BMPs. For example, the P factor under the current conditions scenario for soil/sparse vegetation is 0.22 for residential areas and 0.67 for ski areas, which represents the greater potential for erosion-reducing BMPs in the more highly disturbed soil/sparse vegetation of the residential areas. When multiplied by their respective C factor (0.9

for residential and 0.3 for ski areas), it yields an effective C factor of 0.2 for the current conditions scenario of both land use categories. This represents a 78 percent reduction in erosion in the model within residential areas and a 33 percent reduction in ski areas as a result of existing BMPs (the effect on deposition is variable across the landscape). The effective C factor values also correlate with the C factors in **Table E-5**; a C factor of 0.2 corresponds to an area with no appreciable canopy and 20 percent ground cover and a C-factor of 0.1 represents approximately 40 percent ground cover (grass, litter) with minimal canopy cover.

For the desired conditions scenario for sparsely vegetated ground cover in residential areas, the C factor multiplied by P factor is 0.12 (0.9*0.14=0.12). This gives an effective C factor of 0.12, which is just slightly more than the 0.1 value for the naturally occurring condition ("Other" land use category). This correlates to a C factor for no appreciable canopy cover and close to 40 percent ground cover in **Table E-5**. Note that the change in P factor from current to desired conditions reduces C factor by an additional seven percent (i.e. 78 to 85 percent reduction). This recognizes the potential for additional BMP implementation but also the significant level of BMPs and revegetation currently in place that serve to reduce sediment loading to streams. This scenario is illustrated in the flow chart in **Figure E-8**.

Current Conditions Model Scenario

C Factor
(Base Condition – No BMPs)

		Land Use		
		Residential	**Ski Area**	**None**
Land Cover	**Grass**	0.05	0.05	0.05
	Soil/Sparse Veg	0.9	0.3	0.1
	Rock	0.001	0.001	0.001
	Forest	0.004	0.004	0.004
	Urban	0.03	0.03	0.03
	Water	0	0	0

X

P Factor
(Existing BMP Correction Factor)

		Land Use		
		Residential	**Ski Area**	**None**
Land Cover	**Grass**	1	1	1
	Soil/Sparse Veg	0.22	0.67	1
	Rock	1	1	1
	Forest	1	1	1
	Urban	1	1	1
	Water	1	1	1

=

Effective C Factor
(Existing Load)

		Land Use		
		Residential	**Ski Area**	**None**
Land Cover	**Grass**	0.05	0.05	0.05
	Soil/Sparse Veg	0.2	0.2	0.1
	Rock	0.001	0.001	0.001
	Forest	0.004	0.004	0.004
	Urban	0.03	0.03	0.03
	Water	0	0	0

Desired Conditions Model Scenario

C Factor
(Base Condition – No BMPs)

		Land Use		
		Residential	**Ski Area**	**None**
Land Cover	**Grass**	0.05	0.05	0.05
	Soil/Sparse Veg	0.9	0.3	0.1
	Rock	0.001	0.001	0.001
	Forest	0.004	0.004	0.004
	Urban	0.03	0.03	0.03
	Water	0	0	0

X

P Factor
(Potential BMP Correction Factor)

		Land Use		
		Residential	**Ski Area**	**None**
Land Cover	**Grass**	1	1	1
	Soil/Sparse Veg	0.14	0.4	1
	Rock	1	1	1
	Forest	1	1	1
	Urban	1	1	1
	Water	1	1	1

=

Effective C Factor
(Desired Load)

		Land Use		
		Residential	**Ski Area**	**None**
Land Cover	**Grass**	0.05	0.05	0.05
	Soil/Sparse Veg	0.12	0.12	0.1
	Rock	0.001	0.001	0.001
	Forest	0.004	0.004	0.004
	Urban	0.03	0.03	0.03
	Water	0	0	0

Figure E-8. Flow chart showing the relationship between C factor and P factor in the USPED model.

ArcGIS Model

Several preliminary models were developed in order to test the USPED model and to calibrate results with literature-based values for similar geographic and climatic settings. Two final model scenarios were then generated that provide the information necessary for TMDL development. These are a current conditions scenario and a desired conditions scenario. The desired conditions model scenario meets the criteria of "naturally occurring", which means conditions over which man has no control or from developed land where all reasonable land, soil, and water conservation practices have been applied (ARM, 2005).

The input model grids were assembled in an ArcGIS project. Numeric calculations to the grid datasets were completed using a series of grid statements input into the ArcGIS Spatial Analyst raster calculator. All grid statements are included with the portable ArcGIS project that accompanies this document. The model output consists of an erosion/deposition grid with both negative (erosion) and positive (deposition) values. Summarizing the grid values within a polygon allows tallying the net erosion or deposition within that polygon. Results were summarized by sub-watershed and by land use (see below).

Results

Table E-8 summarizes the estimated annual sediment load associated with the current condition and desired condition scenarios, and the associated reductions in sediment load. Loads are presented by land use category within each 303(d) listed watershed but also include additional sub-watersheds and the total load for each listed watershed.

The percent reductions are the differences in predicted sediment delivered to streams between the current conditions model and the desired conditions model. Sediment reductions are listed for residential and ski area land uses within the sub-watersheds. No reductions are associated with the naturally occurring load ("none" in the land use column). The model results predict that 82,811 tons/year of sediment erodes from hillslopes and is delivered to streams annually. The model further predicts that via additional BMP implementation, the total sediment load can be reduced for the three 303(d) watersheds by 3,453 tons/year.

Examining the sediment loads by land use indicates that under current conditions, 66 percent of sediment loading is from areas without human impacted land uses, 26 percent is from residential areas, and eight percent is from ski areas. The desired condition overall represents a four percent reduction in total sediment from hillslope erosion. However, this reduction requires a 13 percent reduction in hillslope sediment from residential areas and a nine percent reduction in hillslope sediment from ski areas.

Table E-9 summarizes sediment loads by land use, 303(d) watershed, and the entire project area watershed. For the project area, desired sediment loads are 11 percent lower than existing conditions in residential areas and eight percent lower than existing conditions at ski areas. For the entire project area watershed, desired sediment loads from hillslopes are four percent lower than existing conditions. Note: **Tables E-8** and **E-9** do not account for the riparian buffer health, which is incorporated into the attached Riparian Health Addendum.

Table E-8. Results of hillslope sediment modeling, West Fork Gallatin River watershed.

Watershed Information					Current Conditions			Desired Reductions		
303(d) Watershed	**Sub-Watershed**	**Area (acres)**	**Land Use**	**Area (acres)**	**Sediment (tons/yr)**	**Sediment (tons/yr)**	**Sediment (tons/yr)**	**Sediment Reduction (tons/yr)**	**Percent Reduction from Current Conditions**	**Sediment Reduction (tons/yr)**
Middle Fork West Fork Gallatin River	Uppermost Middle Fork West Fork Gallatin River	3236	None	704	976	4,954	19,853	0		1,726
			Residential	945	1,054			92	9%	
			Ski Area	1,587	2,924			310	11%	
	Beehive Creek	2065	None	1,654	768	3,230		0		
			Residential	411	2,462			135	5%	
	Middle Fork West Fork Gallatin River	6204	None	3,205	3,570	11,669		0		
			Residential	1,873	6,702			1,088	16%	
			Ski Area	1,126	1,397			101	7%	
South Fork West Fork Gallatin River	Upper South Fork West Fork Gallatin River	6530	None	3,843	3,184	6,579	47,212	0		1,287
			Residential	626	1,458			753	52%	
			Ski Area	2,061	1,938			147	8%	
	Third Yellow Mule Creek	2306	None	2,289	1,553	1,556		0		
			Residential	17	2			0	6%	
	Muddy Creek	5772	None	5,355	6,450	7,013		0		
			Residential	2	4			0	0%	
			Ski Area	415	559			18	3%	
	Second Yellow Mule Creek	2887	None	2,865	2,558	2,570		0		
			Residential	23	12			3	22%	
	First Yellow Mule Creek	3511	None	3,511	3,689	3,689		0		
	South Fork West Fork Gallatin River	8648	None	6,115	20,542	25,805		0		
			Residential	2,533	5,263			365	7%	

Table E-8. Results of hillslope sediment modeling, West Fork Gallatin River watershed.

Watershed Information					Current Conditions			Desired Reductions		
303(d) Watershed	**Sub-Watershed**	**Area (acres)**	**Land Use**	**Area (acres)**	**Sediment (tons/yr)**	**Sediment (tons/yr)**	**Sediment (tons/yr)**	**Sediment Reduction (tons/yr)**	**Percent Reduction from Current Conditions**	**Sediment Reduction (tons/yr)**
West Fork Gallatin River	North Fork West Fork Gallatin River	6223	None	5,747	5,612	6,867	15,746	0		440
			Residential	476	1,255			149	12%	
	Upper West Fork Gallatin River	553	None	60	159	806		0		
			Residential	493	647			152	23%	
	Crail Creek	1366	None	1,093	323	749		0		
			Residential	273	426			9	2%	
	Lower West Fork Gallatin River	1143	None	904	872	2,388		0		
			Residential	239	1,516			31	2%	
	Lowermost West Fork Gallatin River	792	None	658	4,230	4,937		0		
			Residential	134	707			99	14%	
			TOTALS	51,238	82,811		82,811	3,453		3,453

Table E-9. Sediment loads summarized by land use and 303(d) watershed.

Watersheds	Current Conditions			Desired Reductions		
303(d) Watershed	**Land Use**	**Acres**	**Sediment (tons/yr)**	**Sediment Rate (tons/ac/yr)**	**Desired Load (tons/yr)**	**Percent Reduction from Current Conditions**
Middle Fork West Fork Gallatin River	None	5,563	5,314	1.0	5,314	0%
	Residential	3,229	10,218	3.2	8,903	13%
	Ski Area	2,713	4,321	1.6	3,910	10%
	All Uses	11,505	19,853	1.7	18,126	9%
South Fork West Fork Gallatin River	None	23,978	37,977	1.6	37,977	0%
	Residential	3,200	6,739	2.1	5,983	11%
	Ski Area	2,476	2,497	1.0	2,331	7%
	All Uses	29,654	47,212	1.6	46,291	2%
West Fork Gallatin River	None	8,462	11,196	1.3	11,196	0%
	Residential	1,616	4,550	2.8	4,210	7%
	Ski Area	0	0	0.0	0	0%
	All Uses	10,078	15,746	1.6	15,406	2%
Project Area (Entire West Fork Gallatin River Watershed	None	38,004	54,487	1.4	54,487	0%
	Residential	8,045	21,507	2.7	19,095	11%
	Ski Area	5,189	6,818	1.3	6,241	8%
	All Uses	51,238	82,811	1.6	79,823	4%

Model Uncertainty

Natural processes such as sediment erosion and delivery, associated with rainfall and runoff are infinitely complex. Modeling of these processes requires significant simplification. Notably, the model has limited temporal resolution, and does not account well for seasonal and event scale processes. The USPED model created for the West Fork Gallatin River provides estimates of average annual sediment loads. Examples of similar models in the literature typically over predict annual sediment loads under normal or low runoff conditions and under predict annual loads under high runoff conditions. Therefore, the intent is that the average annual sediment load predicted should be applicable over long periods of time that include both low, average, and high runoff years. It is possible that sediment delivery to streams in a watershed such as the West Fork Gallatin River can be minimal for many consecutive years and then very high during the next year.

The results of the West Fork Gallatin River model predict areas where relatively large amounts of sediment are delivered to streams. These are areas that should be examined more closely to locate areas where BMPs would be most beneficial.

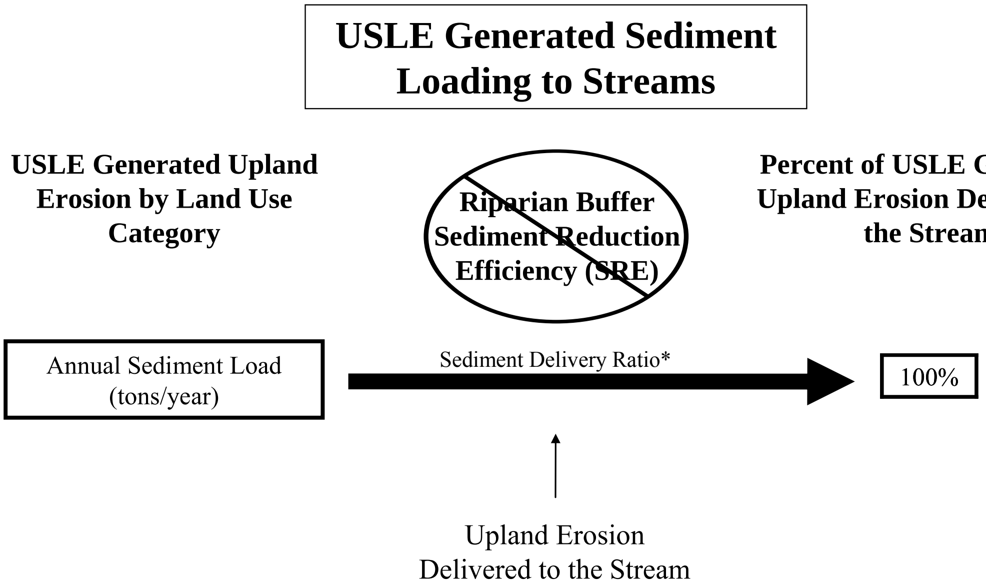
RIPARIAN HEALTH ADDENDUM

Upland Erosion Loading Corrected for Existing and Potential Riparian Buffer Condition

Introduction

The upland erosion modeling effort did not take into account the effect that vegetated riparian buffers have on reducing the upland sediment load delivered to streams. **Figure E-9** depicts the modified USLE modeling process without the influence of riparian buffers included; therefore, it models 100 percent of the USLE generated annual sediment load being delivered to the stream network. Because riparian buffers play a large role in reducing sediment (and other pollutant) loading to streams, a secondary effort to qualify and quantify the influence of riparian buffers was undertaken and is presented here.

Figure E-9. USLE Upland Sediment Modeling Negating the Influence of the Riparian Buffer.



*Sediment delivery ratio based upon distance from stream

This secondary effort provides an additional assessment of the sediment loading from upland sources routed through the existing riparian buffer condition, as well as an assessment of potential sediment loading reductions gained through the application of Best Management Practices (BMPs) to those activities whose actions within the near stream riparian environment have the potential to affect the buffering capacity (i.e. sediment reduction efficiency) of the vegetated riparian buffer.

Although regulations allow that loadings “may range from reasonably accurate estimates to gross allotments” (Water quality planning and management, 40 CFR § 130.2(G)), riparian buffers play a large role in reducing sediment delivery to stream channels, and adjusting the modeled upland sediment loads to reflect this should result in loading estimates that are closer in magnitude to reality. However, it is important to recognize that the results are not actual loading values and more emphasis should be placed on the potential reductions in loading that can be achieved via implementation of upland and riparian BMPs.

Effect of Riparian Buffers on Sediment Loading to Streams

Vegetated riparian buffers function as filters that protect adjoining streams and downstream receiving waters (Martin, 1999). By minimizing disturbance and encroachment, riparian buffers protect and enhance the filtering functions through which riparian corridors sequester and remove sediments, nutrients, and a range of contaminants. These water quality services result from filtration, adsorption, and entrainment by riparian vegetation. Vegetated riparian buffers disperse concentrated or channelized runoff, increasing infiltration, slowing surface runoff, and enhancing the deposition of sediment and sediment associated contaminants from both overland flows and overbank floodwaters (CRWP 2006). Buffers create complex flowpaths that slow the velocity and decrease the turbulence in overland flow. Shallow distributed flow enhances sedimentation and the removal of sediment-associated contaminants while increasing infiltration and reducing surface runoff (Leeds-Harrison, 1999 and Burt, 1999).

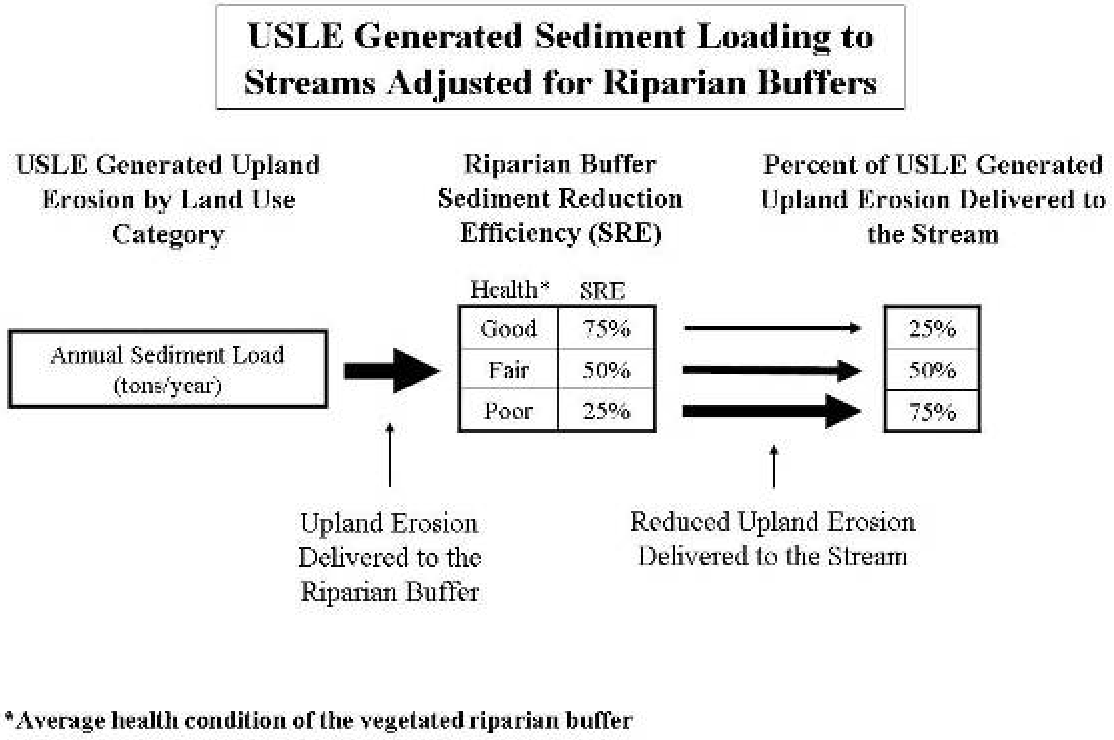
Vegetated riparian buffers maintain the connectivity and exchange of surface water and ground water between rivers and uplands. Maintaining riparian zones and effective land use practices within these zones are widely recognized as two valuable strategies to prevent the degradation of water quality services provided by these essential riparian processes (Hancock, 2002). Because of their ability to reduce upland sources of pollutants, the influence of riparian corridors on water quality is proportionately much greater than the relatively small area in the landscape they occupy. That is, the effectiveness of vegetated riparian buffers is proportional to their widths and overall health.

Sediment removal efficiency relationships developed by Castelle and Johnson (2000) estimated near 80% sediment removal and 65% particulate organic matter removal across a comparable buffer width. Results from within Montana suggest that the application of an 11 meter buffer strip can provide for a uniform loading reduction of 25% generated from upland erosional sources (Middle Blackfoot TMDL). This 25% reduction is significantly lower than those reported in the literature. Other research in southwest Montana reported greater than 90% removal of coarse textured sediment with a six meter buffer on bunchgrass uplands (Hook 2003).

For this analysis, a sediment reduction efficiency of 75% was assumed to represent the loading condition for a healthy (Good) vegetated riparian buffer. This value better reflects those reported in the literature and is closer to results reported for Montana settings while allowing for some hillslope loading from developed and disturbed land. With 75% removal, 25% of the USLE generated upland hillslope load is delivered to the stream and assumed to be the natural occurring annual maximum load from upland hillslope erosion. The remaining 75% of the load is assumed to be controllable by riparian health and associated buffering capacity.

As the condition of the vegetated riparian buffer declines or is degraded, sediment reduction efficiencies of 50% and 25% are then assumed to represent the loading condition for moderately disturbed (Fair) and heavily disturbed (Poor) conditions. That is, as the overall health of the vegetated riparian buffer is degraded, hence reducing its buffering capacity (sediment reduction efficiency), sediment loading delivered to the stream from upland sources increases. With 50% and 25% removal, 50% and 75% of the USLE generated upland erosion is delivered to the stream (**Figure E-10**).

Figure E-10. USLE Upland Sediment Load Adjusted for Riparian Buffer Capacity.



Modeling Approach and Example

This section outlines the approach that was implemented to evaluate the effect that vegetated riparian buffers have on sediment production within the Upper Gallatin TPA.

Desired results from the modeling effort include the following: (1) annual USLE based sediment load from each of the water quality limited segments on the state’s 303(d) List corrected for the existing riparian buffer condition, (2) the mean annual source distribution from each land category type, and (3) annual potential USLE based sediment load from each of the water quality limited segments after the application of upland and riparian buffer BMPs.

Based on these considerations, a simple spreadsheet modeling approach was formulated to facilitate data manipulation, and supply output for this effort. The modeling approach is provided below and for clarity’s sake, an example is provided for Beehive Creek, which is a tributary to the Middle Fork West Fork Gallatin River.

USLE Based Existing Upland Sediment Load Corrected for the Existing Riparian Buffer Condition

This section defines the process by which the existing USLE upland sediment loads provided in **Table E-8** were corrected for the existing riparian buffering condition to more accurately predict the existing sediment load. The existing riparian buffer condition was derived from *Aerial Assessment Reach Stratification Upper Gallatin TMDL Planning Area* (**Appendix E**), in which riparian health was qualified as Good, Fair or Poor (see example **Table E-10,** also **Figure E-11**).

Figure E-11. Existing Riparian Buffer Condition in the West Fork Gallatin River Watershed.

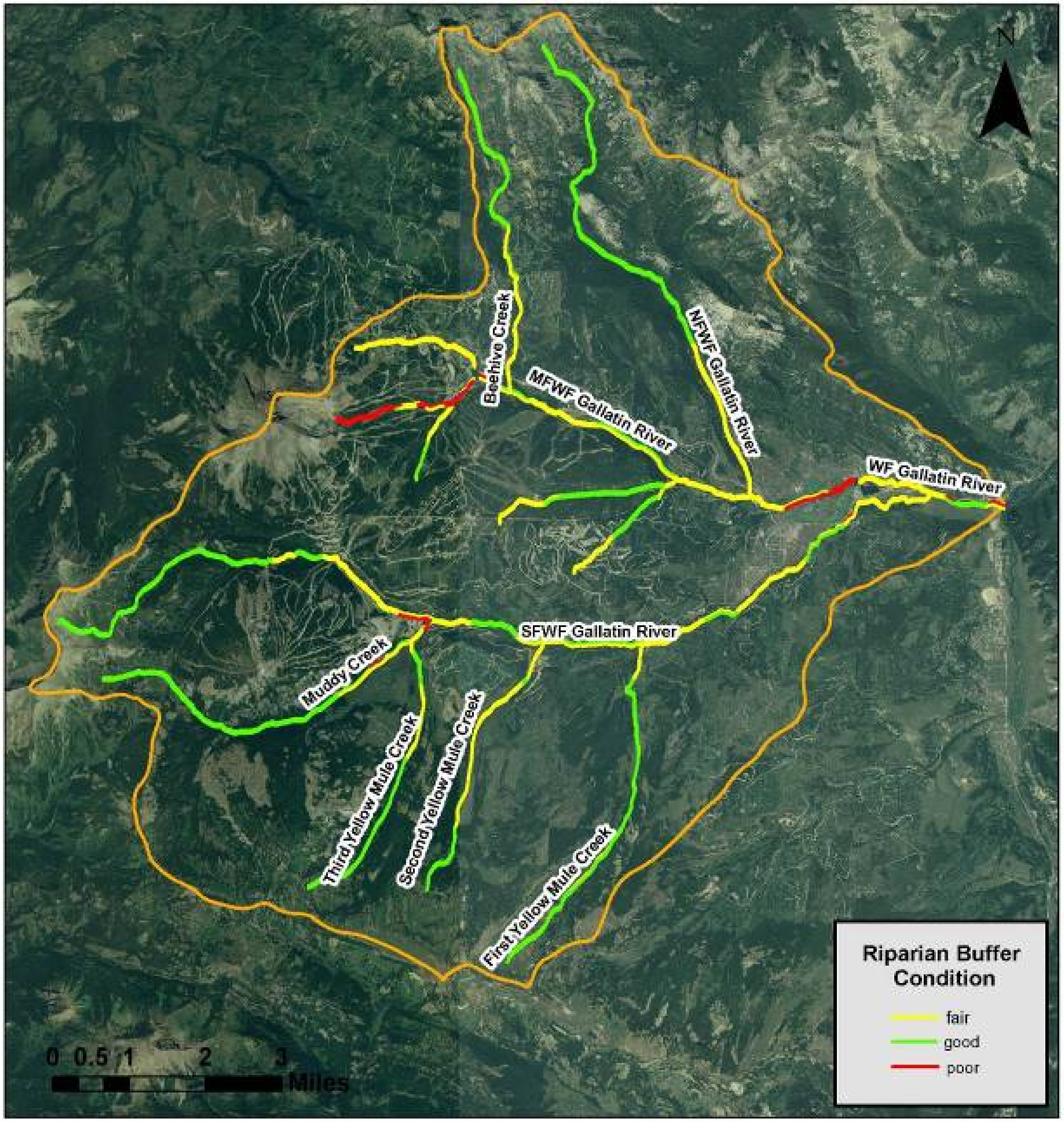


Table E-10. Existing Riparian Buffer Condition as a Percent of the Total Stream Length: Beehive Creek.

Existing Riparian Buffer	Stream Length (mi)	Percent of Total Length
Good	5.7	60%
Fair	3.9	40%
Poor	0.0	0%
Total	9.6	100%

In the example above, Beehive Creek has a total stream length of 9.6 miles when both banks are included. Of those 9.6 miles of stream, the existing health condition of the riparian buffer was defined as consisting of 5.7 miles of Good, 3.9 miles of Fair, and 0.0 miles of Poor; representing 60, 40 and 0 percent of the total stream length, respectively.

Once the existing condition of the riparian buffer was generated by sub-watershed following the procedure above, the existing upland sediment load generated from the USLE model was partitioned by land-use into one of the three riparian health categories based upon the relative percent of the total stream length for each category. Next, the portioned load was reduced by the appropriate sediment reduction efficiency for that riparian health category and then summed to represent the delivered upland sediment load corrected for the existing riparian buffer condition (see example **Table E-11**). Note: Riparian health classifications are not spatially related to land use categories but approximate conditions at the watershed scale.

Table E-11. Upland Erosion USLE Generated Load Adjusted for the Existing Riparian Buffer Condition: Beehive Creek.

Sources	Upland Erosion USLE Generated Load: Existing Condition (tons/yr)	Load Partitioned for Existing Riparian Health Condition (tons/yr)			Delivered Load: Upland Erosion USLE Load Corrected for Existing Riparian Health Condition (tons/yr)
		Good (60%)*	Fair (40%)*	Poor (0%)*	
Natural**	768	144	96	0	240
Residential	2462	366	498	0	865
Total	3230	510	594	0	1105

*The percent value relates to the percent of the total stream length categorized as having that health category.
**Natural sources evaluated using 75% Good, 25% Fair, and 0% Poor riparian health conditions.

In the example above, Beehive Creek has a total upland USLE based modeled load of 3230 tons of sediment per year. This load represents the amount of sediment generated from the existing upland sources and their existing condition. This load was then portioned based upon the existing riparian condition. For example, the sediment load generated from residential sources of 2462 tons/year is partitioned between the riparian health categories based upon their relative watershed extent and then reduced based upon the sediment reduction efficiencies for each health category. For example, at the watershed scale of the 2462 tons/year produced in Beehive Creek from residential sources, 60% of the load was portioned and routed through a Good riparian buffer with a sediment reduction efficiency of 75%, yielding 366 tons of sediment per year for that health category. In addition, 40% of the residential load was portioned and routed through a Fair riparian buffer a sediment reduction efficiency of 50%, yielding 498 tons of sediment per year for that health category. For natural sources (which are assumed to areas where all reasonable BMPs are in place), the existing riparian condition is assumed to be meeting its potential, and the existing load was portioned as 75% Good and 25% Fair. The sediment yields were then summed to represent the delivered sediment load from residential sources corrected for the existing riparian buffer condition (865 tons/year). **Figure E-12** graphically depicts this Beehive Creek example. Therefore, in Beehive Creek, the existing USLE based upland sediment load of 3230 tons/year from all sources was reduced to 1105 tons/year representing the modeled existing upland sediment load delivered to the stream.

USLE Based Upland BMP Sediment Load Corrected for Riparian Best Management Practices

This section provides an assessment of the additional sediment loading reductions gained through the application of Best Management Practices (BMPs) on those activities whose actions within the near stream riparian environment have the potential to affect the buffering capacity (i.e. sediment reduction efficiency) of the vegetated riparian buffer.

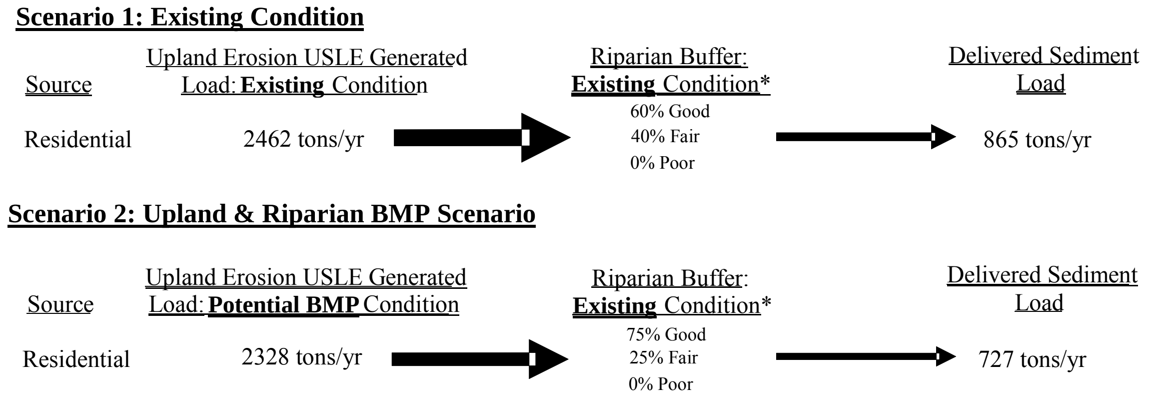
For this analysis, a sediment reduction efficiency of 75%, 50% and 25% was assumed to represent the loading condition for a healthy (Good), moderately disturbed (Fair) and heavily disturbed (Poor) vegetated riparian buffer. Under this BMP scenario, it is assumed that the implementation of BMPs increases the watershed scale buffering condition from its existing health condition to a 75% Good and 25% Fair buffering condition. The concept is that through the application of BMPs, the general health of the vegetated riparian buffer will increase, hence increasing its sediment reduction efficiency. This BMP scenario assumes that 25% of the stream will be left in Fair condition and 0% will be of a Poor condition. This scenario allows some reasonable level of disturbance while not allowing for heavily disturbed conditions.

Following the example in **Table E-11,** the upland erosion USLE generated BMP load was again partitioned and routed through the riparian buffer**.** For this analysis, the upland BMP load was routed through the riparian buffer BMP condition. The resulting load then represents the upland BMP load corrected for the riparian buffer BMP condition (see example **Table E-12 and Figure E-12**).

Table E-12. Upland BMP Load Partitioned and Reduced based upon the BMP Riparian Buffer Condition: Beehive Creek.

Source	Upland Erosion USLE Generated Load: BMP Condition (tons/yr)	Load Partitioned for BMP Riparian Health Condition (tons/yr)		Delivered Load: Upland Erosion USLE BMP Load Corrected for Riparian BMP Health Condition (tons/yr)
		Good (75%)*	Fair (25%)*	
Natural	768	144	96	240
Residential	2328	436	291	727
Total	3096	580	387	967

Figure E-12. Beehive Creek Example Scenarios.



*The percent values relate to the percent total stream length categorized as having that health category.

In the Beehive Creek example, the current estimated annual upland sediment load is 3230 tons/year. Through the application of upland BMPs, it is estimated that the upland USLE based sediment load can be reduced by 4% from 3230 tons/year to 3096 tons/year (**Table E-13**). The annual upland sediment load was reduced from 3230 tons/year to 1105 tons/year when existing riparian vegetation conditions are considered. The annual upland BMP sediment load was reduced from 3096 tons/year to 967 tons/year by applying riparian BMPs. Overall, a 12% reduction is achieved when the existing upland sediment load corrected for existing riparian conditions (1105 tons/year) is compared to the upland BMP load combined with riparian BMP conditions (967 tons/year).

Table E-13. Beehive Creek Summary.

Land Use	Upland Erosion USLE Generated Load: Existing Condition (tons/yr)	Upland Erosion USLE Generated Load: BMP Condition (tons/yr)	Upland BMP Load Reduction (Percent)	Upland Erosion USLE Load Corrected for Existing Riparian Health Condition (tons/yr)	Upland Erosion USLE BMP Load Corrected for Riparian BMP Health Condition (tons/yr)	Upland & Riparian BMP Load Reduction (Percent)
Natural	768	768	0%	240	240	0%
Residential	2462	2328	5%	865	727	16%
Total	3230	3096	4%	1105	967	12%

Results

This section presents the results of this analysis. Again, this data builds upon the upland USLE based sediment modeling results. **Table E-14** includes the existing riparian buffer condition, the existing USLE sediment load corrected for existing riparian conditions, the USLE BMP sediment load corrected for BMP riparian conditions, and the percent reduction that can be achieved through upland and riparian BMPs. Total sediment loads and percent reductions are also provided for the three main sub-watersheds in the Upper Gallatin TPA. Sediment loads for the entire West Fork Gallatin River watershed are summarized at the bottom of **Table E-14**.

Table E-14. Upland Sediment Loading Summary and Percent Reductions by Sub-watershed.

303(d) Watershed	**Sub-Watershed**	**Land Use**	**Riparian Buffer Existing Condition**			Upland Erosion USLE Load Corrected for **Existing** Riparian Health Condition (tons/yr)	Upland Erosion USLE **BMP** Load Corrected for Riparian **BMP** Health Condition (tons/yr)	**Upland & Riparian BMP Load Reduction (Percent)**
			Good (%)	**Fair (%)**	**Poor (%)**			
Middle Fork West Fork Gallatin River Sub-watershed	Uppermost Middle Fork West Fork Gallatin River	Natural	75%	25%	0%	305	305	0%
		Residential	6%	64%	30%	589	301	49%
		Ski Area	6%	64%	30%	1633	817	50%
		Total				2527	1422	44%
	Beehive Creek	Natural	75%	25%	0%	240	240	0%
		Residential	60%	40%	0%	865	727	16%
		Total				1105	967	12%
	Middle Fork West Fork Gallatin River	Natural	75%	25%	0%	1116	1116	0%
		Residential	38%	61%	0%	2715	1754	35%
		Ski Area	38%	61%	0%	566	405	28%
		Total				4396	3275	26%
	Sub-watershed Total	**Natural**				**1661**	**1661**	**0%**
		Residential				**4168**	**2782**	**33%**
		Ski Area				**2199**	**1222**	**44%**
		Total				**8027**	**5664**	**29%**
West Fork Gallatin River Sub-watershed	North Fork West Fork Gallatin River	Natural	75%	25%	0%	1754	1754	0%
		Residential	71%	29%	0%	405	346	15%
		Total				2159	2099	3%
	Upper West Fork Gallatin River	Natural	75%	25%	0%	50	50	0%
		Residential	0%	53%	47%	399	155	61%
		Total				449	204	54%
	Crail Creek	Natural	75%	25%	0%	101	101	0%
		Residential	70%	25%	5%	144	130	9%
		Total				245	231	5%
	Lower West Fork Gallatin River	Natural	75%	25%	0%	272	272	0%
		Residential	0%	100%	0%	758	464	39%
		Total				1030	736	29%
	Lowermost West Fork Gallatin River	Natural	75%	25%	0%	1322	1322	0%
		Residential	49%	33%	17%	297	190	36%
		Total				1619	1512	7%
	Sub-watershed Total	**Natural**				**3499**	**3499**	**0%**
		Residential				**2004**	**1284**	**36%**
		Total				**5502**	**4783**	**13%**
South Fork West Fork Gallatin River Sub-watershed	Upper South Fork West Fork Gallatin River	Natural	75%	25%	0%	995	995	0%
		Residential	59%	38%	4%	527	220	58%
		Ski Area	59%	38%	4%	701	559	20%
		Total				2223	1775	20%
	Third Yellow Mule Creek	Natural	75%	25%	0%	485	485	0%
		Residential	73%	27%	0%	1	1	7%
		Total				486	486	0.01%
	Muddy Creek	Natural	75%	25%	0%	2016	2016	0%
		Residential	77%	19%	4%	1	1	1%
		Ski Area	77%	19%	4%	177	169	4%
		Total				2194	2186	0.4%
	Second Yellow Mule Creek	Natural	75%	25%	0%	799	799	0%
		Residential	44%	56%	0%	5	3	37%
		Total				804	802	0.2%
	First Yellow Mule Creek	Natural	79%	21%	0%	1117	1117	0.0%
		Total				1117	1117	0.0%
	South Fork West Fork Gallatin River	Natural	75%	25%	0%	6419	6419	0%
		Residential	28%	71%	1%	2281	1530	33%
		Total				8700	7950	9%
	Sub-watershed Total	**Natural**				**11832**	**11832**	**0%**
		Residential				**2815**	**1755**	**38%**
		Ski Area				**878**	**729**	**17%**
		Total				**15524**	**14316**	**8%**
West Fork Gallatin River Watershed	**Watershed Total**	**Natural**				**16991**	**16991**	**0%**
		Residential				**8986**	**5822**	**35%**
		Ski Area				**3077**	**1950**	**37%**
		Total				**29054**	**24764**	**15%**

Photos of BMP Examples within the West Fork Gallatin River Watershed

Photo 1. Fiber wattles used at a road crossing.

Photo 2. Fiber wattles used along a road ditch.

Photo 3. Rock lined storm water conveyance channel.

Photo 4. Rock lined storm water conveyance channel and sediment retention pond.

Photo 5. Silt fence installed at road crossing.

Photo 6. Hillslope terracing with logs and inlet protection at culvert.

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APPENDIX F
UNPAVED ROAD SEDIMENT ASSESSMENT

INTRODUCTION

This appendix presents an assessment of sediment associated with both paved and unpaved roads in the West Fork Gallatin River watershed. This project utilized a combination of GIS analysis, field data collection, WEPP roads modeling, and data analysis and extrapolation to estimate sediment loading to streams at or near road crossings. The project includes estimation of existing sediment loading conditions and identification of achievable road sediment loading reductions via the implementation of additional best management practices (BMPs).

The West Fork Gallatin River Roads Assessment consisted of four major tasks:
- Spatial (GIS) data compilation and analysis,
- Field data collection,
- Road sediment load modeling, and
- Extrapolation.

The West Fork Gallatin River Roads Assessment evaluated three sources of sediment loading from roads. These are:
- Road/stream crossings,
- Sediment from traction sanding, and
- Sediment from potential culvert failure.

Road disturbances near and adjacent to stream crossings can be a sediment source to streams. These disturbances include the road surface, cut slope, fill slope, and drainage ditch. Both paved and unpaved roads can contribute sediment to streams, although because paved roads do not contribute sediment from the road surface, they typically contribute a much smaller sediment load than unpaved roads. However, traction sand applied to paved roads in the winter has the potential to be a significant sediment source to streams. Traction sand usage in the watershed consists of application to state Hwy 64 in the winter by the Montana Department of Transportation (MDT) and application to private roads by local homeowner associations and ski areas. Undersized, improperly installed, or inadequately maintained culverts can also be sources of sediment. For instance, significant amounts of sediment may be delivered to streams if culverts fail during large runoff events, or if a culvert does not fail but is undersized, a portion of the road fill material could be eroded by water flowing over or around the culvert. The risk of culvert failure and loading of associated fill material is equal to the probability of the occurrence of a runoff event larger than the capacity of the culvert.

The following sections describe the roads source assessment in more detail. Results of the modeling and load calculations are within each section on sediment sources.

Spatial Data Compilation and Analysis

Compilation and analysis of publicly available GIS data layers identified road/stream crossings and allowed development of a field data collection strategy. Roads data covering Gallatin and Madison Counties intersected with National Hydrography Dataset (NHD) streams identified road-stream intersections. Errors in the road type attributes were corrected by field verification. The intersections (stream crossings) were then categorized by road type (paved, gravel, or dirt), land ownership, and sub-watershed. This analysis identified 98 road-stream intersections in the watershed.

The 80 square-mile West Fork Gallatin River watershed is primarily privately owned (71 %), with the remainder owned by the U.S. Forest Service (28%) and the State of Montana (1%). Total road length in the watershed is 214 miles. All 98 of the road/stream crossings are on privately owned land. **Table F-1** and **Figure F-1** presents information on road/stream crossing types in the watershed and the distribution of the assessed crossings. Although most crossings are paved, a large proportion of unpaved crossings were assessed because unpaved crossings have a much greater capacity to be sediment sources than paved crossings. **Table F-2** contains the distribution of crossings by sub-watershed. The watershed ID listed in **Table F-2** corresponds to the watershed ID label on the map in **Figure F-2** below.

Table F-1. Road/stream crossing types, West Fork Gallatin River watershed.

Road Type	Count	Percent of Crossings	Assessed	Percent Assessed
Paved	70	71%	14	20%
Gravel	17	17%	2	12%
Native/Dirt	11	11%	9	82%
Totals	98	100%	25	26%

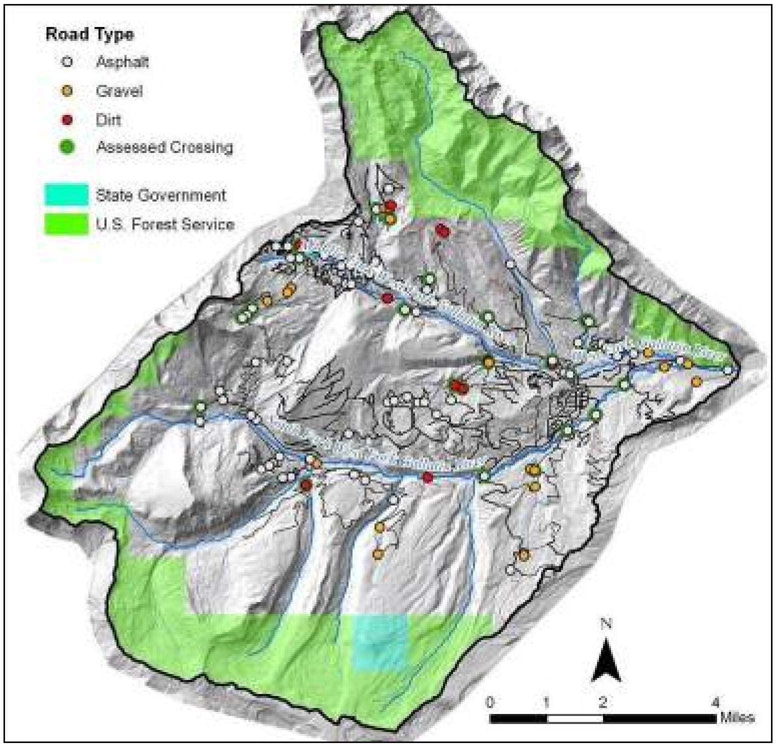


Figure F-1. Distribution and type of road/stream crossings in the project area.

Table F-2. Distribution of road/stream crossings in the West Fork Gallatin River watershed.

Watershed ID	Sub-Watershed Name	Number of Crossings	Acres	Square Miles	Crossings/ Square Mile
1	Beehive Creek	9	2066	3.2	2.8
2	North Fork West Fork Gallatin River	1	6230	9.7	0.1
3	Crail Creek	4	1367	2.1	1.9
4	West Fork Gallatin River above WWTP	6	1143	1.8	3.4
5	Upper Middle Fork West Fork Gallatin River	15	3240	5.1	3.0
6	Upper West Fork Gallatin River	4	554	0.9	4.6
7	Lowermost West Fork Gallatin River	3	794	1.2	2.4
8	Middle Fork West Fork Gallatin River	23	6205	9.7	2.4
9	Upper South Fork West Fork Gallatin River	12	6530	10.2	1.2
10	South Fork West Fork Gallatin River	14	8652	13.5	1.0
11	Muddy Creek	3	5775	9.0	0.3
12	Third Yellow Mule Creek	1	2307	3.6	0.3
13	Second Yellow Mule Creek	3	2889	4.5	0.7
14	First Yellow Mule Creek	0	3514	5.5	0.0

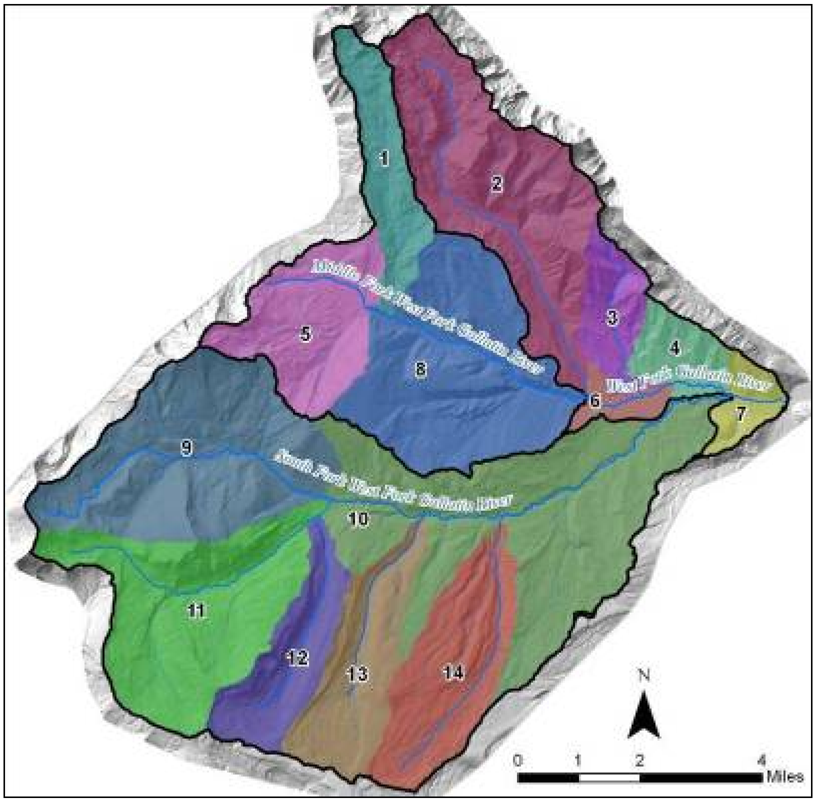


Figure F-2. Sub-watershed delineation in the West Fork Gallatin River watershed.

Field Data Collection

Field crews along with Montana DEQ personnel conducted a field reconnaissance in early October 2008. The field reconnaissance, along with the spatial data component, assisted with identification of representative areas for field data collection. Field data collection forms were developed and reviewed by Montana DEQ. Field data collection was limited by access to private lands. Where access to private land was granted, field crews assessed those stream crossings. When landowners could not be reached, or did not grant permission, stream crossings were not assessed.

Field personnel collected data from 25 road crossings in late October, 2008. The surfaces of 14 of the 25 crossings were asphalt, two were gravel, and nine were native/dirt. Road sediment sources evaluated were:

- Road crossings
- Traction sand
- Potential culvert failure

SEDIMENT FROM ROAD CROSSINGS

The Water Erosion Prediction Project (WEPP) model was the tool chosen for assessment of sediment delivered from road/stream crossings (http://forest.moscowfsl.wsu.edu/fswepp/). Based on the large percentage of paved roads and other TMDL-related roads assessments in Montana, parallel road segments were assumed to be an insignificant source and not included in the analysis. Data collected in the field included the required inputs for the WEPP model. Field data included measurements of each overland flow element (road, fillslope, and buffer). This included:

- soil type,
- rock percent,
- road design,
- road surface type,
- traffic level,
- road width,
- road length (contributing length),
- road gradient,
- fillslope length,
- fillslope gradient,
- buffer length, and
- buffer gradient.

WEPP Modeling

WEPP is a process based, field scale, erosion prediction model that includes a graphical user interface for runoff and erosion prediction. The United States Department of Agriculture-Agricultural Research Service (USDA-ARS) developed WEPP in 1985 (Flanagan and Nearing, 1995) and the U.S. Forest Service developed the interface of the WEPP model, WEPP:Road (Elliot et al., 1999). The WEPP:Road interface (http://forest.moscowfsl.wsu.edu/fswepp/) allows users to predict sediment delivery rates based on various road conditions. The WEPP model was used for predicting sediment delivered from both paved and unpaved roads. Paved surfaces do not generate much sediment within the model, however, both paved and unpaved roads can deliver sediment from the cutslope, fillslope, or ditch.

Field data collected for each crossing were entered into the model. The WEPP model also generates climate input using the Rock:Clime Model version 2004.04.26 (Elliot et al., 1999b). Climate generated for the Big Sky, MT area was modified from the Mystic Lake, MT weather station, the nearest station with similar climate and sufficient data in the correct format for use in the WEPP model. The Mystic Lake climate data were then adjusted for elevation and average annual precipitation to more closely represent Big Sky conditions. All model runs were 50-year simulations, simulating the 50-year average annual sediment load from roads at each assessed crossing. A 30-50 year period of record is typical for this type of simulation (Elliot et al., 1999).

Model simulations yielded two types of output, simple and detailed. The standard WEPP road results window displays the simple output. Following the results link within this window displays the detailed output. The detailed output includes total sediment detachment and total sediment deposition. The difference between total sediment detachment and total sediment deposition gives the current sediment delivery rate for each road crossing. The total sediment detachment is the amount of sediment that would be delivered to the stream if there were no existing BMPs present to mitigate sediment delivery. Thus, the detailed data provides the current sediment load and a means to calculate the current level of sediment mitigation from BMPs.

Modeling Results

Table F-3 on the following page presents WEPP modeling results for the assessed road/stream crossings. It includes the crossing assessment site ID as well as the corresponding sub-watershed (i.e. Middle Fork, South Fork, or West Fork). The sediment detachment values (column three) are the estimated existing amount of sediment detached and transported in the road surface, fill slope, and buffer combined, whereas the sediment deposition values (column four) indicate the existing amount of sediment deposited after detachment and reflects when the capacity of existing BMPs to retain sediment and reduce sediment delivery to streams. Therefore, the sediment delivery values (column five) are the difference between sediment detachment and sediment deposition and represent sediment delivered to the stream at each crossing.

BMP sediment delivery values (column six) represent the sediment detachment calculation reduced by 85 percent, which is the desired reduction in sediment loading. The 85 percent represents full BMP implementation and reflects literature values, which are described further in the “Best Management Practices” section of this report. Finally, BMP sediment reduction values (column seven) are the loading reductions needed to achieve the 85 percent reduction associated with the BMP sediment delivery loads (i.e. BMP Sediment Delivery minus [existing] Sediment Delivery). Because the existing level of BMP implementation and sediment removal efficiency varies by site, the percent reduction needed to achieve the 85 percent reduction is variable from site to site.

It is acknowledged that the existing load and potential reductions are variable from crossing to crossing, but for the purposes of the source assessment and extrapolation, average values were derived for each road crossing type (**Table F-4**). Road type is a combination of road surface (paved, gravel, native/dirt) and traffic level (low, high). Based on the average load per crossing type and number of identified crossings per watershed, annual sediment loads were extrapolated by road type and to each 303(d) listed subwatershed and the entire West Fork Gallatin River watershed (**Tables F-4 and F-5**). For the entire watershed, road crossings are estimated to contribute 8.1 tons per year of sediment to streams. Full BMP implementation should reduce this sediment load to 2.8 tons per year. This represents a 65 percent reduction from the current 8.1 tons delivered.

Table F-3. WEPP modeling results for sediment contributed to streams from assessed road/stream crossings.

Road Crossing ID[2]	Sub-watershed	Sediment Detachment[3]	Sediment Deposition[3]	Sediment Delivery [3]	BMP Sediment Delivery [4]	BMP Sediment Reduction[5]	% Reduction Between Existing and BMP Load
		lbs/year [6]					
C1	SF	1875	1558	317	281	36	11%
C2	SF	--	--	--	--	--	--
C3	MF	118	35	84	18	66	79%
C4	MF	52	36	16	8	8	50%
C5	MF	162	146	16	24	0	0%
C6	MF	107	20	87	16	71	82%
C7	MF	479	102	377	72	306	81%
C8	MF	4	1	3	1	3	67%
C9	MF	99	42	57	15	42	74%
C10	MF	593	325	268	89	186	67%
C11	MF	279	43	235	42	194	82%
C12	WF	8016	5670	2346	1202	1143	49%
C13	MF	88	72	16	13	3	19%
C14	MF	209	42	167	31	136	81%
C15	MF	194	162	32	29	3	9%
C16	MF	1571	431	1140	236	905	79%
C17	MF	2994	727	2267	449	1818	80%
C18	WF	0	0	0	0	0	--
C19	WF	40	7	34	6	28	82%
C20	WF	--	--	--	--	--	--
C21	WF	4	0	4	1	3	75%
C22N	MF	218	20	198	33	165	83%
C22S	MF	83	17	65	12	53	82%
C23	SF	0	0	0	0	0	--
C24	SF	63	8	55	9	45	84%
C25	SF	95	55	40	14	26	65%
C26	SF	25	5	20	4	16	80%
C27	SF	337	196	141	51	90	64%

[1]. Model results are obtained through the WEPP detailed results output.

[2]. Crossings C2 and C20 are located on the crown of a road and do not contribute sediment to a drainage. Crossing C22 (C22N and C22S) were treated as separate roads because C22N was gravel and C22S was paved.

[3]. Modeled results of the 50-year average of total annual sediment detached, deposited, and delivered to the stream.

[4]. Reduced sediment delivery based on an 85% sediment reduction rate for a vegetated buffer.

[5]. Reduction in sediment due to the implementation of BMPs.

[6]. Sediment is presented in lbs per area of contributing road segment.

SF= South Fork West Fork Gallatin River, MF=Middle Fork West Fork Gallatin River, WF=West Fork Gallatin River

Table F-4. Summary of road crossing sediment loading by road type for the West Fork Gallatin River watershed.

Road Surface	Traffic Level	Number of Crossings	Average Modeled Sediment Yield per Crossing Type	Total Sediment Yield	Average Sediment Yield with BMPs	Total Sediment Yield with BMPs
			tons/year	**tons/year**	**tons/year**	**tons/year**
Paved	Low	55	0.03	1.4	0.01	0.4
Paved	High	15	0.23	3.5	0.11	1.6
Graveled	Low	15	0.02	0.3	0.01	0.2
Graveled	High	2	0.10	0.2	0.02	0.0
Native/Dirt	None/Low	11	0.25	2.8	0.07	0.7
Totals:		**98**		**8.1**		**2.9**

Table F-5. Sediment loading from road/stream crossings, West Fork Gallatin River watershed.

303(d) Watershed	Sub-Watershed Name	Number of Crossings (Surface - Traffic)						Existing Sediment Load (tons/yr)	Existing Sediment Load (tons/yr)	Desired Sediment Load (tons/yr)
		All	**Paved Low**	**Paved High**	**Gravel Low**	**Gravel High**	**Native/ Dirt Low**			
Middle Fork West Fork Gallatin River	Uppermost Middle Fork West Fork Gallatin River	15	8	4	1	1	1	1.5	4.8	1.7
	Beehive Creek	9	4	1	3		1	0.6		
	Middle Fork West Fork Gallatin River	23	13	2		1	7	2.6		
South Fork West Fork Gallatin River	Upper South Fork West Fork Gallatin River	12	11	1				0.5	2.1	0.7
	Third Yellow Mule Creek	1					1	0.3		
	Muddy Creek	3	2		1			0.1		
	Second Yellow Mule Creek	3	1		2			0.1		
	First Yellow Mule Creek	0						0.0		
	South Fork West Fork Gallatin River	14	5	3	5		1	1.2		
West Fork Gallatin River	North Fork West Fork Gallatin River	1	1					0.0	1.2	0.4
	Upper West Fork Gallatin River	4	2	2				0.5		
	Crail Creek	4	4					0.1		
	Lower West Fork Gallatin River	6	4	1	1			0.4		
	Lowermost West Fork Gallatin River	3		1	2			0.3		
	TOTALS:	83	47	11	14	1	10	**8.1**	**8.1**	**2.8**

SEDIMENT FROM TRACTION SAND APPLICATION

The harsh winter climate and mountain setting of the watershed requires the application of traction sand to paved roads, typically from November through May. This sand can accumulate on road surfaces and then be transported to streams during snowmelt and from runoff during warmer months.

Field crews identified road crossings where tractions sand was likely to be a significant sediment source. Road sanding rates for Montana Hwy 64 from MDT and snow removal contractors working for Big Sky area homeowner associations provided the data necessary to develop sand application rates. These rates were then applied to the paved road crossings in the watershed.

Application Rates

Traction sand delivery for all privately owned paved was based on an application rate of 120 cubic yards over 15 miles of road, which was provided by the Big Sky Homeowners Association. Using an average road width of 17 feet and the application rate of 120 cubic yards annually, traction sand would cover the road to a depth of 0.03 inches. The traction sand estimate for Hwy 64 was based on the average annual volume and tonnages applied to the nine-mile stretch of the highway from Hwy 191 to the West Fork Gallatin River watershed boundary in Madison County between 2005 and 2008 (**Table F-6**). Using an average road width of 26 feet, the average yearly application of 2,850 cubic yards of traction sand would cover the road to a depth of 0.75 inches.

Table F-6. Road sanding rates from MDT for Montana Highway 64.

Year	Road Sand Application	
	cubic yards	tons
2005	2,736	3,797
2006	3,554	4,932
2007	2,025	2,810
2008	3,084	4,280
Average	2,850	3,955

Assessment Approach

Contributing road lengths for the assessed road/stream crossings (discussed under “Field Data Collection”) were used for the traction sand load analysis. For Hwy 64, the road length multiplied by the measured width and the 0.75 inch depth equals the volume of traction sand available for delivery each year. Field observations of six road crossings on Hwy 64 indicate that much of the traction sand is retained by the vegetated buffer between the road and stream; however, significant volumes of traction sand also build up along guardrails and other barriers at the edges of roads (**Figure F-3**). From these observations and literature-based values for buffer effectiveness (see the Best Management Practices section below), it was estimated that approximately 15 percent of the applied sand is delivered to streams on a yearly basis.

Figure F-3. Typical build up of traction sand adjacent to a guardrail along Hwy 64. Crossing C12, North Fork West Fork Gallatin River.

However, some of the sand that remains in the buffer or along the road may also eventually be delivered to streams. To approximate the effect of sand accumulating along the road over several years, it was assumed that sand stored in sand berms that form along the sides of the road is available for delivery for a period of five years. Based on this assumption, up to 56 percent of the traction sand applied to the contributing road area in a given year is delivered to streams over a five-year period. This percentage is based on the sum of the estimated percentage available annually over the five year period, which is presented in **Table F-7**. For example, 15 percent of winter 2008-2009 traction sand is delivered to streams in 2009, 15 percent of the remaining winter 2007-2008 traction sand is delivered in 2009 (15% X 85%=12.8%), and so on for five years. It is acknowledged that this is a rough estimate of potential traction sand delivered to streams but annual traction sand loads were estimated in this manner because the accumulation of residual traction sand was observed as a potentially significant sediment source that could be reduced.

Table F-7. Estimated yearly sediment delivery for traction sand on Highway 64.

Road Sand Delivery	Date Applied	Percent Delivered in 2009
First Year	Winter 2008-2009	15.0%
Second Year	Winter 2007-2008	12.8%
Third Year	Winter 2006-2007	10.8%
Fourth Year	Winter 2005-2006	9.2%
Fifth Year	Winter 2004-2005	7.8%
	Total Delivery in 2009	55.6%

Results

Based on the application rate for Hwy 64 and private roads and assuming 56 percent as the yearly sediment delivery rate for traction sand at all paved crossings, 138 tons of traction sand per year is delivered to streams from road/stream crossings along Hwy 64 and 17 tons of traction sand are delivered to streams from all other paved crossings.

Table F-8 lists the sediment loads from traction sand for the sub-watersheds in the project area. Overall, traction sand contributes 155 tons per year of sediment to streams in the West Fork Gallatin River watershed. Implementation of BMPs for traction sand could reduce the delivery of traction sand to streams from the current 56 percent of sand applied to roads to 15 percent of sand applied. This represents a 73 percent reduction from current levels. This is effectively equivalent to preventing roadside accumulation from year to year but the reduction could be achieved by a combination of BMPs, which may include a lower application rate, street sweeping, barriers to divert runoff carrying traction sand away from road crossings, improving maintenance of existing BMPs, altering plowing speed at crossings, and structural control measures. It is acknowledged that public safety is a primary factor in the usage of traction sand, and the reduction in loading from traction sand is anticipated to be achieved by improving BMPs without sacrificing public safety. BMPs are described in more detail in the "Best Management Practices for Roads" section below.

Table F-8. Sediment loading from traction sand for the West Fork Gallatin River watershed.

303(d) Sub-watershed	Sub-Watershed	Number of Crossings				Existing Traction Sand Sediment Load (tons/yr)	Desired Traction Sand Sediment Load, 15% Delivery (tons/year)
		All Types	Total Paved	Hwy 64	Private Paved		
Middle Fork West Fork Gallatin River	Upper Middle Fork West Fork Gallatin River	15	12	2	10	33.5	9.0
	Beehive Creek	9	5	1	4	16.4	4.4
	Middle Fork West Fork Gallatin River	23	15	2	13	34.3	9.3
South Fork West Fork Gallatin River	Upper South Fork West Fork Gallatin River	12	12		12	3.4	0.9
	Third Yellow Mule Creek	1	0		0	0.0	0.0
	Muddy Creek	3	2		2	0.6	0.2
	Second Yellow Mule Creek	3	1		1	0.3	0.1
	First Yellow Mule Creek	0	0		0	0.0	0.0
	South Fork West Fork Gallatin River	14	8		8	2.3	0.6
West Fork Gallatin River	North Fork West Fork Gallatin River	1	1		1	0.3	0.1
	Upper West Fork Gallatin River	4	4	2	2	31.2	8.4
	Crail Creek	4	4		4	1.1	0.3
	Lower West Fork Gallatin River	6	5	1	4	16.4	4.4
	Lowermost West Fork Gallatin River	3	1	1	0	15.3	4.1
	TOTALS:	98	70	9	61	**155**	**42**

CULVERT ASSESSMENT

Field crews assessed the water conveyance structures at the 25 measured crossings to determine whether they are barriers to fish passage, and whether they are at risk for failure during high flow. Culverts that fail can deliver significant sediment to streams. Of the 25 assessed crossings, eight are bridges, 14 are corrugated metal culverts, two are corrugated plastic culverts, and one is a concrete culvert.

The bridge crossings assessed during the field data collection had no fish passage issues and were removed from this analysis. The bridges were also adequately sized to convey large flows and not likely to fail even under extreme flood events. In addition, since bridges do not have a large amount of fill covering them, the amount of sediment potentially delivered to streams in the event of a bridge failure is low. Therefore, both the fish passage analysis and the potential sediment from culvert failure analysis excluded road/stream crossings with bridges.

Data collected at each crossing for the fish passage and culvert failure potential assessments included:

- Structure type,
- Structure size,
- Structure slope,
- Upstream bankfull width,
- Upstream bankfull height,
- Fill height, length, and width,
- Outlet invert height,
- Outlet pool depth,
- Comments, and
- Photos.

FISH PASSAGE

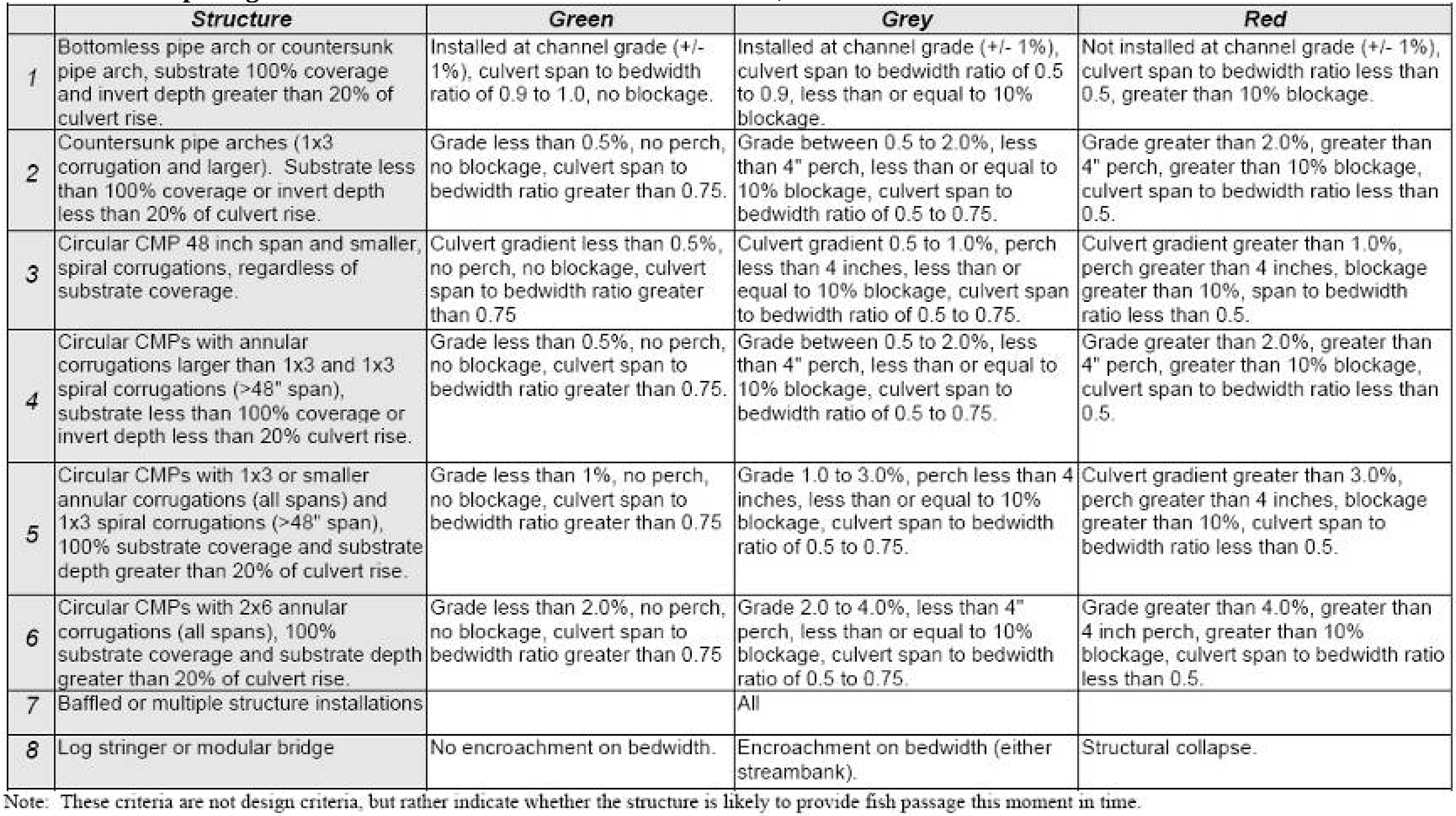
Approach

Measurements collected at the assessed road/stream crossings provided the data to determine if the culverts were fish passage barriers at the flow condition at the time the measurements were taken. This evaluation used criteria from the document A Summary of Technical Considerations to Minimize the Blockage of Fish at Culverts on the National Forests of Alaska (U.S. Forest Service, 2002). The analysis evaluates large (>48-inches) and small (<48-inches) culverts differently and uses site-specific information to classify culverts as green (passing all life stages of salmonids), red (partial or total barrier to salmonids), or grey (needs a more detailed analysis). Indicators used in the classification are:

- Culvert slope,
- Culvert perch (outlet drop),
- Culvert blockage, and
- Constriction ratio (the ratio of the culvert width to bankfull width).

The criteria for the indicators for different culvert types are shown in **Table F-9**.

Table F-9. Fish passage evaluation criteria from U.S. Forest Service, 2002.



	Structure	*Green*	*Grey*	*Red*
1	Bottomless pipe arch or countersunk pipe arch, substrate 100% coverage and invert depth greater than 20% of culvert rise.	Installed at channel grade (+/- 1%), culvert span to bedwidth ratio of 0.9 to 1.0, no blockage.	Installed at channel grade (+/- 1%), culvert span to bedwidth ratio of 0.5 to 0.9, less than or equal to 10% blockage.	Not installed at channel grade (+/- 1%), culvert span to bedwidth ratio less than 0.5, greater than 10% blockage.
2	Countersunk pipe arches (1x3 corrugation and larger). Substrate less than 100% coverage or invert depth less than 20% of culvert rise.	Grade less than 0.5%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75.	Grade between 0.5 to 2.0%, less than 4" perch, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Grade greater than 2.0%, greater than 4" perch, greater than 10% blockage, culvert span to bedwidth ratio less than 0.5.
3	Circular CMP 48 inch span and smaller, spiral corrugations, regardless of substrate coverage.	Culvert gradient less than 0.5%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75	Culvert gradient 0.5 to 1.0%, perch less than 4 inches, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Culvert gradient greater than 1.0%, perch greater than 4 inches, blockage greater than 10%, span to bedwidth ratio less than 0.5.
4	Circular CMPs with annular corrugations larger than 1x3 and 1x3 spiral corrugations (>48" span), substrate less than 100% coverage or invert depth less than 20% culvert rise.	Grade less than 0.5%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75.	Grade between 0.5 to 2.0%, less than 4" perch, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Grade greater than 2.0%, greater than 4" perch, greater than 10% blockage, culvert span to bedwidth ratio less than 0.5.
5	Circular CMPs with 1x3 or smaller annular corrugations (all spans) and 1x3 spiral corrugations (>48" span), 100% substrate coverage and substrate depth greater than 20% of culvert rise.	Grade less than 1%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75	Grade 1.0 to 3.0%, perch less than 4 inches, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Culvert gradient greater than 3.0%, perch greater than 4 inches, blockage greater than 10%, culvert span to bedwidth ratio less than 0.5.
6	Circular CMPs with 2x6 annular corrugations (all spans), 100% substrate coverage and substrate depth greater than 20% of culvert rise.	Grade less than 2.0%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75	Grade 2.0 to 4.0%, less than 4" perch, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Grade greater than 4.0%, greater than 4 inch perch, greater than 10% blockage, culvert span to bedwidth ratio less than 0.5.
7	Baffled or multiple structure installations		All	
8	Log stringer or modular bridge	No encroachment on bedwidth.	Encroachment on bedwidth (either streambank).	Structural collapse.

Note: These criteria are not design criteria, but rather indicate whether the structure is likely to provide fish passage this moment in time.

Results

Table F-10 lists the number of culverts by fish passage classification. Thirteen of the 17 assessed culverts fail the fish passage criteria and two require additional analysis to determine fish passage (rows 3 and 4 in **Table F-9**). This leaves two culverts (12 percent) that meet fish passage criteria. All of the culverts that received a red classification failed due to slope. Five of these also failed the outlet drop criteria. The two culverts that fall in the gray category do so because of a low constriction ratio. **Figure F-4** shows the spatial distribution of assessed culverts and associated fish passage classification.

Table F-10. Assessed culverts and fish passage criteria.

Culvert Classification or Indicator	Definition of Indicator	Number of Culverts	Percentage of Culverts Assessed
Green	High certainty of meeting juvenile fish passage at all flows.	2	12%
Grey	Additional analysis is required to determine juvenile fish passage ability.	2	12%
Red	High certainty of not providing juvenile fish passage at all desired stream flows.	13	76%

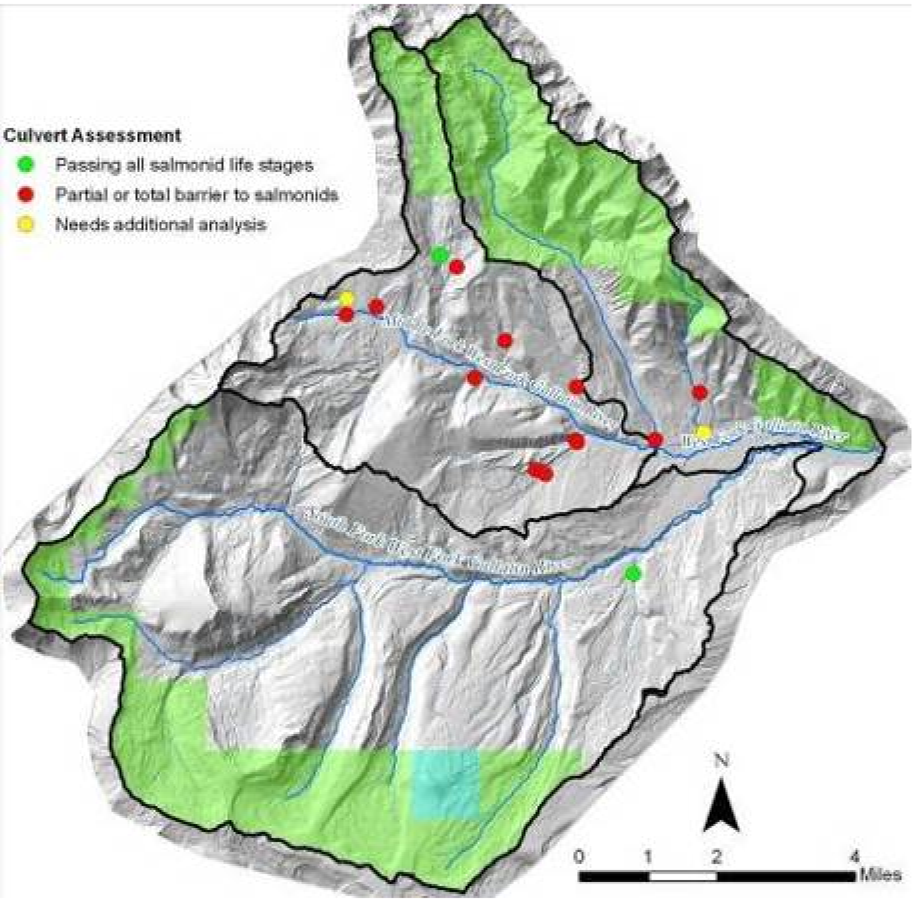


Figure F-4. Distribution and rating of culverts evaluated for fish passage.

SEDIMENT FROM POTENTIAL CULVERT FAILURE

Approach

Regional regression equations allow calculation of flood frequency and magnitude in areas where stream gage data is not available (Parrett and Johnson, 1998). These equations allow using basin or channel characteristics to calculate peak discharges for flood events of various frequencies. This analysis used the bankfull width measured above the 17 assessed culverts to calculate discharge (Q) for 2, 5, 10, 25, 50, and 100 year flood frequencies.

The next step is to establish the flow capacity of the assessed culverts. This analysis used design criteria for highway culverts (UDFCD, 2008 and Herr, 1972) to determine whether the existing culverts are adequately sized to convey discharge at the calculated flood discharges. **Figure F-5** is an example culvert capacity chart (Figure UC-8 in UDFCD, 2008) that illustrates the relationship between the culvert headwater (water height at inlet) and discharge, for various culvert sizes, culvert slopes, and lengths.

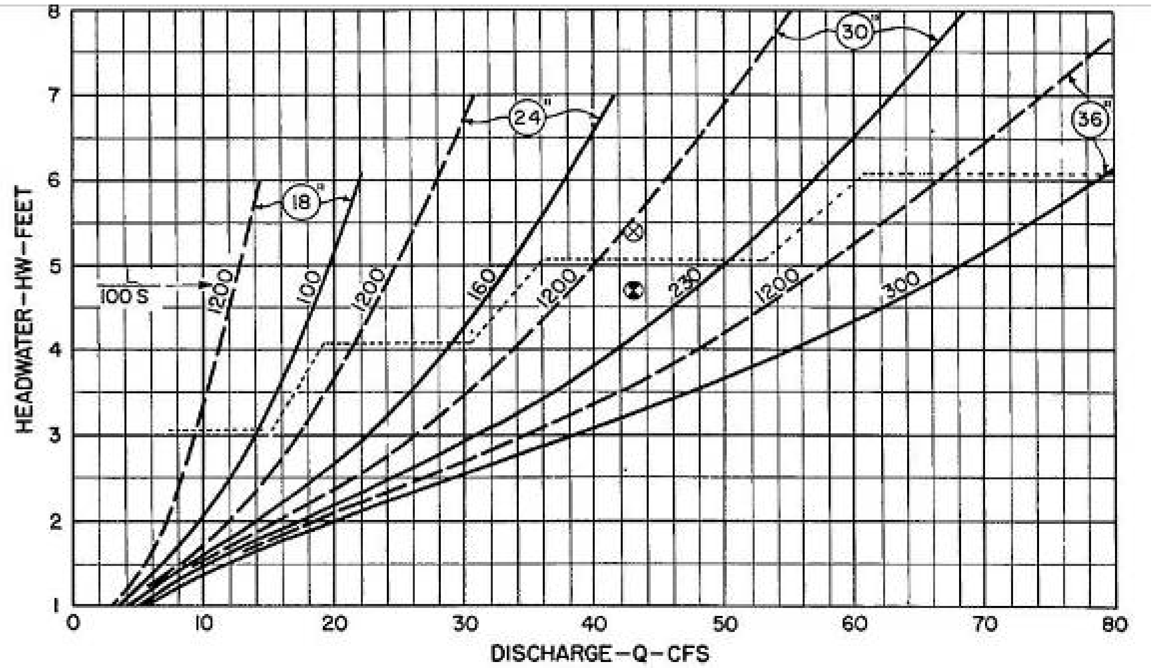


Figure F-5. Example culvert capacity chart (Figure UC-8 in UDFCD, 2008).

The culvert headwater was calculated as the fill height minus one foot. Field observations indicate that water height, and thus the headwater; will typically reach one foot below the fill height before it overtops the road in a low spot. In some cases, this height was greater than the maximum recommended headwater height for the culvert diameter (the top of the capacity curves in **Figure F-5**). In these cases, the headwater was taken as the maximum value of the capacity curve.

Table F-11 tabulates the site specific conditions of the assessed culverts. In addition to location, size, and slope of the culverts, **Table F-11** lists the:

- Calculated runoff events (Qx),

- Culvert headwater,
- Maximum capacity of the culvert (cfs),
- Maximum Q event that will pass through the culvert, and
- Amount of fill material at risk for failure.

Two of the road crossings (C7 and C17) are configured such that prior to overtopping, water will flow along the road ditch, downstream to a nearby road crossing. This mitigates the risk of failure at the assessed crossing but increases the risk at the downstream crossing by increasing the drainage area.

A common BMP for culverts is to design them to accommodate the 25-year storm event; this capacity is specified as a minimum in both the International Building Code Standards for 2006 (ICC 2006) and Water Quality BMPs for Montana Forests (DNRC 2006), and it is typically the minimum used by the USFS. Therefore, fill was only assumed to be at-risk in culverts that cannot convey a 25-year event.

Results

Table F-12 summarizes the results of the culvert analysis. These data suggest that all culverts assessed will convey a two-year (Q2) runoff event, but one culvert is not adequately sized to convey a five-year event, four will not convey a 10-year event, and three will not convey a 25-year event. An estimated 67 of the 98 crossings in the watershed have culverts, and the percentage of crossings at risk was estimated by dividing the number of crossings failing at a given discharge by the total number of crossings with culverts (67).

In many cases, if the culvert cannot convey a flood flow, water will overtop the crossing, but the crossing will not fail and the sediment load is not delivered. The probability of culvert failure is unknown, but is set at 25 percent in this analysis. If the average sediment load at risk of failure is multiplied by the number of crossings, the 25 percent probability of failure, and annual probability of the relevant level of discharge (i.e. Q5, Q10, or Q25), this yields the yearly potential sediment delivery (**Table F-12**).

Almost half of the assessed culverts will not convey a 25-year event, and based on the culvert analysis, 323 tons of road fill are at risk of eroding into streams within the watershed annually. Although passing the 25-year event was used in the BMP analysis, other considerations such as fish passage, the potential for large debris loads, and the level of development and road density upstream of the culvert should also be taken into consideration during culvert installation and replacement, and may necessitate the need for a larger culvert. For instance, because an increase in road density (and impervious surfaces) may increase the peak discharge and/or the frequency of events close to or greater than the 25-year event, a higher level of BMPs may be necessary to minimize sediment loading to streams and attain water quality standards. Particularly in areas with a high level of growth, increasing road density, or a large proportion of undersized culverts (<25-year event), meeting the 100-year event is recommended for new and replacement culverts. This capacity typically allows for aquatic organism passage and corresponds to the guideline for the USFS, BLM, and USFWS for fish-bearing streams (INFISH 1995), and it should help offset some of the risk from undersized culverts and provide a greater margin of safety for changes in hydrology associated with future growth.

Table F-11. Potential culvert failure data analysis table.

Site ID	Sub-watershed	Structure Type	Culvert Diameter (ft)	Slope (%)	Upstream Bankfull Width (ft)	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)	Hw (ft)	Max Capacity (cfs)	Maximum Q Event	Fill (tons)	Comments
C4	Beehive Creek	CMP	1.6	22	1.9	2	8	17	35	58	89	7	42	Q25	257	
C7	Upper Middle Fork West Fork Gallatin River	CMP	2	10	4	7	24	47	89	139	201	7	42	Q5	1418	Will spill before culvert fails
C9	Middle Fork West Fork Gallatin River	CMP	2	9	2.2	2	10	20	42	69	105	6	38	Q10	216	
C16	Middle Fork West Fork Gallatin River	CMP	2	5	4.6	9	30	57	106	164	234	7	42	Q5	115	
C19	Crail Creek	CMP	2	8	4	7	24	47	89	139	201	6	38	Q5	195	
C6	Upper Middle Fork West Fork Gallatin River	CMP	2	8	3.5	6	20	39	76	119	174	7	42	Q10	815	
C14	Middle Fork West Fork Gallatin River	CMP	3	7	7.3	21	61	107	190	281	388	10	110	Q10	1405	
C11	Middle Fork West Fork Gallatin River	CPP	3	4	5	11	34	64	118	181	257	3	28	Q2	189	
C8	Middle Fork West Fork Gallatin River	CC	3	2	4	7	24	47	89	139	201	6	80	Q25	450	
C17	Middle Fork West Fork Gallatin River	CMP	4	11	4.2	8	26	50	95	147	212	12	215	Q100	964	Will spill before culvert fails
C18	Upper West Fork Gallatin River	CMP	4	2	2.8	4	14	28	57	92	136	7	145	Q100	183	
C22	Middle Fork West Fork Gallatin River	CMP	4	5	5	11	34	64	118	181	257	11	195	Q50	1019	
C5	Upper Middle Fork West Fork Gallatin River	CMP	4	1	2.7	4	13	27	55	88	131	5	103	Q50	247	
C15	Middle Fork West Fork Gallatin River	CPP	4	5	6.5	17	51	91	164	246	342	12	215	Q25	2026	
C25	South Fork West Fork Gallatin River	CMP	5	1	9.5	34	91	155	264	383	517	6	125	Q5	202	
C3	Beehive Creek	CMP	7	2	11.3	46	118	197	327	469	624	19	625	Q100	1117	

Table F-11. Potential culvert failure data analysis table.

Site ID	Sub-watershed	Structure Type	Culvert Diameter (ft)	Slope (%)	Upstream Bankfull Width (ft)	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)	Hw (ft)	Max Capacity (cfs)	Maximum Q Event	Fill (tons)	Comments
C12	Upper West Fork Gallatin River	CMP	12	3	10	37	98	166	281	407	546	24	1425	Q100	4402	

CMP - Corrugated Metal Pipe
CC - Concrete Culvert
CPP - Corrugated Plastic Pipe

Table F-12. Summary results of potential culvert failure sediment load analysis.

Calculated Discharge Event	Number of Culverts Passing	Number of Culverts Failing	Percent Passing	Percent Failing	Average Sediment at Risk of Failure (tons)	Number of Crossings at Risk	Yearly Probability of Discharge	Sediment Delivery (tons/yr)
Q2	17	0	100%	0%			0.5	
Q5	16	1	94%	6%	189	4	0.2	37
Q10	12	5	71%	29%	482	16	0.1	190
Q25	9	8	53%	47%	812	12	0.04	96
Q50	6	11	35%	65%			0.02	
Q100	4	13	24%	76%			0.01	
				TOTALS:	1484	32		**323**

BEST MANAGEMENT PRACTICES

BMP efficiencies vary by the type of BMP implemented. Based on the average literature value for sediment reduction associated with vegetated buffers, 85 percent was used as the desired reduction factor for additional BMP implementation for road crossings and traction sand. The following studies support the 85 percent BMP reduction factor:

- Oat buffer strips, six meters in length, reduced sediment mass by 76 percent (Hall et al., 1983).
- Mickelson et al. (2003) determined that the first few meters of the buffer strip trapped the majority of deposited sediment. Buffer strips 4.6 meters long and with a drainage area to buffer strip area ratio of 10:1 reduced sediment by 71 percent while the 9.1 meters long buffer strip with a ratio of 5:1 reduced sediment delivery by 87 percent.
- Grassed waterways reduced suspended sediment concentrations by 94 and 98 percent in wet and dry antecedent moisture conditions, respectively (Asmussen et al., 1977).
- Han et al. (2005) determined that vegetative filter strips, 10 meters in length, were effective at removing more than 85 percent of the incoming total suspended sediment from highway runoff.

A reduction of 85 percent was chosen as a goal based on literature values but because of existing BMPs and the varying effectiveness of BMPs, it may not be achievable in some areas but a greater amount of reduction may be possible in other areas. Additionally, the reduction factor was based on effectiveness of buffers but buffers are not a formal BMP goal and are only one aspect of BMPs that may be used for road crossings and traction sand to achieve the necessary reductions. Additional details regarding the BMP scenario for each source category are discussed below.

Road Crossings

For each WEPP-modeled road crossing, the total sediment detached represented a condition with no BMPs and the total sediment deposited represents the effect of existing BMPs. Therefore, the total sediment delivered is the detached minus the deposited sediment. In all road crossings evaluated, there was some level of BMPs already in place. Reductions listed in **Table F-13** represent the additional reduction in sediment delivery that equates to 15 percent of the total detached sediment load.

Implementation of BMPs for roads could include increased vegetation in the road ditch and buffer, adding check dams, rocks, or fiber rolls to ditches, reducing the contributing road length through the use of water bars or drainage dips, or re-surfacing dirt and gravel roads.

Traction Sand

The desired reduction aims to decrease the amount of traction sand delivered to streams from 56 to 15 percent. Implementation of BMPs for road traction sand include structural methods such as swales, detention basins, and vegetative filter strips or non-structural methods such as improved snow fences or storage, street sweeping, altering application rates, and using advanced snowplow technology. Additionally, traction sand applicators range from permanent MDT employees to seasonal staff, and traction sand loading may be decreased by improved staff training for traction sand BMPs and/or utilization of MDT BMP publications such as Recommendations for Winter Traction Materials Management on Roadways Adjacent to Bodies of Water (Staples et al. 2004) and fact sheets.

Culvert Failure

The BMP approach used for the culvert analysis used the 25-year event as a minimum, but because an increase in road density (and impervious surfaces) may increase the peak discharge and/or the frequency of events close to or greater than the 25-year event, a higher level of BMPs may be necessary to minimize sediment loading to streams and attain water quality standards. Particularly in areas with a high level of growth, increasing road density, or a large proportion of undersized culverts (<25-year event), meeting the 100-year event is recommended for new and replacement culverts. This capacity typically allows for aquatic organism passage and corresponds to the guideline for the USFS, BLM, and USFWS for fish-bearing streams (INFISH 1995), and it should help offset some of the risk from undersized culverts and provide a greater margin of safety for changes in hydrology associated with future growth.

SEDIMENT LOAD ANALYSIS SUMMARY

Based on the roads source assessment, traction sand and potentially fill from failing culverts are the largest sediment sources associated with roads within the West Fork Gallatin River watershed. Sediment loading associated with roads is similar within the South Fork and West Fork subwatersheds and greatest within the Middle Fork watershed, which is where most of the ski resort and residential development is concentrated.

Table F-13. Summary of sediment sources in the West Fork Gallatin River watershed evaluated in this study.

303(d) Sub-watershed	Current Crossing Sediment Load (tons/yr)	Desired Crossing Sediment Load (tons/yr)	Current Traction Sand Sediment Load (tons/yr)	Desired Traction Sand Sediment Load (tons/yr)	Current Potential Culvert Failure Sediment Load (tons/yr)	Desired Culvert Failure Sediment Load (tons/yr)
Middle Fork West Fork Gallatin River	4.8	1.7	84.2	22.7	155.0	0.0
South Fork West Fork Gallatin River	2.1	0.7	6.5	1.8	109.0	0.0
West Fork Gallatin River	1.2	0.4	64.4	17.4	59.0	0.0
	8.1	**2.9**	**155.0**	**41.8**	**323.0**	**0.0**

Roads Assessment Uncertainty

Natural processes such as sediment erosion and delivery from roads or other landscape features, associated with rainfall and runoff are very complex and modeling of these processes requires significant simplification. Notably, the models have limited temporal resolution, and do not account well for seasonal and event scale processes. Additionally, the roads model was not calibrated and is acknowledged to be a very rough estimate of loading associated with roads. The model is intended to identify the relative sediment contribution from roads and areas that should be examined more closely to locate where BMPs would be most beneficial. The WEPP model used for the West Fork Gallatin River provides estimates of yearly sediment loads based on a 50-year average of climatic conditions. Sediment models tend to over predict annual sediment loads under normal or low runoff conditions and under predict annual loads under high runoff conditions. Therefore, the intent is that the average annual sediment load predicted should be applicable over long periods of time that include both low, average, and high runoff years. It is possible that sediment delivery to streams in a watershed such as the West Fork Gallatin River can be minimal for many consecutive years and then very high during the next year.

The annual estimate of traction sand application is based on actual application rates but there is a large degree of uncertainty regarding the delivery rate and amount of traction sand retained from year to year because the estimate is based on a combination of field observations and literature-based values and no measurements were conducted. Additionally, traction sand is reclaimed in the spring near Meadow Village (personal comm. R. Edwards, 2010), indicating the delivery rate likely differs between Hwy 64 and private roads in the watershed.

For the culvert assessments, peak flows generated for each culvert using regression equations may over or under estimate peak discharge, and therefore peak flows computed by a different method could result in different conclusions regarding culvert capacity. Because problems related to undersized (or improperly installed or maintained) culverts may range from being a chronic source of sediment during storm events to contributing a substantial load to a stream during complete failure, the greatest amount of uncertainty related to the culvert assessment is identifying the probability of culvert failure and estimating the annual load related to culverts. Despite the high degree of uncertainty related to annual loading associated with culverts, they were included in the analysis to identify the potential significance of loading associated with culverts and aid in TMDL implementation.

The fish passage assessment is intended to be a rapid assessment tool and it is acknowledged that instead of being strictly a barrier or non-barrier, fish passage for a particular culvert is more likely a continuum based on factors such as fish species, size, migration pattern relative to stream hydrology, and jumping ability. Additionally, although fish barriers are generally considered a negative, in some instances, they are a barrier that separates native and non-native fish. Therefore, prior to replacing culverts classified as fish barriers, each culvert should be evaluated individually.

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EXAMPLES OF CULVERTS AND BMPS

Bottomless corrugated steel culvert.

Perched corrugated steel culvert.

Example of concrete culvert.

Corrugated plastic culvert, fish passage barrier.

Erosion of road fill material adjacent to perched corrugated steel culvert.

Correct culvert installation.

Fiber wattles used to control road ditch erosion.

APPENDIX G
2008 SEDIMENT AND HABITAT DATA COLLECTION METHODS AND DATA SUMMARY UPPER GALLATIN TMDL PLANNING AREA

G1.0 INTRODUCTION

This appendix includes a summary of the field protocols and results from stream channel and habitat data collected in the Upper Gallatin TPA during the summer of 2008 to facilitate sediment TMDL development. It is an excerpt from the Upper Gallatin Base Parameter Report (PBS&J 2010), 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 16 monitoring sites on 5 streams (**Figure G-1**) following protocols established in Longitudinal Field Methodology for the Assessment of Sediment and Habitat Impairments (MT DEQ 2008a). Data collected at each monitoring site was analyzed with two different approaches:

1. By reach type as assigned in the Aerial Assessment Database, and;
2. Individually for each monitoring site.

In the “reach type” assessment, monitoring sites are grouped based on the reach type as assigned in the Aerial Assessment Database. This assessment is based on the premise behind the study design, which assumes that stream reaches with the same Ecoregion, valley gradient, stream order and confinement will have similar characteristics. This assessment may provide valuable information for defining future sediment TMDL criteria specific to the reach types identified within the Upper Gallatin TPA.

Each monitoring site was also analyzed individually. Analyzing streams individually provides an at-a-glance method for identifying conditions that may differ from what is expected. This analysis may provide valuable information for assessing existing conditions along these stream segments.

G1.1 Aerial Assessment Database

The Aerial Assessment reach stratification process involved dividing each stream into distinct reaches based on four landscape factors: Ecoregion, valley gradient, Strahler stream order, and valley confinement following the methodology outlined in Watershed Stratification Methodology for TMDL Sediment and Habitat Investigations (MT DEQ 2008b). Each individual combination of the four landscape factors is referred to as a “reach type” in this report based on the following definition:

> *Reach Type - Unique combination of Ecoregion, gradient, Strahler stream order and confinement*

Reach types were described using the following naming convention based on the reach type identifiers presented in **Table G-1**:

> *Level III Ecoregion – Valley Gradient – Strahler Stream Order – Confinement*

Table G-1. Reach Type Identifiers.

Landscape Factor	Stratification Category	Reach Type Identifier
Level III Ecoregion	Middle Rockies	MR
Valley Gradient	0-<2%	0
	2-<4%	2
	4-<10%	4
	>10%	10
Strahler Stream Order	first order	1
	second order	2
	third order	3
	fourth order	4
Confinement	unconfined	U
	confined	C

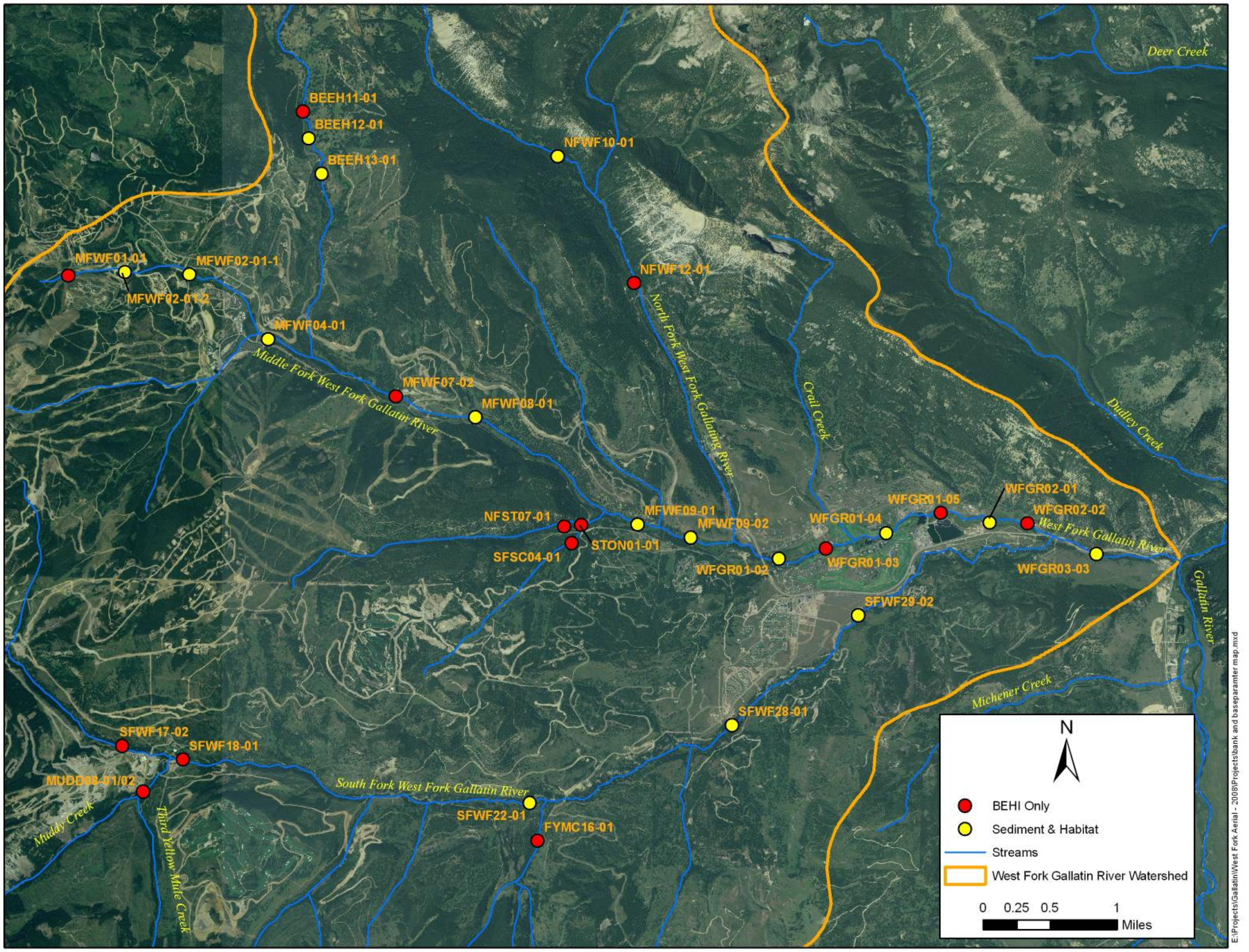
Thus, a stream reach identified as MR-0-3-U is a low gradient (0-<2%), 3rd order, unconfined stream in the Middle Rockies Level III Ecoregion.

In the Upper Gallatin TPA, stream reach data was compiled into an Aerial Assessment Database, which included a total of 157 stream reaches and a total of 14 reach types (**Table G-2**). Out of the 14 reach types identified in the West Fork Gallatin River watershed, 7 were assessed in the field for sediment and habitat conditions. A more complete discussion of this assessment can be found in Aerial Assessment Reach Stratification Upper Gallatin TMDL Planning Area (PBS&J 2009a).

Table G-2. Monitoring Sites in Assessed Reach Types. No reference

Reach Type	Monitoring Sites	Number of Sites
MR-4-1-C	MFWF04-01	1
MR-4-1-U	MFWF02-01-1, MFWF02-01-2, BEEH13-01	3
MR-2-1-U	BEEH12-01	1
MR-2-2-U	MFWF08-01, NFWF10-01	2
MR-2-3-U	MFWF09-01, MFWF09-02, WFGR01-02, WFGR01-04, SFWF28-01	5
MR-0-3-U	WFGR02-01, SFWF22-01, SFWF29-02	3
MR-0-4-U	WFGR03-03	1

Figure G-1. Upper Gallatin TPA Sediment and Habitat Monitoring Sites.



G2.0 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 2008a). All field forms used in the study are standard forms used by DEQ for sediment and habitat assessments.

G2.1 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.

G2.2 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.

G2.3 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 2008a). 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.

G2.4 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.

G2.5 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 2008a).

G2.6 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 2008a). 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.

G2.7 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.

G2.8 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 2008a). 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.

G2.9 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.

G2.10 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 2008a).

G2.11 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 2008a).

G2.12 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.

G2.13 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.

G2.14 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 Upper Gallatin TMDL Planning Area (PBS&J 2009b).

G2.15 Water Surface Slope

Water surface slope measurements were estimated using a clinometer.

G2.16 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

G3.0 Data Summary

Tables G-3and **G-4** present sediment and habitat data for each individual reach sampled following the aforementioned assessment procedures.

Table G-3. Individual assessment reach data from 2008.

Reach ID	Date	Cell	Reach Type	Existing Rosgen Stream Type	Potential Rosgen Stream Type	GIS Calculated Sinuosity	Field Slope (Percent)	Aerial Assessment Valley Gradient	Bankfull Channel Width	Width / Depth Ratio	Maximum Depth	Floodprone Width	Entrenchment Ratio	Riffle Pebble Count D50	Riffle Pebble Count Percent <2mm	Riffle Pebble Count Percent <6mm	Riffle Grid Toss Percent <6mm	Riffle Stability Index	Mean Residual Pool Depth	Number of Pools per 1000 Feet	Number of Individual Pieces of LWD per 1000 Feet	Number of LWD Aggregates per 1000 Feet	Total Number of LWD per 1000 Feet	Percent Understory Shrub Cover	Percent Bare/Disturbed Ground	Percent Riprap	Percent Overstory Canopy Cover	Right Bank Mean Riparian Zone Width	Left Bank Mean Riparian Zone Width
MFWF09-02	7/28/08	1	MR-2-3-U	C4	C4	1.29	1.2	2-<4%	25.7	20.4	1.8	>298	11.6	28	5	15	5	- -	1.9	9	8	0	15	65	0	0	5	15	100
MFWF09-02	7/28/08	2	MR-2-3-U	C3/4	C4	1.29	1.2	2-<4%	20.2	13.8	1.9	310.2	15.4	- -	- -	- -	- -	88						55	5	0	0	98	45
MFWF09-02	7/28/08	3	MR-2-3-U	C3	C4	1.29	1.2	2-<4%	28.5	22.9	2.3	173.5	6.1	69	7	11	1	- -						60	5	0	8	125	10
MFWF09-02	7/28/08	4	MR-2-3-U	B3/4c	C4	1.29	1.2	2-<4%	20.8	13.8	1.9	40.8	2.0	- -	- -	- -	- -	- -						53	3	0	5	190	13
MFWF09-02	7/28/08	5	MR-2-3-U	C4	C4	1.29	1.2	2-<4%	31.8	24.9	1.8	211.8	6.7	51	3	6	5	88						60	5	0	8	125	10
MFWF09-01	7/28/08	1	MR-2-3-U	B3	C3b	1.24	2.3	2-<4%	18.6	14.2	2.1	37.6	2.0	73	4	8	5	- -	1.3	4	34	0	34	28	10	0	3	200	4
MFWF09-01	7/28/08	2	MR-2-3-U	F3/4	C3b	1.24	2.3	2-<4%	19.1	13.1	2.0	23.1	1.2	- -	- -	- -	- -	- -						23	28	0	8	200	0
MFWF09-01	7/28/08	3	MR-2-3-U	C4b	C3b	1.24	2.3	2-<4%	24.3	17.3	2.0	106.3	4.4	47	5	6	2	- -						48	5	0	5	167	0
MFWF09-01	7/28/08	4	MR-2-3-U	C3/4b	C3b	1.24	2.3	2-<4%	28.4	26.7	2.2	293.4	10.3	- -	- -	- -	- -	- -						55	5	0	33	100	10
MFWF09-01	7/28/08	5	MR-2-3-U	C3b	C3b	1.24	2.3	2-<4%	22.9	17.4	1.8	278.9	12.2	76	4	6	1	- -						25	0	0	43	23	50
MFWF08-01	7/29/08	1	MR-2-2-U	C3b	B3	1.11	3.0	2-<4%	16.3	11.0	2.1	55.3	3.4	92	4	12	5	- -	1.4	6	34	9	149	10	3	0	43	200	200
MFWF08-01	7/29/08	2	MR-2-2-U	C3b	B3	1.11	3.0	2-<4%	19.5	15.2	2.2	66.0	3.4	- -	- -	- -	- -	- -						23	3	0	40	200	200
MFWF08-01	7/29/08	3	MR-2-2-U	B3	B3	1.11	3.0	2-<4%	19.9	14.2	2.2	37.9	1.9	80	3	5	3	- -						10	3	0	25	200	200
MFWF08-01	7/29/08	4	MR-2-2-U	- -	B3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -						10	0	0	23	200	200
MFWF08-01	7/29/08	5	MR-2-2-U	C3b	B3	1.11	3.0	2-<4%	17.0	11.1	2.4	61.0	3.6	70	3	4	0	- -						3	3	0	48	- -	- -
MFWF04-01	7/29/08	1	MR-4-1-C	B4	B4	1.14	3.5	4-<10%	17.8	16.6	1.8	33.8	1.9	61	5	9	5	- -	1.1	15	58	3	100	30	0	0	28	175	200
MFWF04-01	7/29/08	2	MR-4-1-C	C4b	B4	1.14	3.5	4-<10%	16.0	12.7	1.8	63.0	3.9	27	9	16	7	- -						28	0	0	25	200	200
MFWF04-01	7/29/08	3	MR-4-1-C	C4b	B4	1.14	3.5	4-<10%	21.2	23.7	1.4	102.2	4.8	55	4	4	1	- -						45	0	0	8	200	200
MFWF02-01-1	7/29/08	1	MR-4-1-U	E4b	E4b	1.34	2.3	4-<10%	8.2	9.7	1.2	35.2	4.3	27	15	24	7	- -	0.8	25	50	2.5	55	70	0	0	15	200	200
MFWF02-01-1	7/29/08	2	MR-4-1-U	C4b	E4b	1.34	2.3	4-<10%	11.7	18.0	1.4	35.7	3.1	23	5	7	4	- -						20	0	0	25	150	150
MFWF02-01-1	7/29/08	3	MR-4-1-U	E4b	E4b	1.34	2.3	4-<10%	5.1	5.0	1.1	55.1	10.8	- -	- -	- -	- -	- -						75	0	0	15	31	31
MFWF02-01-1	7/29/08	4	MR-4-1-U	C4b	E4b	1.34	2.3	4-<10%	13.5	20.8	1.0	50.5	3.7	26	5	8	3	- -						45	0	0	5	25	25
WFGR02-01	7/30/08	1	MR-0-3-U	C3	C3	1.29	1.5	0-<2%	44.2	30.4	2.3	324.2	7.3	105	5	9	3	- -	1.4	7	0	0	11	48	0	0	0	125	200
WFGR02-01	7/30/08	2	MR-0-3-U	C3	C3	1.29	1.5	0-<2%	40.9	25.7	2.3	289.9	7.1	- -	- -	- -	- -	- -						70	0	0	0	200	200
WFGR02-01	7/30/08	3	MR-0-3-U	C3	C3	1.29	1.5	0-<2%	34.0	19.0	2.2	180.0	5.3	85	8	12	3	- -						30	0	0	0	125	200
WFGR02-01	7/30/08	4	MR-0-3-U	C3	C3	1.29	1.5	0-<2%	39.0	28.1	2.0	219.0	5.6	- -	- -	- -	- -	- -						58	0	0	3	- -	- -
WFGR02-01	7/30/08	5	MR-0-3-U	C3	C3	1.29	1.5	0-<2%	33.3	22.5	2.6	163.3	4.9	70	9	12	1	- -						50	13	0	3	200	200
WFGR01-04	7/30/08	1	MR-2-3-U	C3b	C3	1.10	2.0	2-<4%	40.7	33.7	2.4	>291.7	7.2	116	7	8	1	- -	- -	0	0	0	0	43	0	0	0	18	60
WFGR01-04	7/30/08	2	MR-2-3-U	C3b	C3	1.10	2.0	2-<4%	30.8	21.7	2.1	154.8	5.0	- -	- -	- -	- -	- -						68	5	0	0	11	28
WFGR01-04	7/30/08	3	MR-2-3-U	- -	C3	- -	- -	2-<4%	- -	- -	- -	- -	- -	87	13	13	15	- -						63	3	0	0	19	5
WFGR01-04	7/30/08	4	MR-2-3-U	C3b	C3	1.10	2.0	2-<4%	25.5	14.9	2.4	61.5	2.4	- -	- -	- -	- -	- -						55	0	0	0	50	33
WFGR01-04	7/30/08	5	MR-2-3-U	B3	C3	1.10	2.0	2-<4%	38.6	28.6	2.1	60.6	1.6	74	17	19	3	- -						80	0	0	0	55	13

Table G-3. Individual assessment reach data from 2008.

Reach ID	Date	Cell	Reach Type	Existing Rosgen Stream Type	Potential Rosgen Stream Type	GIS Calculated Sinuosity	Field Slope (Percent)	Aerial Assessment Valley Gradient	Bankfull Channel Width	Width / Depth Ratio	Maximum Depth	Floodprone Width	Entrenchment Ratio	Riffle Pebble Count D50	Riffle Pebble Count Percent <2mm	Riffle Pebble Count Percent <6mm	Riffle Grid Toss Percent <6mm	Riffle Stability Index	Mean Residual Pool Depth	Number of Pools per 1000 Feet	Number of Individual Pieces of LWD per 1000 Feet	Number of LWD Aggregates per 1000 Feet	Total Number of LWD per 1000 Feet	Percent Understory Shrub Cover	Percent Bare/Disturbed Ground	Percent Riprap	Percent Overstory Canopy Cover	Right Bank Mean Riparian Zone Width	Left Bank Mean Riparian Zone Width
WFGR01-02	7/30/08	1	MR-2-3-U	C4b	C3b	1.21	2.4	2-<4%	29.5	18.5	2.0	>234.5	7.9	48	11	12	2	- -	1.4	4	1	2	13	38	10	0	35	18	>200
WFGR01-02	7/30/08	2	MR-2-3-U	C3/4b	C3b	1.21	2.4	2-<4%	27.6	17.2	2.2	>247.6	9.0	- -	- -	- -	- -	- -						55	3	0	50	43	>200
WFGR01-02	7/30/08	3	MR-2-3-U	C3b	C3b	1.21	2.4	2-<4%	34.3	27.5	2.0	98.3	2.9	67	5	9	6	- -						48	0	8	60	10	>200
WFGR01-02	7/30/08	4	MR-2-3-U	C3/4b	C3b	1.21	2.4	2-<4%	37.3	26.8	2.1	267.3	7.2	- -	- -	- -	- -	- -						45	8	5	53	88	>200
WFGR01-02	7/30/08	5	MR-2-3-U	C3b	C3b	1.21	2.4	2-<4%	43.3	35.0	1.7	149.3	3.4	93	3	5	1	- -						53	0	0	8	133	84
SFWF22-01	7/31/08	1	MR-0-3-U	- -	C4	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.1	11	15	10	106	5	15	0	80	10	>200
SFWF22-01	7/31/08	2	MR-0-3-U	C4	C4	1.76	<2%	0-<2%	45.0	23.2	3.3	356.0	7.9	52	7	8	1	- -						45	5	0	8	190	81
SFWF22-01	7/31/08	3	MR-0-3-U	- -	C4	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -						28	0	0	0	450	25
SFWF22-01	7/31/08	4	MR-0-3-U	C3	C4	- -	- -	0-<2%	- -	- -	- -	- -	- -	65	9	16	3	- -						20	8	0	0	256	144
SFWF22-01	7/31/08	5	MR-0-3-U	- -	C4	1.76	<2%	0-<2%	38.0	19.3	2.7	278.0	7.3	- -	- -	- -	- -	- -						0	0	0	33	200	200
SFWF28-01	7/31/08	1	MR-2-3-U	C3b	B3	1.10	2.1	2-<4%	45.0	26.1	3.3	123.0	2.7	95	3	5	10	- -	1.1	4	19	1	27	0	0	0	40	>200	>200
SFWF28-01	7/31/08	2	MR-2-3-U	B3	B3	1.10	2.1	2-<4%	52.2	28.8	2.2	87.2	1.7	- -	- -	- -	- -	- -						3	3	0	68	>200	>200
SFWF28-01	7/31/08	3	MR-2-3-U	B3	B3	1.10	2.1	2-<4%	49.0	27.2	2.4	77.0	1.6	118	2	3	2	55						3	8	0	93	>200	>200
SFWF28-01	7/31/08	4	MR-2-3-U	C3b	B3	1.10	2.1	2-<4%	40.0	22.3	2.6	93.0	2.3	- -	- -	- -	- -	- -						8	10	0	63	>200	>200
SFWF28-01	7/31/08	5	MR-2-3-U	C3b	B3	1.10	2.1	2-<4%	34.2	16.7	3.2	85.2	2.5	82	3	4	0	- -						0	5	0	78	>200	>200
WFGR03-03	8/1/08	1	MR-0-4-U	C3	B3c	1.01	1.5	0-<2%	47.2	22.9	2.8	242.2	5.1	85	10	10	2	- -	1.2	1	11	0	11	30	0	0	98	>200	99
WFGR03-03	8/1/08	2	MR-0-4-U	B3c	B3c	1.01	1.5	0-<2%	52.0	29.5	2.5	85.0	1.6	- -	- -	- -	- -	- -						33	0	0	95	>200	46
WFGR03-03	8/1/08	3	MR-0-4-U	B3c	B3c	1.01	1.5	0-<2%	47.0	22.5	2.8	77.0	1.6	92	10	11	3	- -						18	0	0	85	>200	17
WFGR03-03	8/1/08	4	MR-0-4-U	B3c	B3c	1.01	1.5	0-<2%	45.0	21.9	2.6	79.0	1.8	- -	- -	- -	- -	- -						23	0	0	95	>200	48
WFGR03-03	8/1/08	5	MR-0-4-U	F3	B3c	1.01	1.5	0-<2%	44.0	20.4	3.0	58.0	1.3	98	6	7	1	- -						43	0	0	98	>200	83
BEEH12-01	8/1/08	1	MR-2-1-U	F4	E4	1.47	1.2	2-<4%	23.3	38.0	1.4	25.3	1.1	40	6	14	7	- -	1.1	15	4	0	4	30	10	0	0	7	7
BEEH12-01	8/1/08	2	MR-2-1-U	B4c	E4	1.47	1.2	2-<4%	17.3	20.3	1.2	29.3	1.7	- -	- -	- -	- -	- -						15	30	0	3	12	8
BEEH12-01	8/1/08	3	MR-2-1-U	F4	E4	1.47	1.2	2-<4%	19.1	19.9	1.3	21.1	1.1	36	19	22	5	- -						25	28	0	0	4	5
BEEH12-01	8/1/08	4	MR-2-1-U	F4	E4	1.47	1.2	2-<4%	19.8	21.1	1.3	22.8	1.2	- -	- -	- -	- -	- -						25	5	0	0	7	8
BEEH12-01	8/1/08	5	MR-2-1-U	E4	E4	1.47	1.2	2-<4%	14.4	15.0	1.4	35.4	2.5	58	4	8	10	- -						40	30	0	0	5	13
SFWF29-02	8/4/08	1	MR-0-3-U	C3	C3	1.30	1.0	0-<2%	37.0	17.9	2.6	387.0	10.5	90	2	9	2	- -	2.0	4	21	1	36	58	0	0	38	>200	>200
SFWF29-02	8/4/08	2	MR-0-3-U	C3	C3	1.30	1.0	0-<2%	63.0	67.7	2.5	213.0	3.4	- -	- -	- -	- -	65						45	8	0	50	>200	>200
SFWF29-02	8/4/08	3	MR-0-3-U	C3	C3	1.30	1.0	0-<2%	56.0	43.9	2.5	158.0	2.8	107	5	6	2	69						45	0	0	80	>200	>200
SFWF29-02	8/4/08	4	MR-0-3-U	B3c	C3	1.30	1.0	0-<2%	49.0	29.9	2.7	109.0	2.2	- -	- -	- -	- -	76						33	0	0	90	>200	>200
SFWF29-02	8/4/08	5	MR-0-3-U	C3	C3	1.30	1.0	0-<2%	60.0	39.5	2.3	233.0	3.9	67	5	6	3	- -						48	0	0	38	>200	>200
MFWF02-01-2	8/4/08	1	MR-4-1-U	E4a	E4a	1.27	7.5	4-<10%	3.8	3.4	1.4	29.8	7.8	29	10	12	23	- -	0.5	56	188	2	198	0	0	0	75	>200	145
MFWF02-01-2	8/4/08	2	MR-4-1-U	E4a	E4a	1.27	7.5	4-<10%	4.7	4.7	1.4	72.7	15.5	- -	- -	- -	- -	- -						0	0	0	60	>200	>200
MFWF02-01-2	8/4/08	3	MR-4-1-U	E4a	E4a	1.27	7.5	4-<10%	6.5	8.1	1.2	50.5	7.8	30	9	9	16	- -						0	0	0	65	>200	>200
MFWF02-01-2	8/4/08	4	MR-4-1-U	B4a	E4a	1.27	7.5	4-<10%	8.4	19.0	0.6	19.4	2.3	- -	- -	- -	- -	- -						0	0	0	90	>200	>200
MFWF02-01-2	8/4/08	5	MR-4-1-U	B4a	E4a	1.27	7.5	4-<10%	9.0	18.8	0.7	13.8	1.5	33	10	14	5	- -						0	10	0	45	>100	>100

Table G-3. Individual assessment reach data from 2008.

Reach ID	Date	Cell	Reach Type	Existing Rosgen Stream Type	Potential Rosgen Stream Type	GIS Calculated Sinuosity	Field Slope (Percent)	Aerial Assessment Valley Gradient	Bankfull Channel Width	Width / Depth Ratio	Maximum Depth	Floodprone Width	Entrenchment Ratio	Riffle Pebble Count D50	Riffle Pebble Count Percent <2mm	Riffle Pebble Count Percent <6mm	Riffle Grid Toss Percent <6mm	Riffle Stability Index	Mean Residual Pool Depth	Number of Pools per 1000 Feet	Number of Individual Pieces of LWD per 1000 Feet	Number of LWD Aggregates per 1000 Feet	Total Number of LWD per 1000 Feet	Percent Understory Shrub Cover	Percent Bare/Disturbed Ground	Percent Riprap	Percent Overstory Canopy Cover	Right Bank Mean Riparian Zone Width	Left Bank Mean Riparian Zone Width
BEEH13-01	8/5/08	1	MR-4-1-U	B3a	B3a	1.13	5.3	4-<10%	15.1	13.6	1.5	56.6	3.7	67	4	6	3	- -	1.1	23	94	3	153	0	0	0	65	83	>200
BEEH13-01	8/5/08	2	MR-4-1-U	B3a	B3a	1.13	5.3	4-<10%	13.9	12.9	1.3	39.4	2.8	- -	- -	- -	- -	- -						0	3	0	78	33	>158
BEEH13-01	8/5/08	3	MR-4-1-U	B3a	B3a	1.13	5.3	4-<10%	17.7	20.8	1.3	24.7	1.4	81	4	8	15	- -						0	10	0	43	>200	>170
BEEH13-01	8/5/08	4	MR-4-1-U	B3a	B3a	1.13	5.3	4-<10%	14.0	13.0	2.2	25.0	1.8	- -	- -	- -	- -	- -						0	10	0	65	>200	>200
BEEH13-01	8/5/08	5	MR-4-1-U	B3a	B3a	1.13	5.3	4-<10%	15.0	12.8	1.8	22.0	1.5	90	3	6	0	- -						0	25	0	53	>200	>200
NFWF10-01	8/5/08	1	MR-2-2-U	C4b	C4b	1.15	2.0	2-<4%	16.3	11.3	1.8	120.3	7.4	55	6	8	1	- -	1.1	20	75	12	169	0	0	0	80	>200	>200
NFWF10-01	8/5/08	2	MR-2-2-U	C4b	C4b	1.15	2.0	2-<4%	24.0	24.6	1.8	184.0	7.7	- -	- -	- -	- -	- -						0	0	0	65	>200	>200
NFWF10-01	8/5/08	3	MR-2-2-U	C4b	C4b	1.15	2.0	2-<4%	28.1	26.5	1.5	100.1	3.6	34	6	10	5	- -						0	8	0	70	>200	>200
NFWF10-01	8/5/08	4	MR-2-2-U	C4b	C4b	1.15	2.0	2-<4%	19.2	15.1	1.6	69.2	3.6	- -	- -	- -	- -	- -						0	0	0	58	>200	81
NFWF10-01	8/5/08	5	MR-2-2-U	C4b	C4b	1.15	2.0	2-<4%	22.2	20.8	1.9	97.2	4.4	75	3	5	4	- -						0	8	0	80	>125	>130

Table G-4. Pool data per assessment reach.

Reach ID	Reach Type	Pool	Residual Depth (Feet)	Pool Grid Toss Percent <6mm	Spawning Gravels Identified
MFWF09-02	MR-2-3-U	1	1.7	- -	- -
MFWF09-02	MR-2-3-U	2	2.1	1	N
MFWF09-02	MR-2-3-U	3	1.7	4	Y
MFWF09-02	MR-2-3-U	4	2.1	10	N
MFWF09-02	MR-2-3-U	5	1.7	3	N
MFWF09-02	MR-2-3-U	6	1.7	7	Y
MFWF09-02	MR-2-3-U	7	2.1	1	Y
MFWF09-02	MR-2-3-U	8	2.5	1	N
MFWF09-02	MR-2-3-U	9	1.6	- -	- -
MFWF09-01	MR-2-3-U	1	2.3	2	N
MFWF09-01	MR-2-3-U	2	1.0	0	N
MFWF09-01	MR-2-3-U	3	1.4	0	N
MFWF09-01	MR-2-3-U	4	0.5	3	N
MFWF08-01	MR-2-2-U	1	1.9	6	Q
MFWF08-01	MR-2-2-U	2	1.6	5	N
MFWF08-01	MR-2-2-U	3	0.9	3	N
MFWF08-01	MR-2-2-U	4	1.2	2	N
MFWF08-01	MR-2-2-U	5	2.0	0	N
MFWF08-01	MR-2-2-U	6	0.6	1	Q
MFWF04-01	MR-4-1-C	1	1.3	8	Y
MFWF04-01	MR-4-1-C	2	1.1	- -	- -
MFWF04-01	MR-4-1-C	3	0.9	- -	- -
MFWF04-01	MR-4-1-C	4	1.1	4	Y
MFWF04-01	MR-4-1-C	5	0.9	- -	- -
MFWF04-01	MR-4-1-C	6	1.2	5	Y
MFWF04-01	MR-4-1-C	7	- -	- -	- -
MFWF04-01	MR-4-1-C	8	- -	- -	- -
MFWF04-01	MR-4-1-C	9	1.4	1	Y
MFWF02-01-1	MR-4-1-U	1	1.1	3	Y
MFWF02-01-1	MR-4-1-U	2	0.8	1	N
MFWF02-01-1	MR-4-1-U	3	- -	- -	- -
MFWF02-01-1	MR-4-1-U	4	- -	- -	- -
MFWF02-01-1	MR-4-1-U	5	- -	- -	- -
MFWF02-01-1	MR-4-1-U	6	0.6	12	Y
MFWF02-01-1	MR-4-1-U	7	- -	- -	- -
MFWF02-01-1	MR-4-1-U	8	- -	- -	- -
MFWF02-01-1	MR-4-1-U	9	0.7	29	Y
MFWF02-01-1	MR-4-1-U	10	0.6	39	Y

Table G-4. Pool data per assessment reach.

Reach ID	Reach Type	Pool	Residual Depth (Feet)	Pool Grid Toss Percent <6mm	Spawning Gravels Identified
WFGR02-01	MR-0-3-U	1	1.8	5	Y
WFGR02-01	MR-0-3-U	2	1.6	- -	- -
WFGR02-01	MR-0-3-U	3	1.3	3	N
WFGR02-01	MR-0-3-U	4	1.0	- -	- -
WFGR02-01	MR-0-3-U	5	1.5	- -	- -
WFGR02-01	MR-0-3-U	6	1.1	1	N
WFGR02-01	MR-0-3-U	7	1.7	0	not indicated
WFGR01-04	MR-2-3-U	- -	- -	- -	- -
WFGR01-02	MR-2-3-U	1	- -	- -	- -
WFGR01-02	MR-2-3-U	2	1.1	0	Y
WFGR01-02	MR-2-3-U	3	- -	- -	- -
WFGR01-02	MR-2-3-U	4	1.6	- -	- -
SFWF22-01	MR-0-3-U	1	2.8	1	N
SFWF22-01	MR-0-3-U	2	1.7	0	Y
SFWF22-01	MR-0-3-U	3	1.2	- -	- -
SFWF22-01	MR-0-3-U	4	1.2	- -	- -
SFWF22-01	MR-0-3-U	5	2.2	- -	- -
SFWF22-01	MR-0-3-U	6	2.2	1	not indicated
SFWF22-01	MR-0-3-U	7	2.0	0	N
SFWF22-01	MR-0-3-U	8	1.9	0	Q
SFWF22-01	MR-0-3-U	9	4.2	- -	- -
SFWF22-01	MR-0-3-U	10	2.7	9	N
SFWF22-01	MR-0-3-U	11	1.2	5	N
SFWF28-01	MR-2-3-U	1	0.9	1	N
SFWF28-01	MR-2-3-U	2	0.5	1	Y
SFWF28-01	MR-2-3-U	3	0.6	1	N
SFWF28-01	MR-2-3-U	4	0.6	0	not indicated
SFWF28-01	MR-2-3-U	5	1.2	0	N
SFWF28-01	MR-2-3-U	6	0.8	2	not indicated
SFWF28-01	MR-2-3-U	7	2.6	- -	- -
SFWF28-01	MR-2-3-U	8	1.2	0	N
WFGR03-03	MR-0-4-U	1	1.2	1	N
WFGR03-03	MR-0-4-U	2	1.1	5	N
BEEH12-01	MR-2-1-U	1	0.8	4	Y
BEEH12-01	MR-2-1-U	2	0.5	9	Y
BEEH12-01	MR-2-1-U	3	1.1	- -	- -
BEEH12-01	MR-2-1-U	4	1.8	8	Y
BEEH12-01	MR-2-1-U	5	0.8	- -	- -
BEEH12-01	MR-2-1-U	6	1.6	4	Y
BEEH12-01	MR-2-1-U	7	0.8	- -	- -
BEEH12-01	MR-2-1-U	8	1.9	- -	- -
BEEH12-01	MR-2-1-U	9	0.8	- -	- -
BEEH12-01	MR-2-1-U	10	0.6	7	Y
BEEH12-01	MR-2-1-U	11	1.2	6	Y

Table G-4. Pool data per assessment reach.

Reach ID	Reach Type	Pool	Residual Depth (Feet)	Pool Grid Toss Percent <6mm	Spawning Gravels Identified
BEEH12-01	MR-2-1-U	12	1.8	- -	- -
BEEH12-01	MR-2-1-U	13	0.9	- -	- -
BEEH12-01	MR-2-1-U	14	0.9	12	Y
BEEH12-01	MR-2-1-U	15	0.7	12	Y
SFWF29-02	MR-0-3-U	1	2.8	1	N
SFWF29-02	MR-0-3-U	2	1.4	1	N
SFWF29-02	MR-0-3-U	3	2.4	7	N
SFWF29-02	MR-0-3-U	4	2.4	3	Q
SFWF29-02	MR-0-3-U	5	1.4	1	N
SFWF29-02	MR-0-3-U	6	1.5	6	Q
SFWF29-02	MR-0-3-U	7	2.0	- -	- -
SFWF29-02	MR-0-3-U	8	1.8	0	N
MFWF02-01-2	MR-4-1-U	1	0.3	26	Y
MFWF02-01-2	MR-4-1-U	2	0.4	- -	- -
MFWF02-01-2	MR-4-1-U	3	0.4	- -	- -
MFWF02-01-2	MR-4-1-U	4	0.4	33	not indicated
MFWF02-01-2	MR-4-1-U	5	0.4	- -	- -
MFWF02-01-2	MR-4-1-U	6	0.7	- -	- -
MFWF02-01-2	MR-4-1-U	7	0.6	7	Y
MFWF02-01-2	MR-4-1-U	8	0.4	1	Y
MFWF02-01-2	MR-4-1-U	9	0.5	- -	- -
MFWF02-01-2	MR-4-1-U	10	0.4	- -	- -
MFWF02-01-2	MR-4-1-U	11	0.4	- -	- -
MFWF02-01-2	MR-4-1-U	12	0.5	- -	- -
MFWF02-01-2	MR-4-1-U	13	0.8	12	Y
MFWF02-01-2	MR-4-1-U	14	0.6	7	Y
MFWF02-01-2	MR-4-1-U	15	0.4	- -	- -
MFWF02-01-2	MR-4-1-U	16	1.0	- -	- -
MFWF02-01-2	MR-4-1-U	17	0.4	- -	- -
MFWF02-01-2	MR-4-1-U	18	0.6	- -	- -
MFWF02-01-2	MR-4-1-U	19	0.6	- -	- -
MFWF02-01-2	MR-4-1-U	20	0.7	6	Y
MFWF02-01-2	MR-4-1-U	21	0.4	33	Y
MFWF02-01-2	MR-4-1-U	22	- -	- -	- -
MFWF02-01-2	MR-4-1-U	23	0.5	- -	- -
MFWF02-01-2	MR-4-1-U	24	0.5	- -	- -
MFWF02-01-2	MR-4-1-U	25	0.4	3	Y
MFWF02-01-2	MR-4-1-U	26	0.9	2	Y
MFWF02-01-2	MR-4-1-U	27	1.2	- -	- -
MFWF02-01-2	MR-4-1-U	28	0.4	- -	- -
BEEH13-01	MR-4-1-U	1	1.4	1	Y
BEEH13-01	MR-4-1-U	2	1.7	1	Y
BEEH13-01	MR-4-1-U	3	0.9	1	Y
BEEH13-01	MR-4-1-U	4	- -	3	Y
BEEH13-01	MR-4-1-U	5	1.8	2	Y
BEEH13-01	MR-4-1-U	6	1.8	0	Y
BEEH13-01	MR-4-1-U	7	1.0	0	Y

Table G-4. Pool data per assessment reach.

Reach ID	Reach Type	Pool	Residual Depth (Feet)	Pool Grid Toss Percent <6mm	Spawning Gravels Identified
BEEH13-01	MR-4-1-U	8	1.3	0	Y
BEEH13-01	MR-4-1-U	9	- -	- -	- -
BEEH13-01	MR-4-1-U	10	2.4	3	Y
BEEH13-01	MR-4-1-U	11	1.7	5	Y
BEEH13-01	MR-4-1-U	12	0.4	- -	- -
BEEH13-01	MR-4-1-U	13	1.0	2	Y
BEEH13-01	MR-4-1-U	14	0.5	3	Y
BEEH13-01	MR-4-1-U	15	0.3	- -	- -
BEEH13-01	MR-4-1-U	16	0.6	- -	- -
BEEH13-01	MR-4-1-U	17	1.0	7	Y
BEEH13-01	MR-4-1-U	18	0.5	- -	- -
BEEH13-01	MR-4-1-U	19	1.0	- -	- -
BEEH13-01	MR-4-1-U	20	0.5	- -	- -
BEEH13-01	MR-4-1-U	21	1.1	3	Y
BEEH13-01	MR-4-1-U	22	1.0	1	N
BEEH13-01	MR-4-1-U	23	0.7	- -	- -
NFWF10-01	MR-2-2-U	1	0.6	8	Y
NFWF10-01	MR-2-2-U	2	1.0	3	N
NFWF10-01	MR-2-2-U	3	1.0	8	Q
NFWF10-01	MR-2-2-U	4	1.0	1	Y
NFWF10-01	MR-2-2-U	5	0.8	5	Y
NFWF10-01	MR-2-2-U	6	0.8	4	N
NFWF10-01	MR-2-2-U	7	1.3	1	Q
NFWF10-01	MR-2-2-U	8	- -	- -	- -
NFWF10-01	MR-2-2-U	9	1.6	12	Q
NFWF10-01	MR-2-2-U	10	1.6	0	Y
NFWF10-01	MR-2-2-U	11	1.0	1	N
NFWF10-01	MR-2-2-U	12	1.6	3	Y
NFWF10-01	MR-2-2-U	13	1.0	1	Y
NFWF10-01	MR-2-2-U	14	1.4	4	Y
NFWF10-01	MR-2-2-U	15	0.8	2	Y
NFWF10-01	MR-2-2-U	16	0.7	1	Y
NFWF10-01	MR-2-2-U	17	0.9	1	N
NFWF10-01	MR-2-2-U	18	1.2	3	Q
NFWF10-01	MR-2-2-U	19	1.2	4	Y
NFWF10-01	MR-2-2-U	20	- -	- -	- -

Y = Spawning Gravels Present
N = Spawning Gravels Absent
Q = Questionable Spawning Gravels

G4.0 REFERENCES

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APPENDIX H
RESPONSE TO PUBLIC COMMENTS

The public comment period for *The West Fork Gallatin River Watershed Total Maximum Daily Loads (TMDLs) and Framework Watershed Water Quality Improvement Plan* was initiated on August 24th, 2010 and concluded on Sept 13th, 2010. A public meeting was held in Big Sky, MT on August 25th.

A single comment letter was submitted to DEQ by the Blue Water Task Force during the public comment period. Original comment letters are held on file at the DEQ and may be viewed upon request.

Commentor: Kristin Gardner, Blue Water Task Force

Thank you for allowing comment on the West Fork Gallatin Total Maximum Daily Load and Framework Watershed Water Quality Improvement document. I recommend that the following items be addressed in the document:

Comment #1:
Page 68, Section 6.4.3: Background and/or reference for considering HIBI < 4.0 for further evaluation for nutrient compliance.

DEQ Response to Comment #1:
HIBI values and their utilization as supplemental indicators of nutrient impairment are addressed in the assessment methodology, *Assessment Methodology for Determining Wadeable Stream Impairment due to Excess Nutrients (Nitrogen and Phosphorus)* (Suplee, M., and R. Sada de Suplee. 2010). The document has been modified to clarify that HIBI value evaluation is included as part of the assessment methodology referenced above.

Comment #2:
Page 96, Section 6.5.2, Figure 6-17: I am concerned by potential interpretation of decreasing algae trends in time. Our contractor, Jeff Dunn (PBSJ), mentioned that he was worried that lower levels of chlorophyll a were measured because of the new DEQ chlorophyll a sampling methods. He did not visually observe decreasing algal densities over time. I also have not visually observed less algae over time. I believe that there should be a note discussing precaution in interpreting the lower levels b/c of the change in methodology. The decrease of algae over time was brought up by a member in the audience at the public meeting. Also, nitrate data collected by the Blue Water Task Force does not suggest lower nitrate concentrations over time. You cannot tell this by looking at the plots on Figure 6-18 because they are 3 year averages – can you separate out this plot so that one can distinguish between years?

DEQ Response to Comment #2:
Figure 6-17 is not intended to show changes in algal conditions over time, but to illustrate chlorophyll-*a* concentrations recorded during three distinct sampling events. Sampling methods utilized in 2005 entailed collecting 5 algae samples from a single reach transect. Sampling methods utilized in 2008 entailed collecting a single algae sample from each of 11 transects

through the reach. The DEQ believes that the 11 transect method better represents algal conditions for the *entire reach* being assessed; however no formal evaluation or comparison of the two methods has been conducted.

It is likely that differences in chlorophyll-*a* concentration witnessed over time are not the result of a change in methodology, but a function of late season algal senescence. Algal biomass, as measured by ash-free dry weight (g/m^2) was very high (>200 g/m^2) in August of 2008, even while chlorophyll-*a* concentrations were low, indicating that substantial algae was present, yet had begun to die off (senesce) thereby reducing its chlorophyll-*a* content. DEQ acknowledges that algal conditions in the West Fork Gallatin and South Fork West Fork Gallatin River have not decreased substantially over time, as photographic assessments of algae as well as observations by contractors and local researchers attest.

Figure 6-18 illustrates average NO_3+NO_2 loading conditions observed over time in the West Fork Gallatin River, and is shown to support average loading reductions needed to meet water quality targets. DEQ acknowledges that this chart represents an average summer condition, but also provides loading conditions observed during sampling events in 2006, 2007 and 2008 (Figures 6-19 through 6-23, Appendix A) where stream flows allowed calculation of NO_3+NO_2 loads.

Modifications were made to document Section 6.5.2 to clarify algal observations and biomass results. Likewise, Figures 6-17a through 6-17h were added to Appendix A to illustrate algal densities over time through the reach.

Comment #3:
Section 6.5.3: There are no plots of algae or nitrate in the South Fork. I suggest you add them. Also, can you emphasize the need for future study in the South Fork to determine why there was excess algae levels in the Lower South Fork – maybe this should go in Section 8.0?

DEQ Response to Comment #3:
Plots and tables of NO_3+NO_2 concentrations (Figure 6-30, Table 6-32) and figures of algal concentrations (Figures 6-31 through 6-40) were added to clarify algal conditions observed in the South Fork West Fork Gallatin River. The discussion of NO_3+NO_2 and algal conditions in Section 6.5.3 has also been modified to better describe nutrient conditions observed in the South Fork. Additionally, Section 8.0 was modified to address the need to further address nuisance algal growth in the South Fork West Fork Gallatin River.

Comment #4:
References: A few cited references are missing. Page 145, cites DEQ 2007 Nonpoint Source Management Plan. Also page 149, EPA construction BMPs cited as EPA, 2009.

DEQ Response to Comment #4:
DEQ has made the changes and thanks you for your thorough review.