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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.

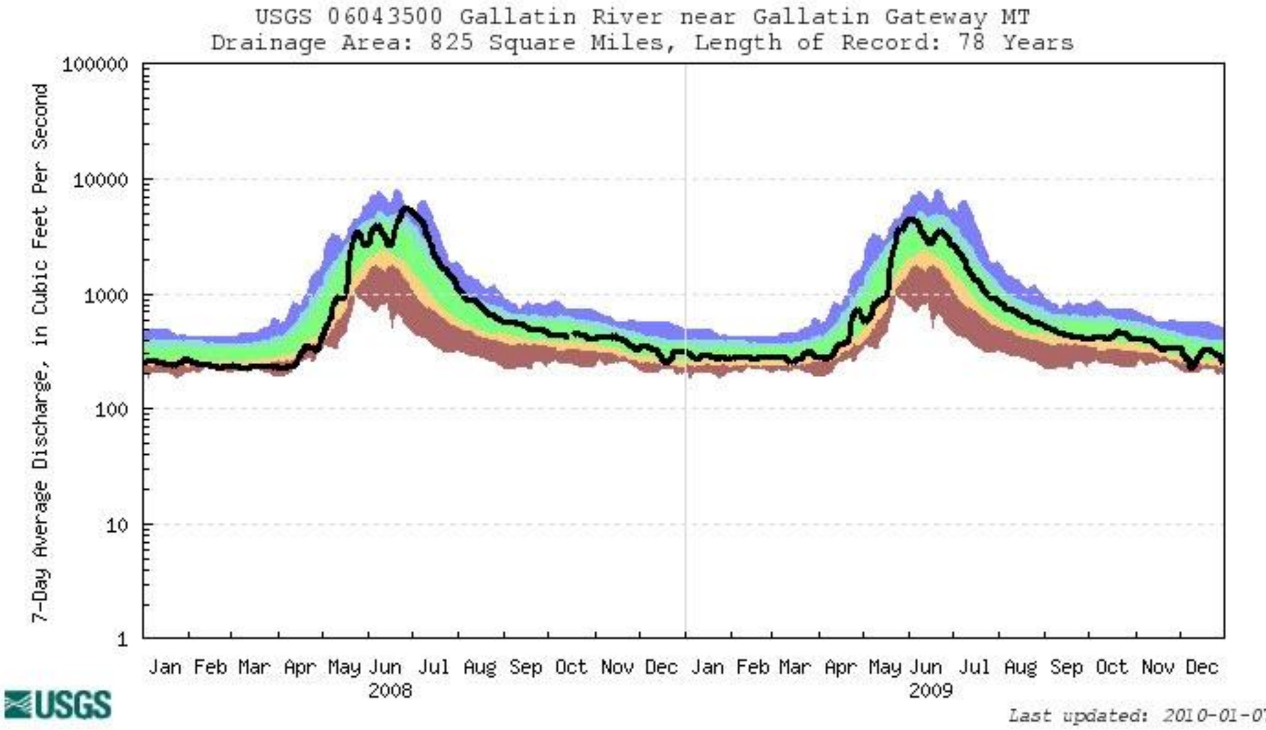

Figure 2-9. Hydrograph summarizing Gallatin River flows at gaging station 06043500 at Gallatin gateway based on weekly flows over a 78-year period of record

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 sculpin. 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:

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

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.

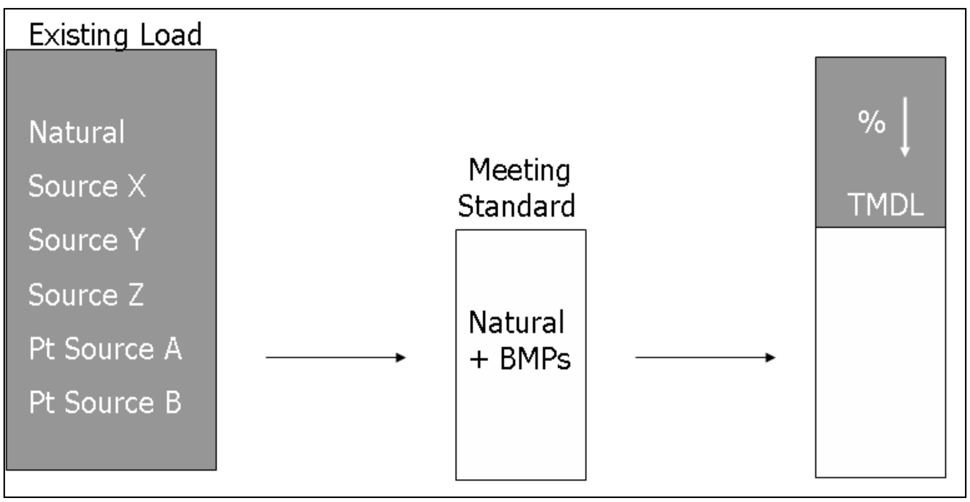

Figure 4-1. Schematic example of TMDL development.

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.

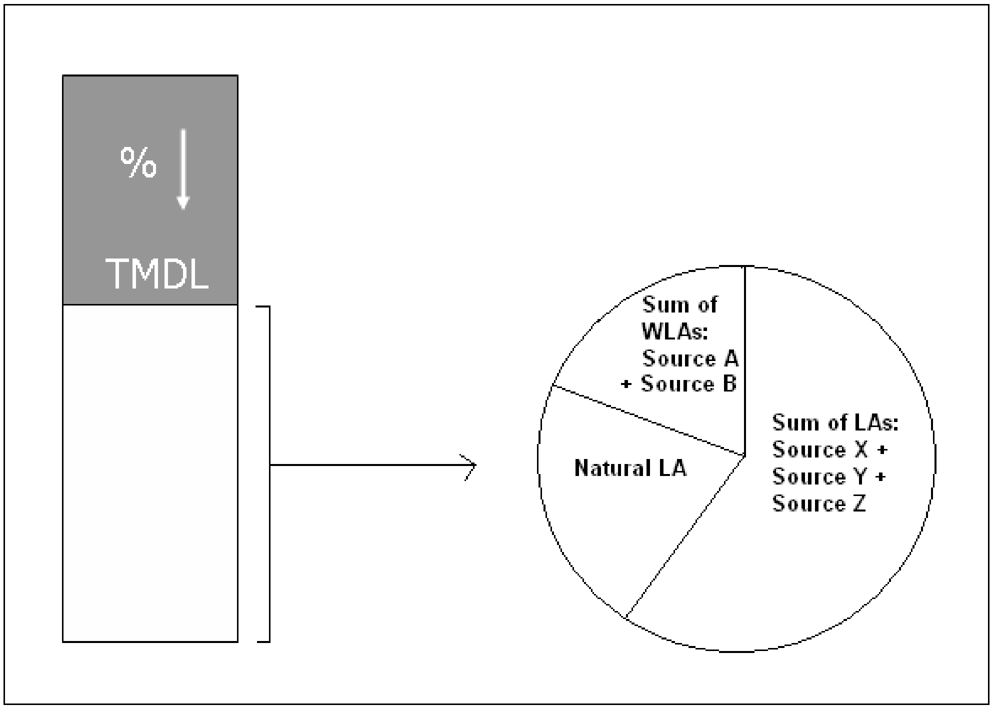

Figure 4-2. Schematic diagram of TMDL and allocations.

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.

<table>
<tr><th>Level III Ecoregion</th><th>Gradient</th><th>Strahler Stream Order</th><th>Confinement</th><th>Reach Type</th><th>Number of Monitoring Reaches</th><th>Total Number of Stratified Reaches</th></tr>
<tr><td rowspan="7">Middle Rockies</td><td rowspan="2">0-<2%</td><td>3</td><td>Unconfined</td><td>MR-0-3-U</td><td>3</td><td>12</td></tr>
<tr><td>4</td><td>Unconfined</td><td>MR-0-4-U</td><td>1</td><td>4</td></tr>
<tr><td rowspan="3">2-<4%</td><td>1</td><td>Unconfined</td><td>MR-2-1-U</td><td>1</td><td>1</td></tr>
<tr><td>2</td><td>Unconfined</td><td>MR-2-2-U</td><td>2</td><td>6</td></tr>
<tr><td>3</td><td>Unconfined</td><td>MR-2-3-U</td><td>5</td><td>9</td></tr>
<tr><td rowspan="2">4-<10%</td><td>1</td><td>Confined</td><td>MR-4-1-C</td><td>1</td><td>10</td></tr>
<tr><td>1</td><td>Unconfined</td><td>MR-4-1-U</td><td>3</td><td>40</td></tr>
</table>

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

<u>Less than 6mm</u>
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

<u>Less than 2mm</u>
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.

		Channel Form (median)		Fine Sediment:(mean)				Instream Habitat			Riparian Health
				Riffle Pebble Count		Grid Toss %<6mm		Residual Pool Depth (mean)	Frequency (#/mile)		
Monitoring Site	Potential Rosgen Stream Type/Reach Gradient	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.

		Channel Form (median)		Fine Sediment: (mean)				Instream Habitat			Riparian Health
				Riffle Pebble Count		Grid Toss %<6			Frequency (#/mile)		
Monitoring Site	Potential Rosgen Stream Type/Reach Gradient	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).

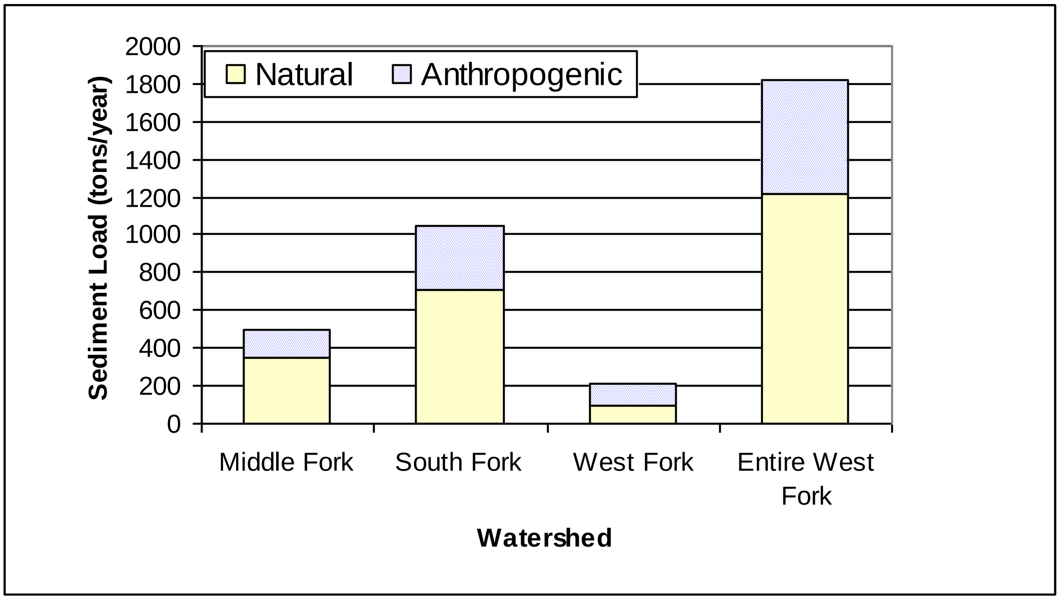

Figure 5-6. Existing annual sediment load from streambank erosion by 303(d) listed watershed within the West Fork Gallatin River watershed.

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.

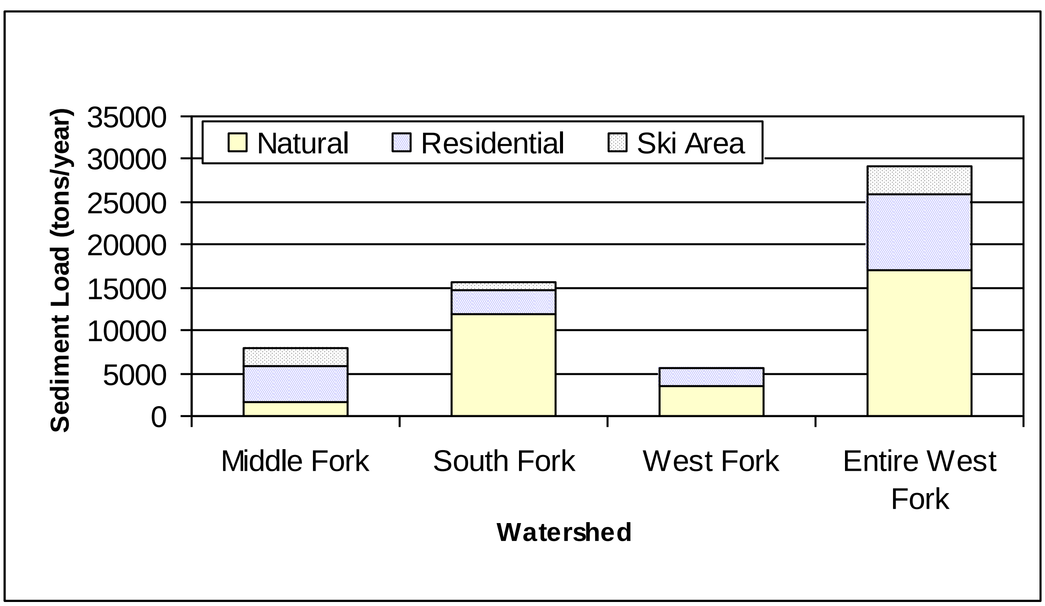

Figure 5-7. Existing annual sediment load from upland erosion by 303(d) listed watershed within the West Fork Gallatin River watershed.

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**.

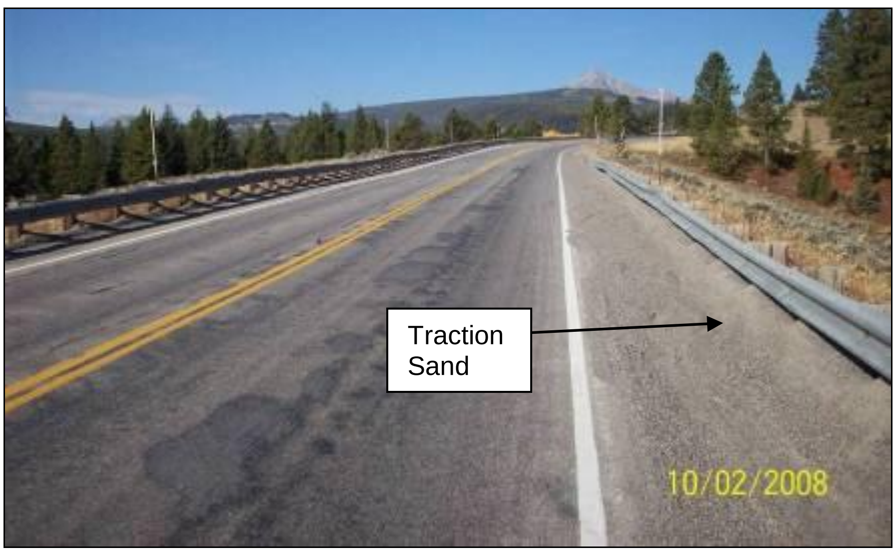

Figure 5-8. Assessment crossing C12 (North Fork West Fork Gallatin River) showing typical build up of traction sand adjacent to a guardrail along Highway 64.

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**.

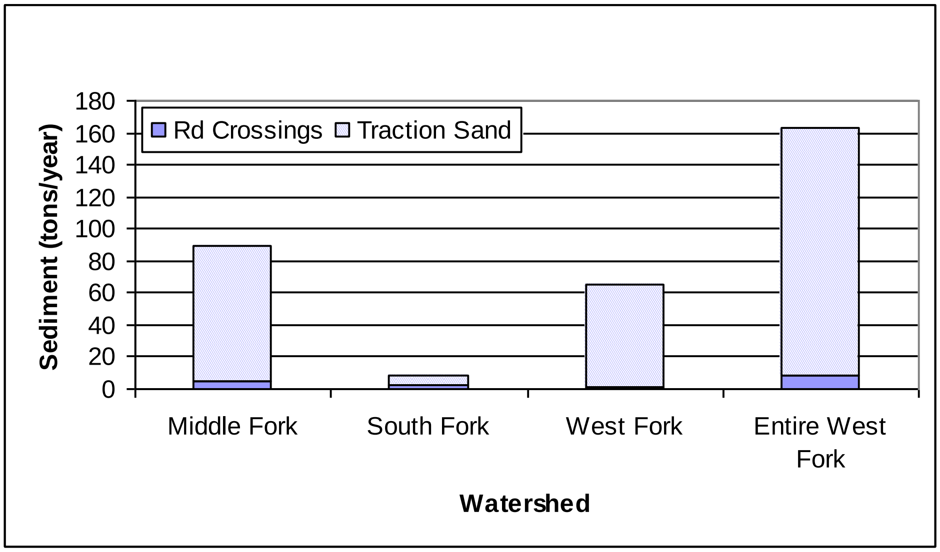

Figure 5-9. Existing annual sediment load from roads and traction sand by 303(d) listed watershed within the West Fork Gallatin River watershed.

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.

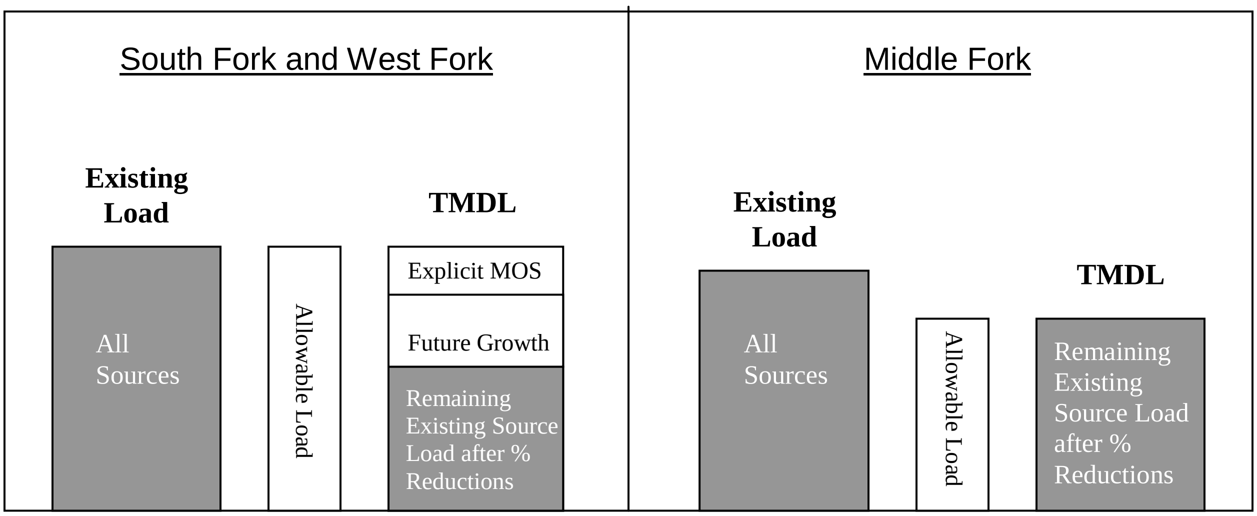

Figure 5-11. Schematic diagram of TMDL and allocation approach for the West Fork Gallatin River watershed

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

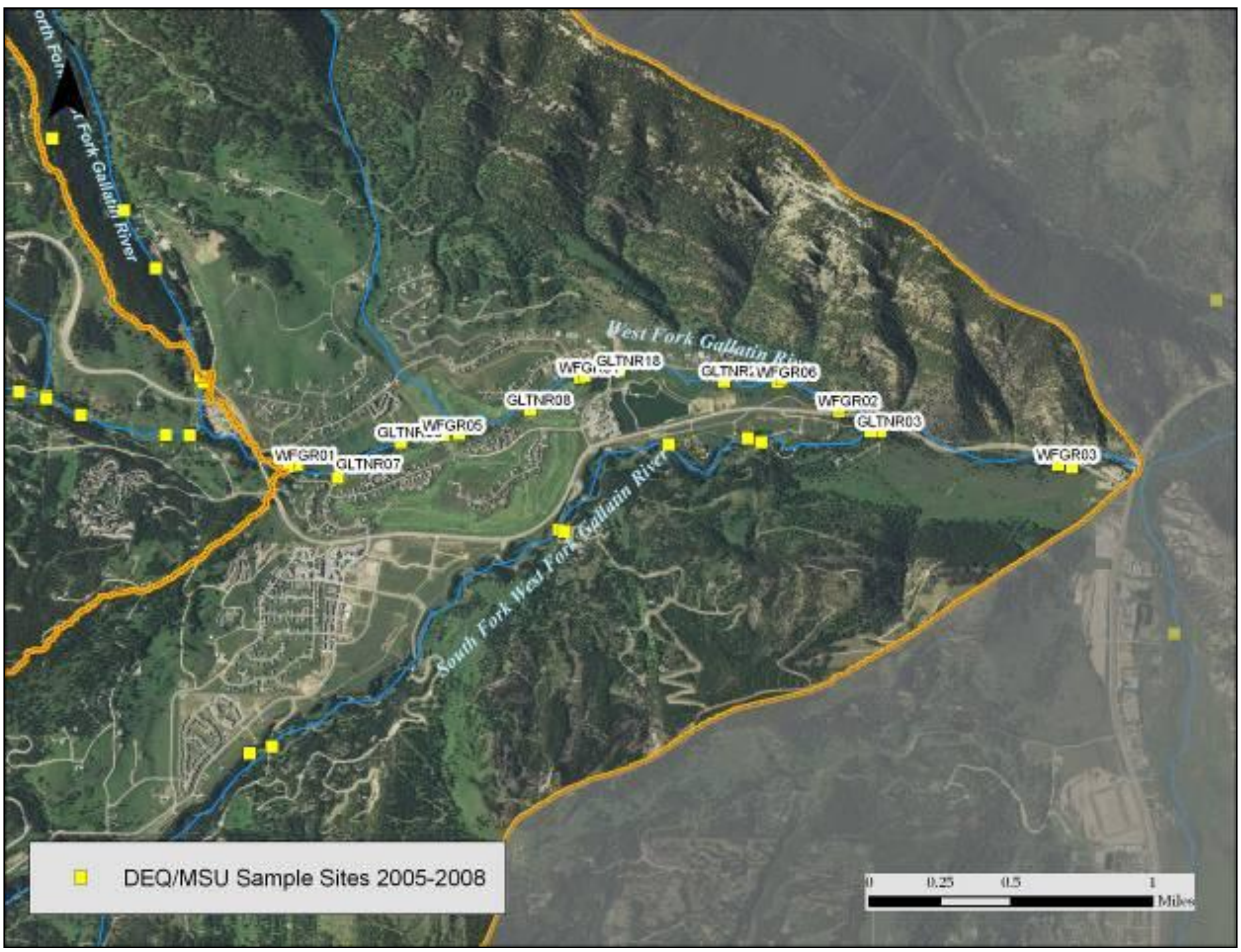

Figure 6-5. West Fork Gallatin River: Nutrient Sampling Sites

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

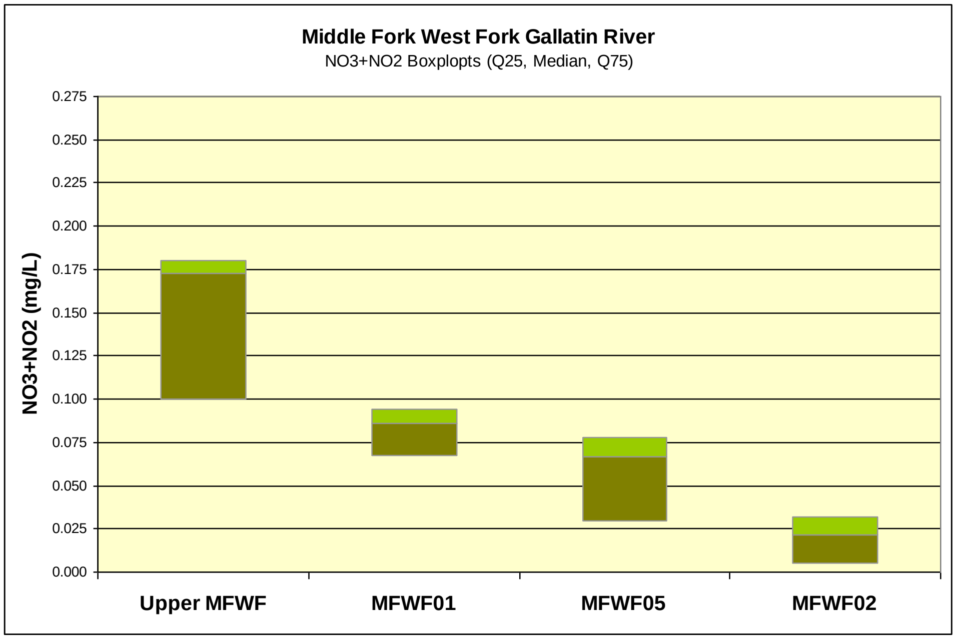

Figure 6-10. NO_3+NO_2 Boxplots: Middle Fork West Fork Gallatin River

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.

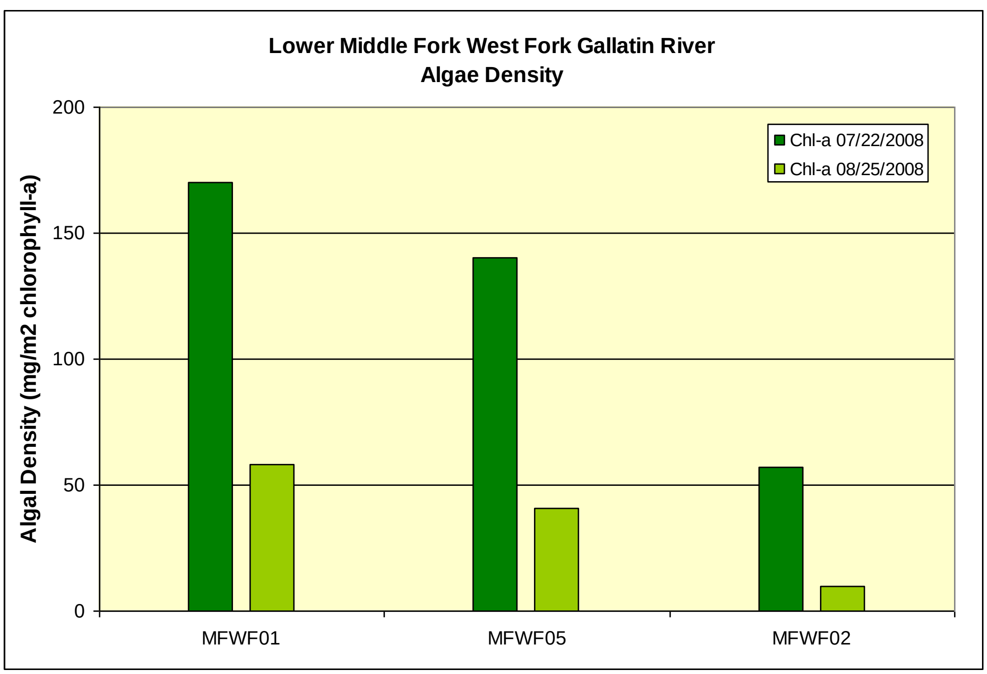

Figure 6-11. Chlorophyll-*a* Concentrations: Lower Middle Fork West Fork Gallatin River

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.

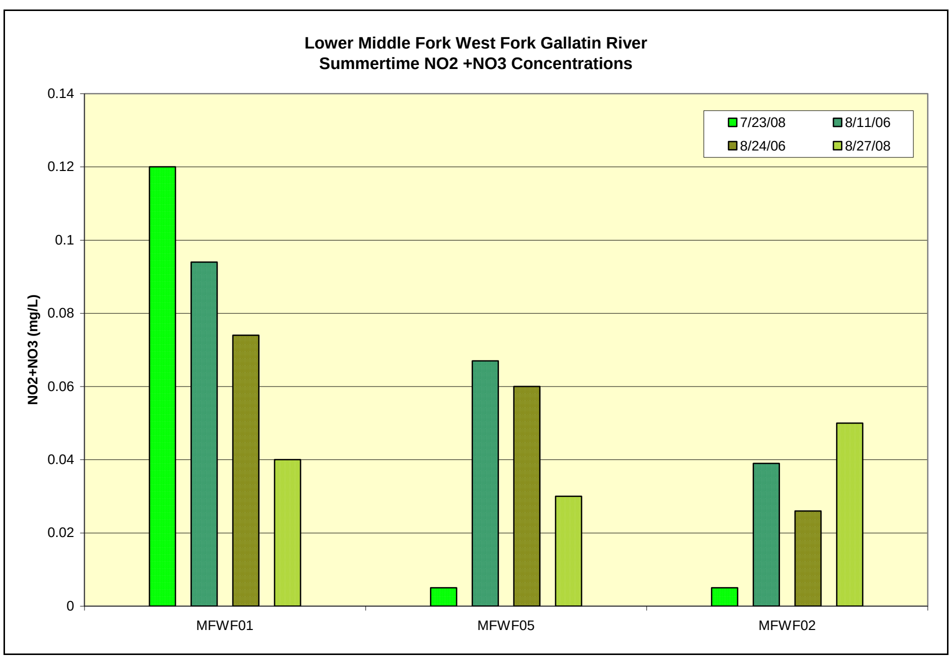

Figure 6-12. Measured NO_3+NO_2 Summer Concentrations, Middle Fork West Fork Gallatin River 2006-2008

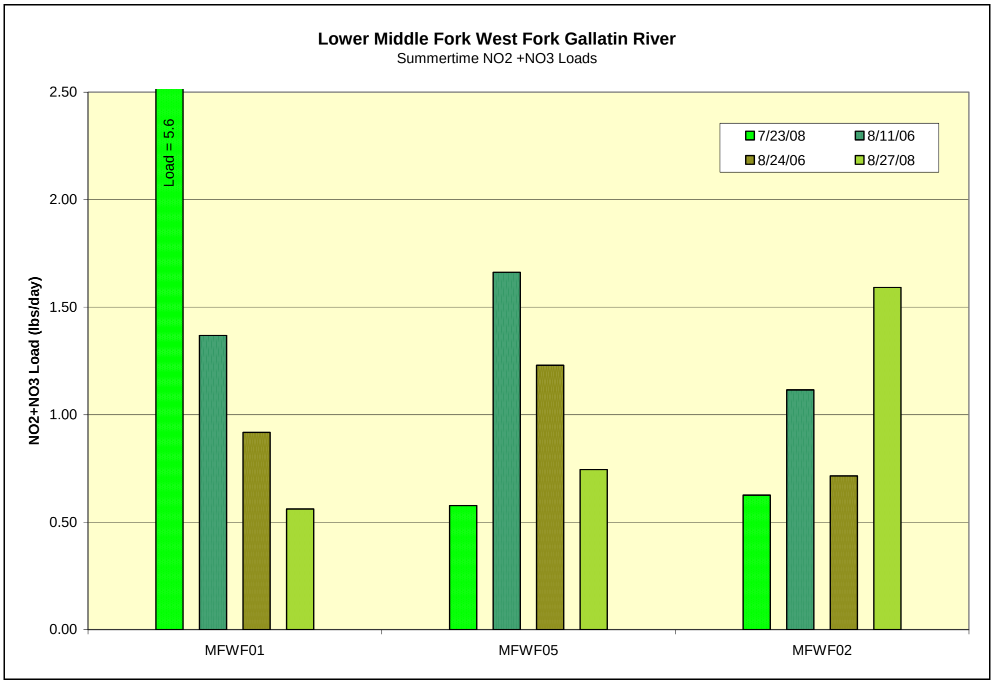

Figure 6-13. Measured NO_3+NO_2 Summer Loads, Middle Fork West Fork Gallatin River 2006-2008

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

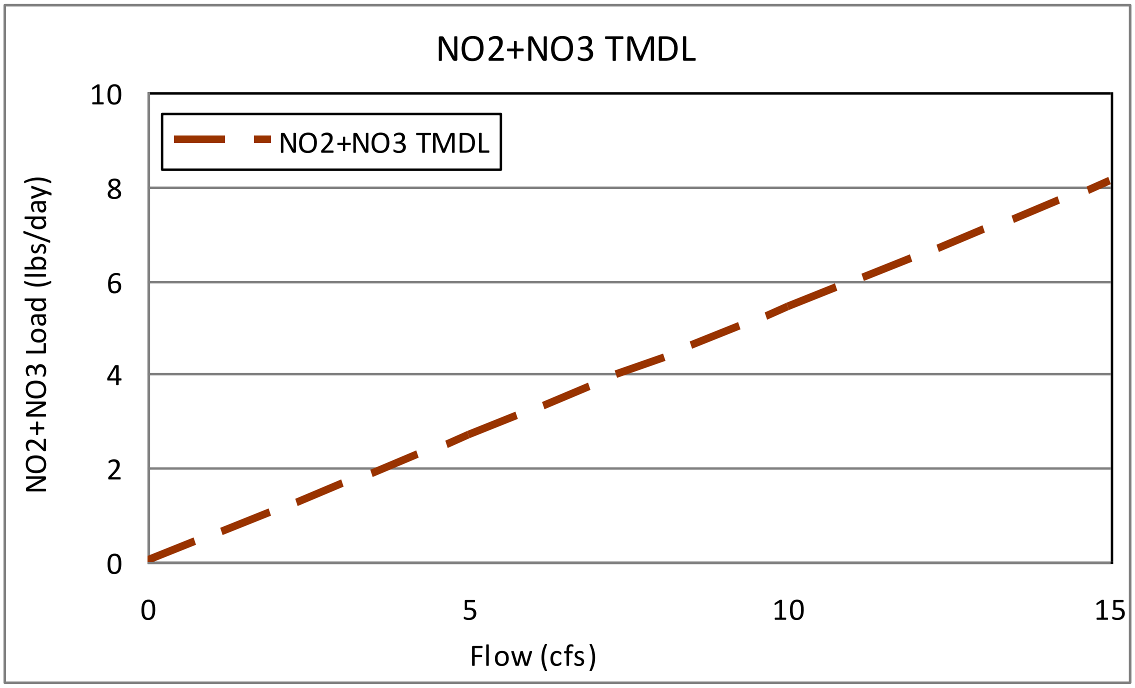

Figure 6-14. NO_3+NO_2 TMDL as a function of flow: Middle Fork West Fork Gallatin River

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:

TMDL = ∑WLA + ∑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}***

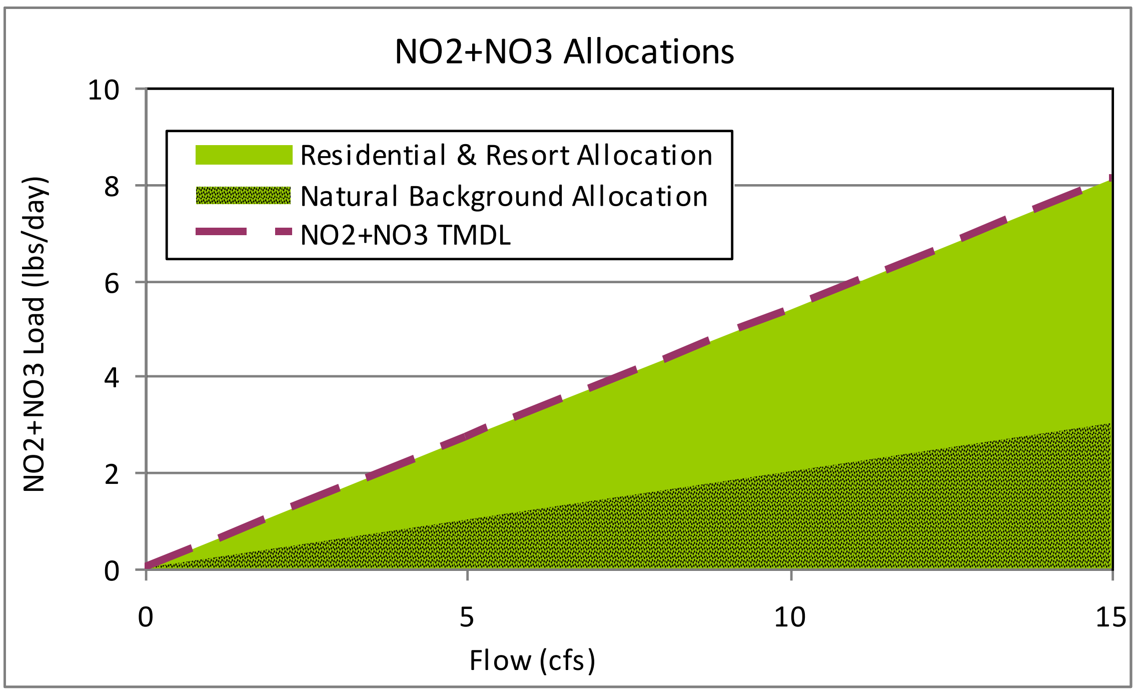

Figure 6-15. NO_3+NO_2 TMDL and Load Allocations, Middle Fork West Fork Gallatin River

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

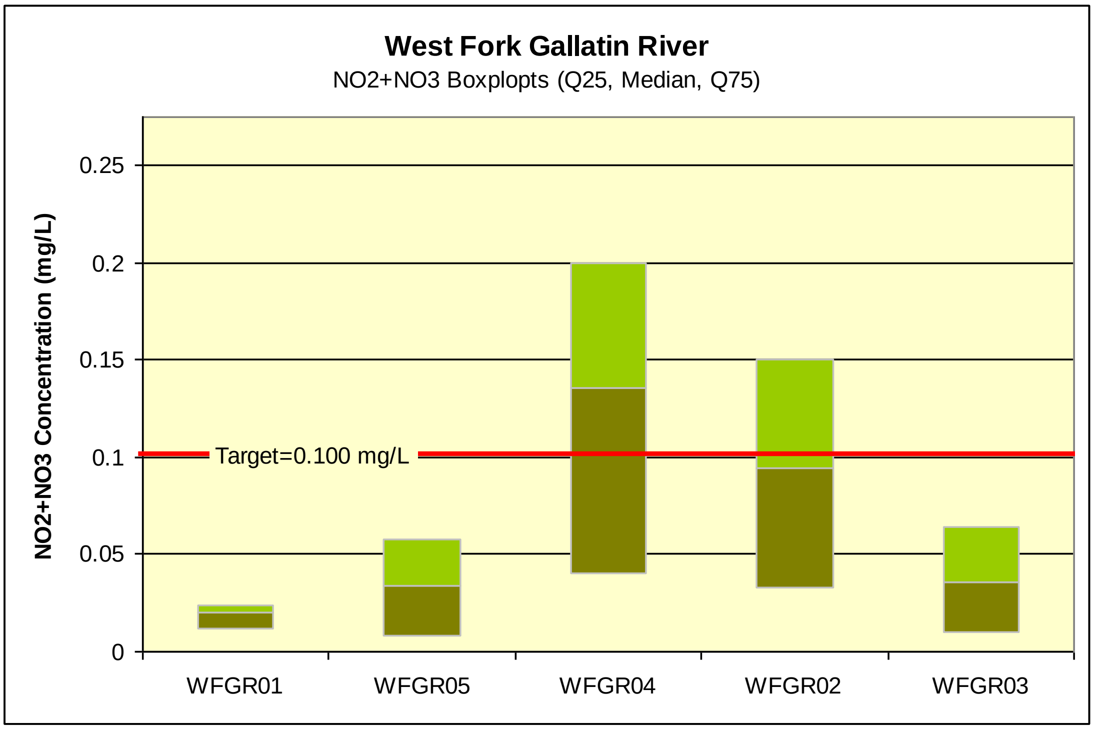

Figure 6-16. NO_3+NO_2 Boxplots: West Fork Gallatin River

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.

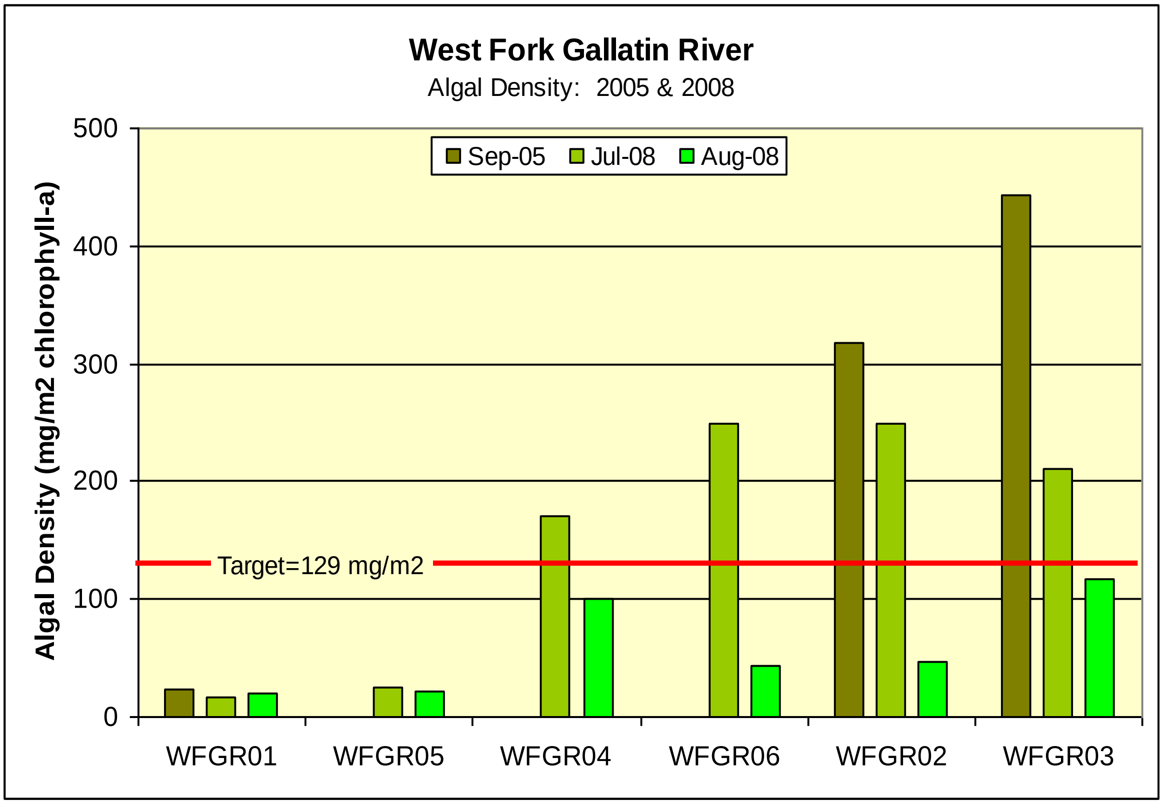

Figure 6-17. Chlorophyll-*a* Concentrations: West Fork Gallatin River

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.

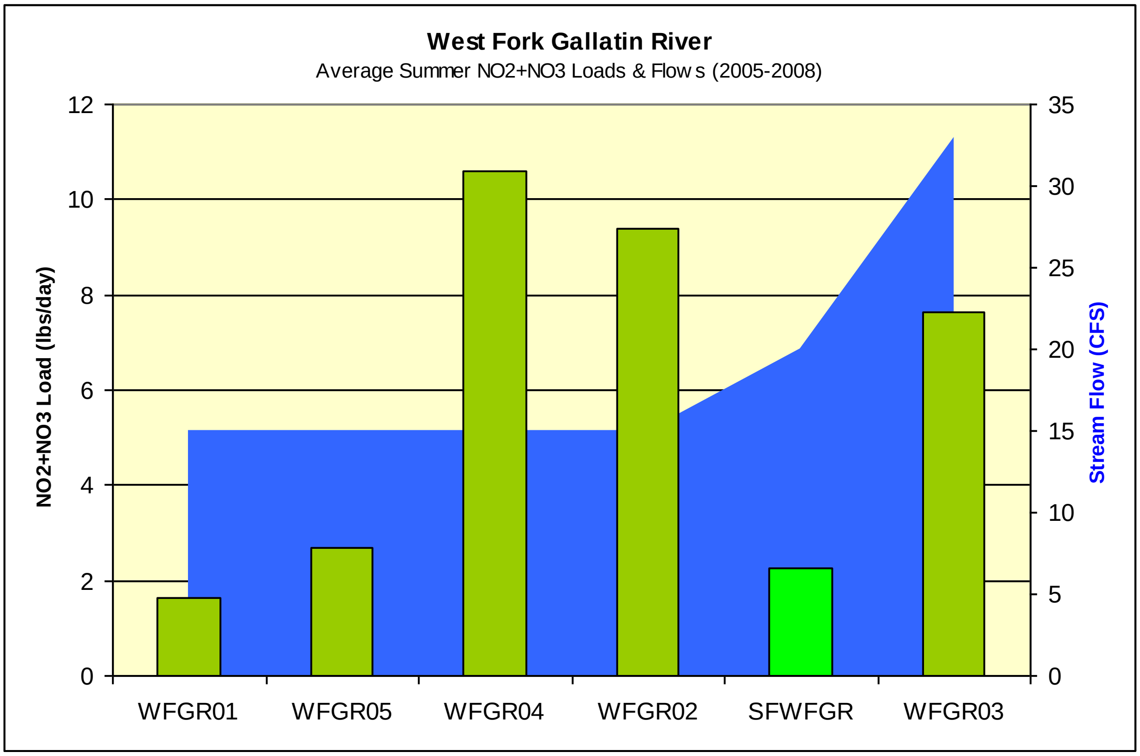

Figure 6-18. Average August NO_3+NO_2 Loads, West Fork Gallatin River 2005-2008.

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

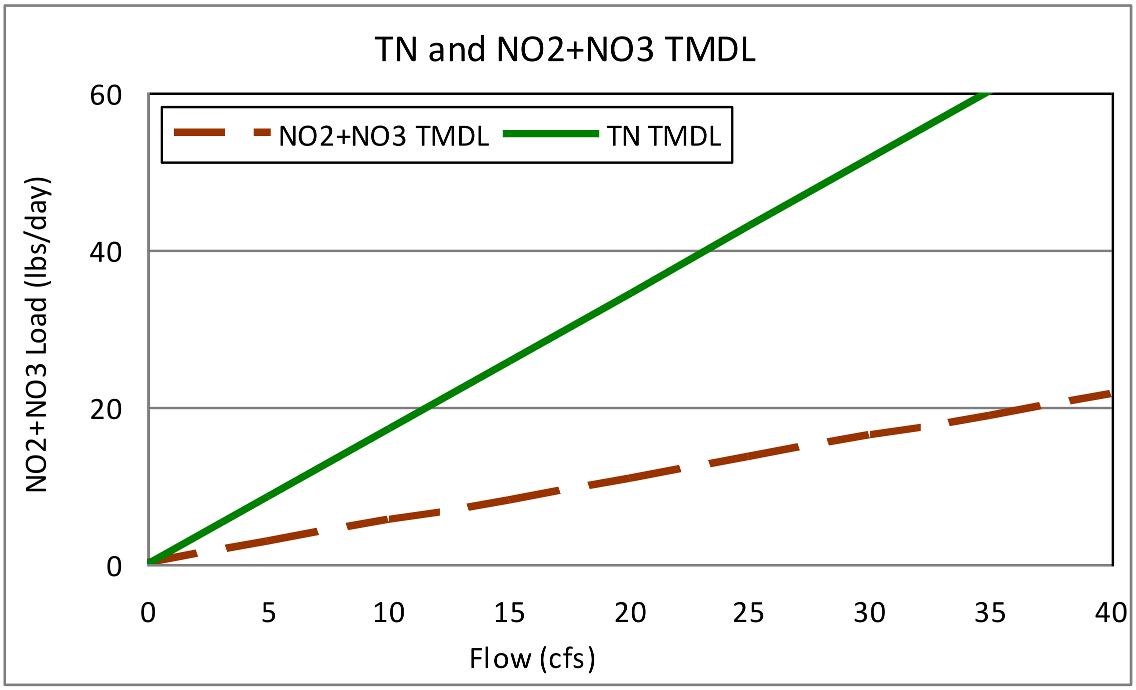

Figure 6-26. TN and NO_3+NO_2 TMDLs as a function of flow

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.

$$LA_{ww} = 0 \text{ lbs/day}$$

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}**

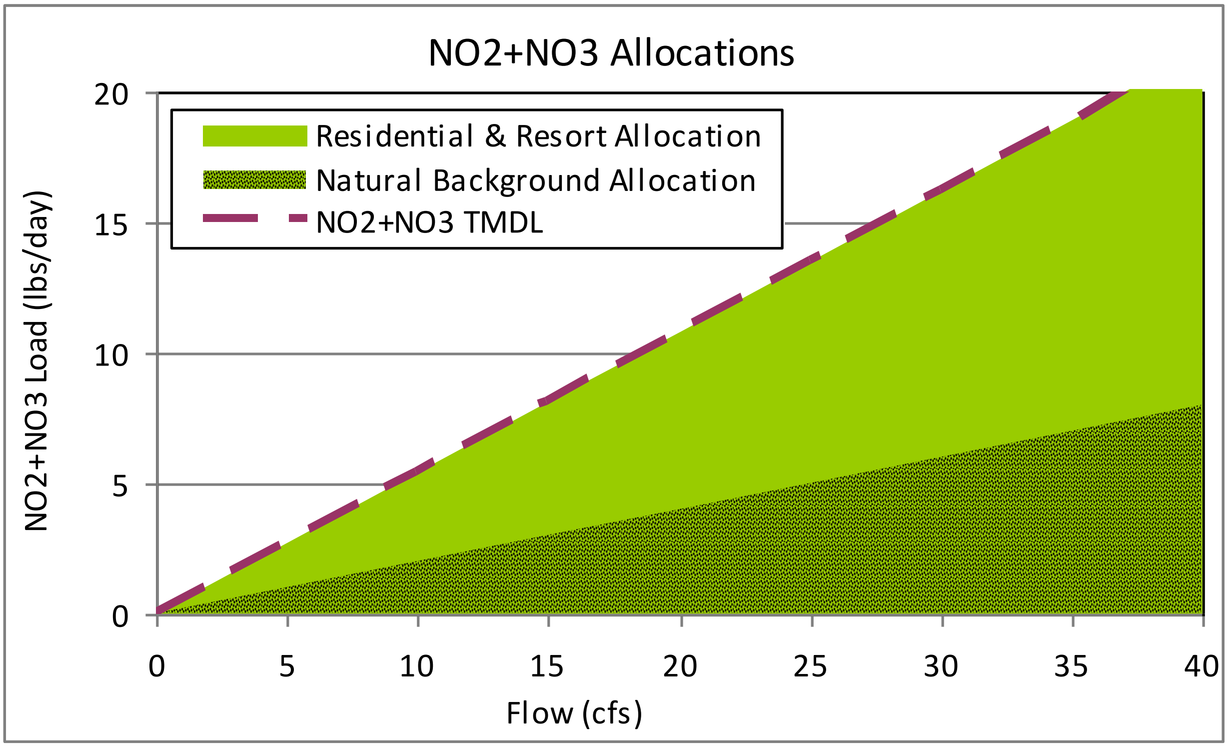

Figure 6-27a. NO_3+NO_2 TMDL and Load Allocations, West Fork Gallatin River

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.

$$LA_{ww} = 0 \text{ lbs/day}$$

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*

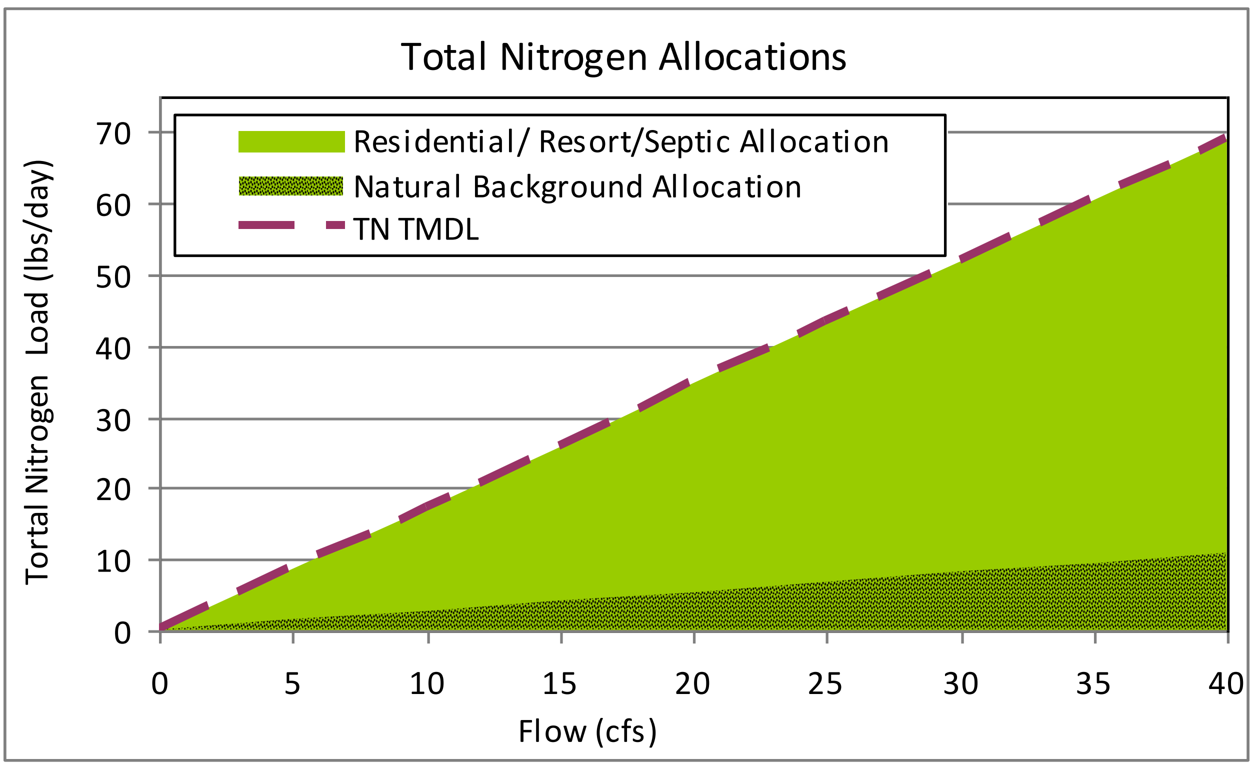

Figure 6-27b.TN TMDL and Load Allocations, West Fork Gallatin River

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

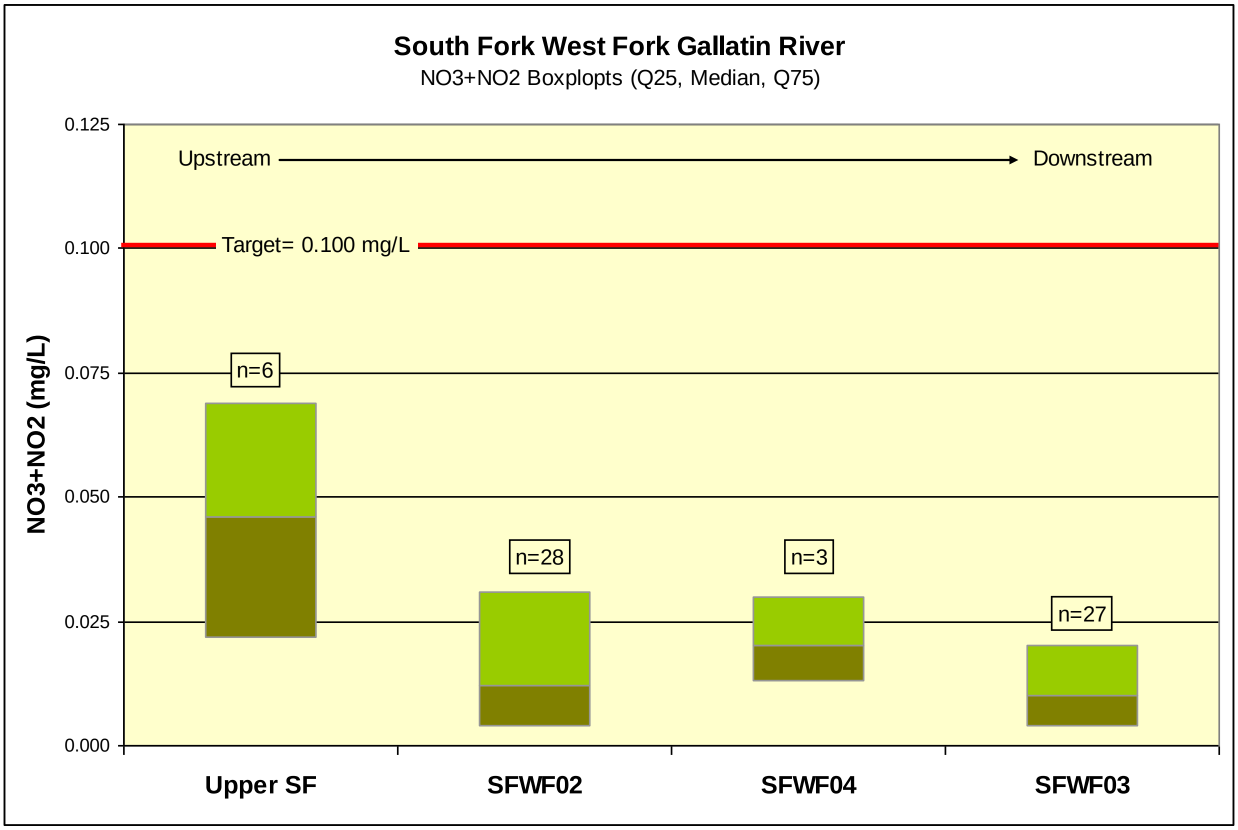

Figure 6-30. NO_3+NO_2 Boxplots: South Fork West Fork Gallatin River

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

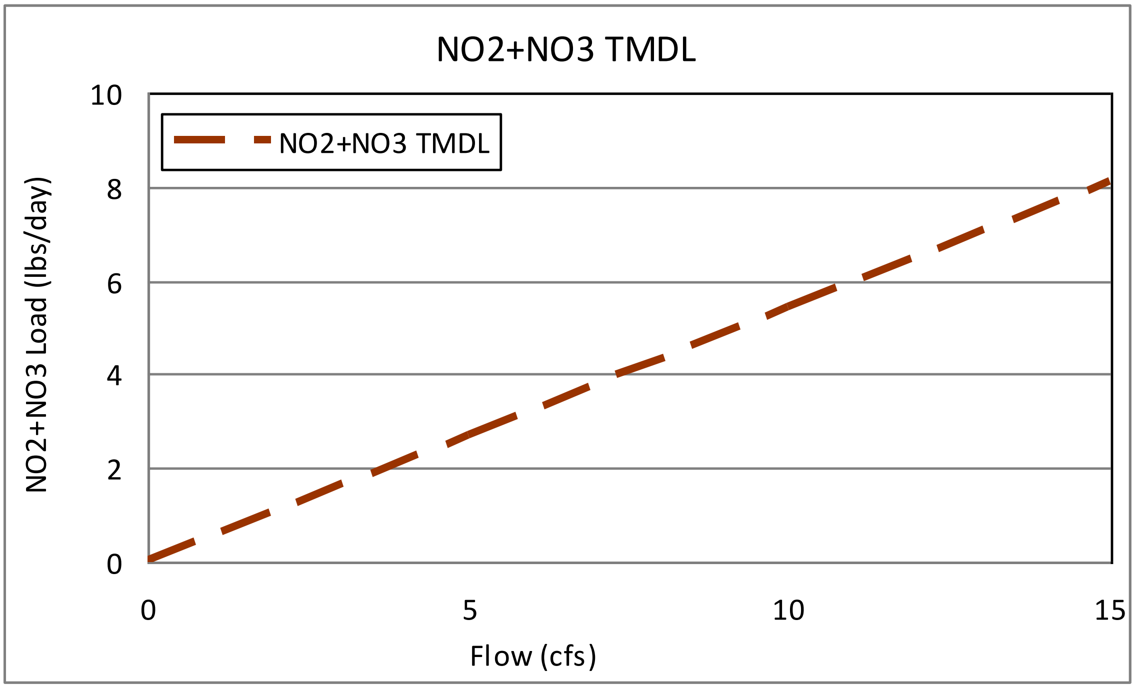

Figure 6-41. NO_3+NO_2 TMDL as a function of flow: South Fork West Fork Gallatin River

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* = ∑*WLA* + ∑*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.

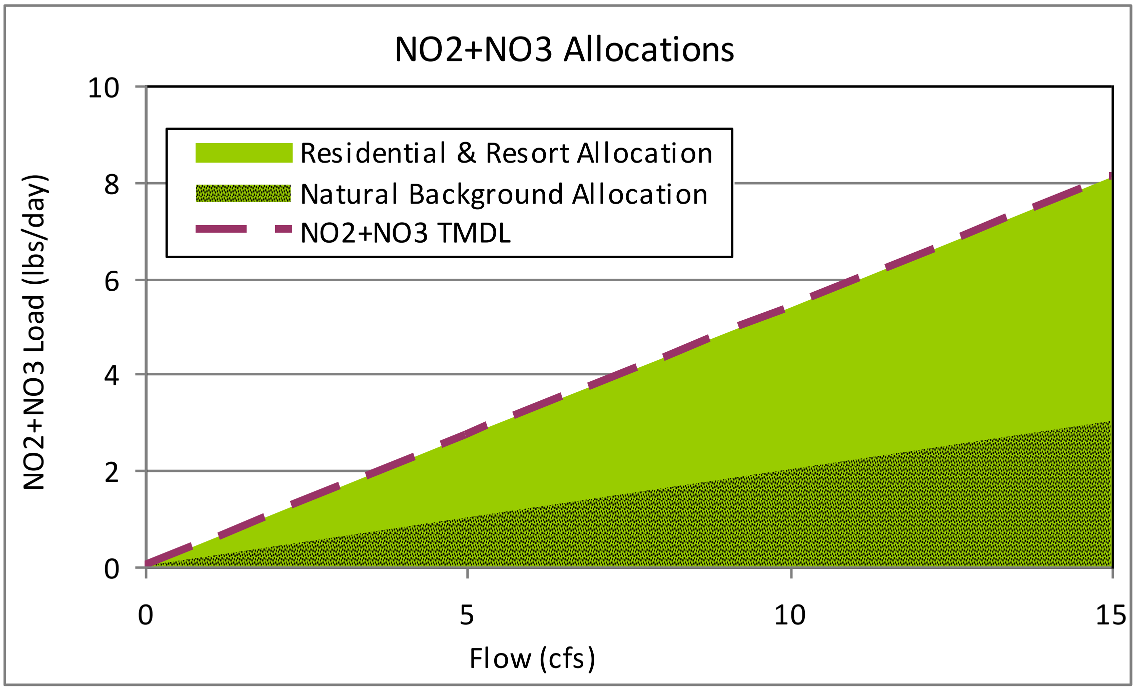

Figure 6-42. NO_3+NO_2 TMDL and Load Allocations, South Fork West Fork Gallatin River

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

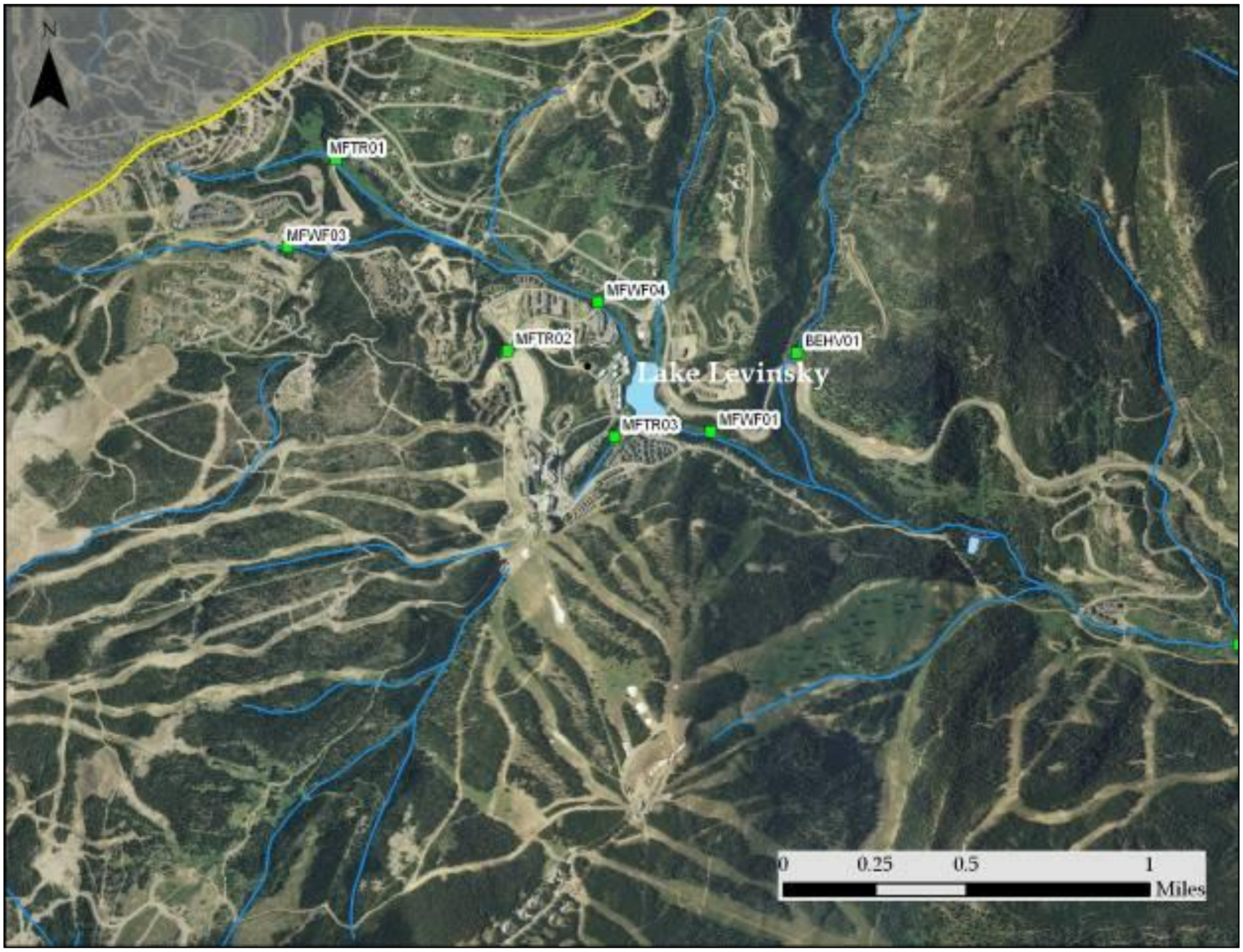

Figure 7-3. Upper Middle Fork West Fork Gallatin River Sampling Sites

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**).

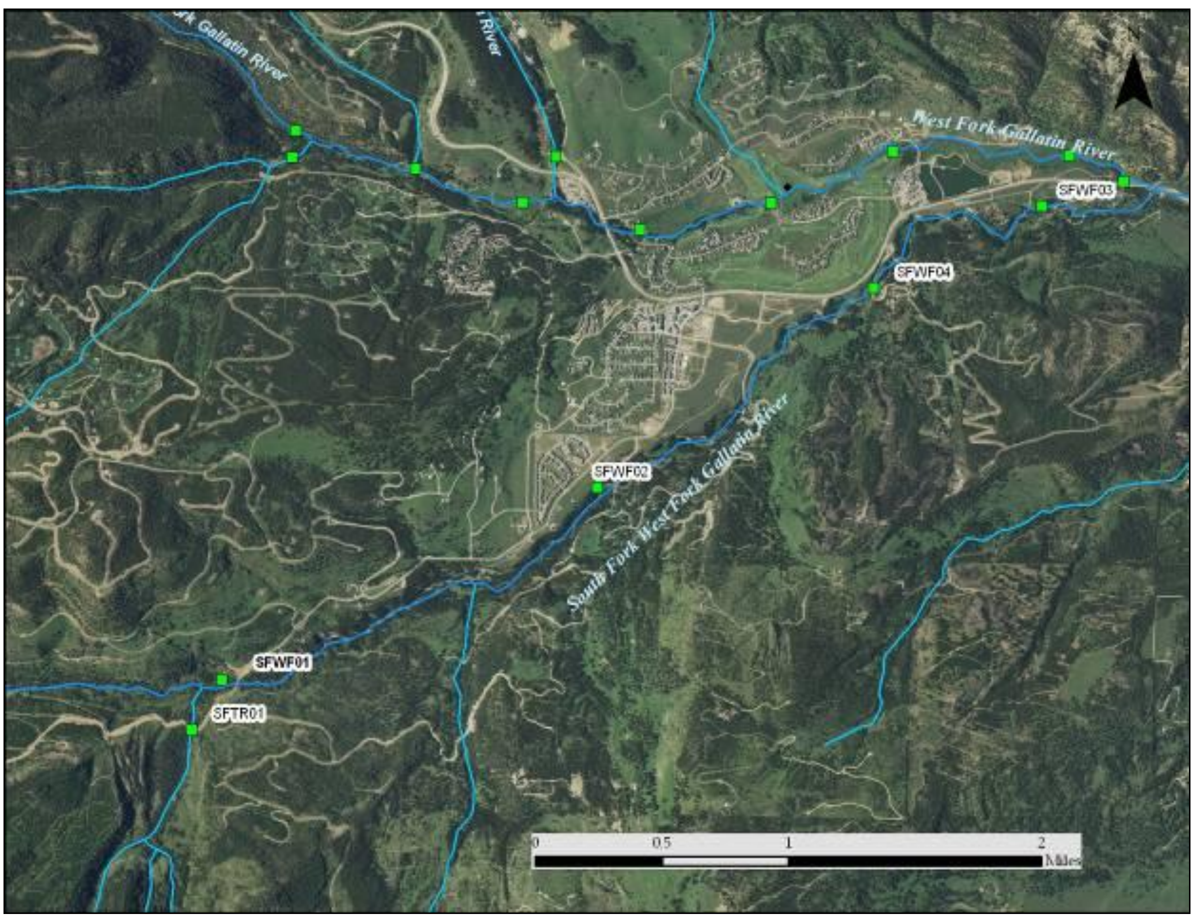

Figure 7-6. South Fork Gallatin River Sampling Sites

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**).

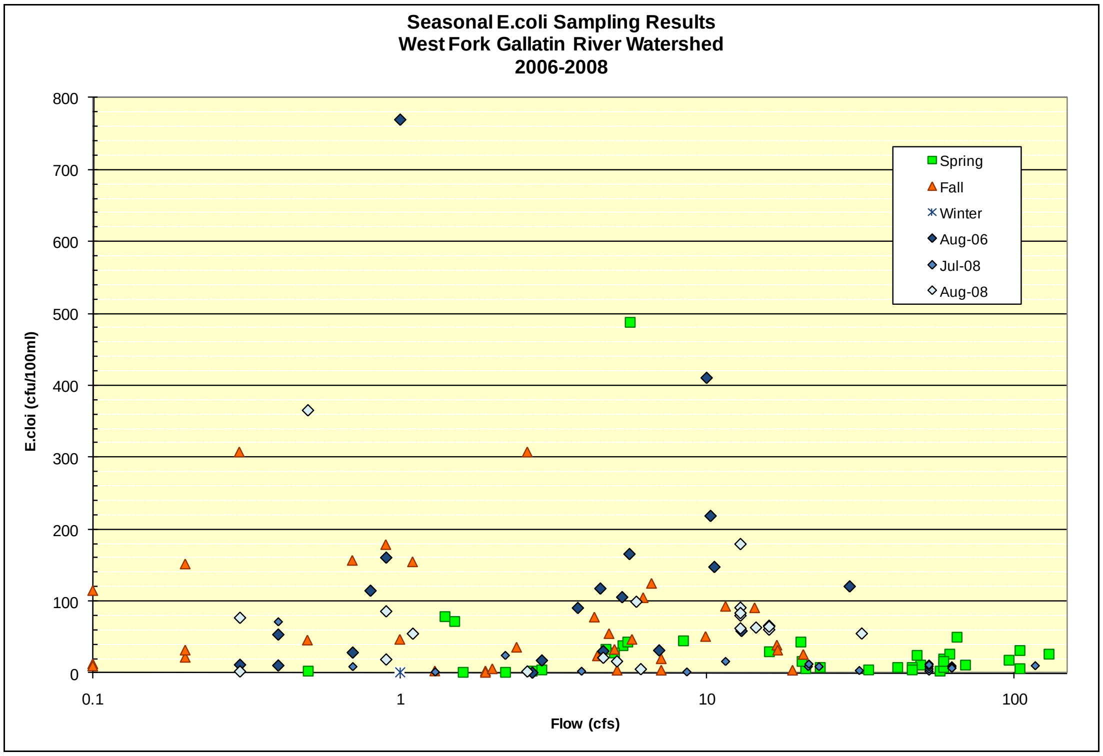

Figure 7-7. Seasonal E. Coli Concentrations in the West Fork Gallatin Watershed, 2006-2008

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.*

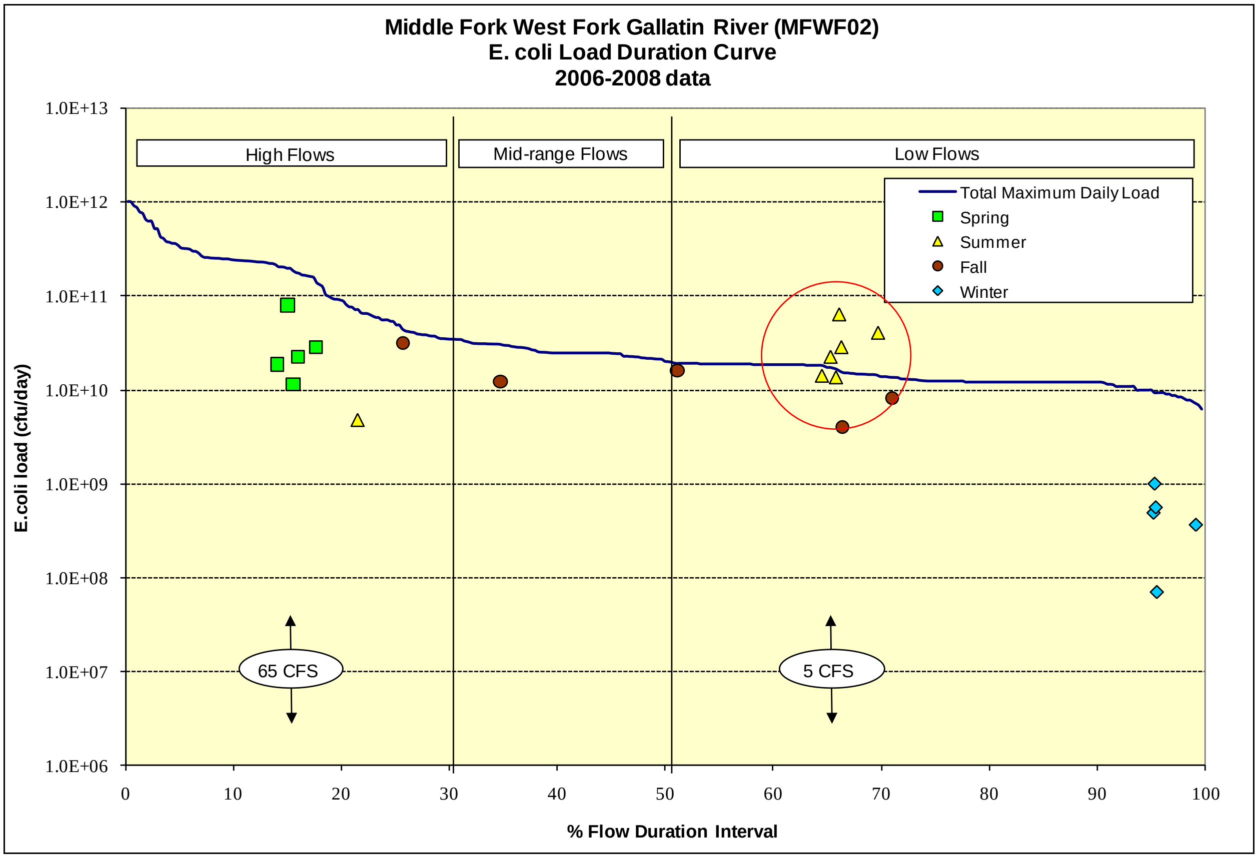

Figure 7-8. E. Coli Load Duration Curve at MFWF02 on the Middle Fork West Fork Gallatin River.

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

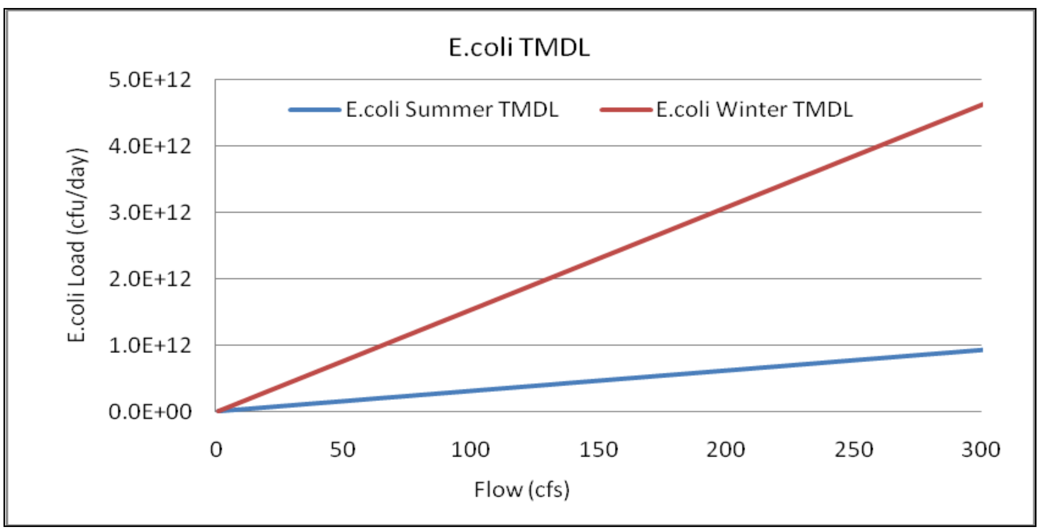

Figure 7-12. Seasonal E. Coli TMDLs as a function of flow

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**

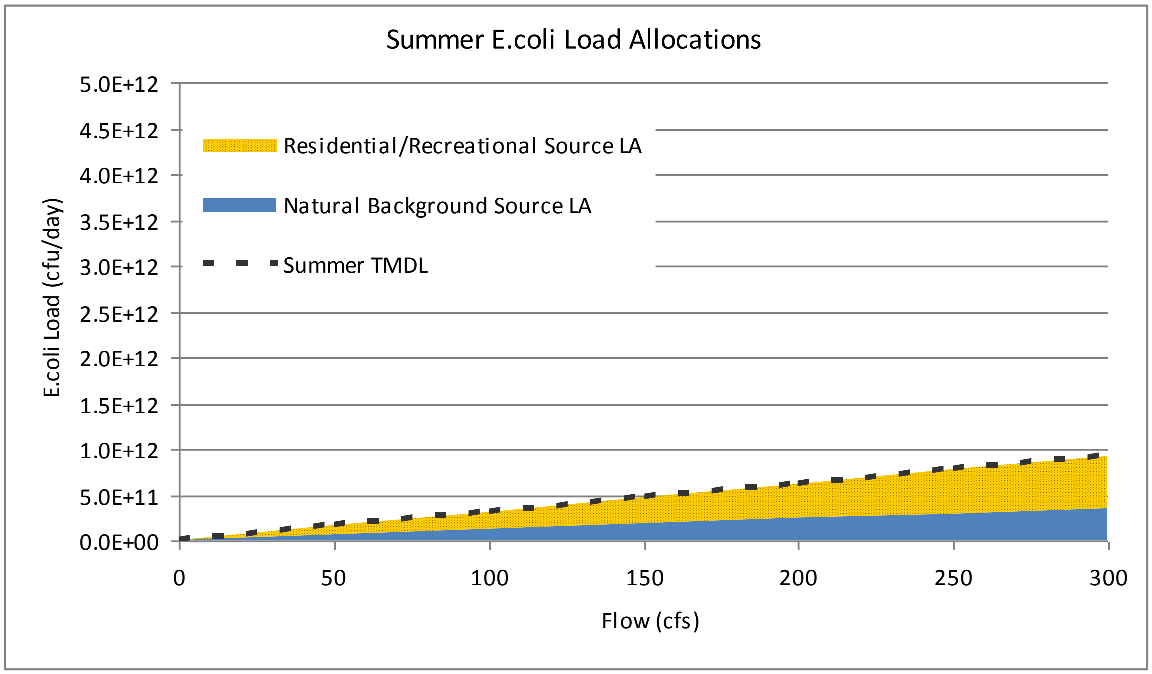

Figure 7-13. Summer E. Coli TMDL and Load Allocations

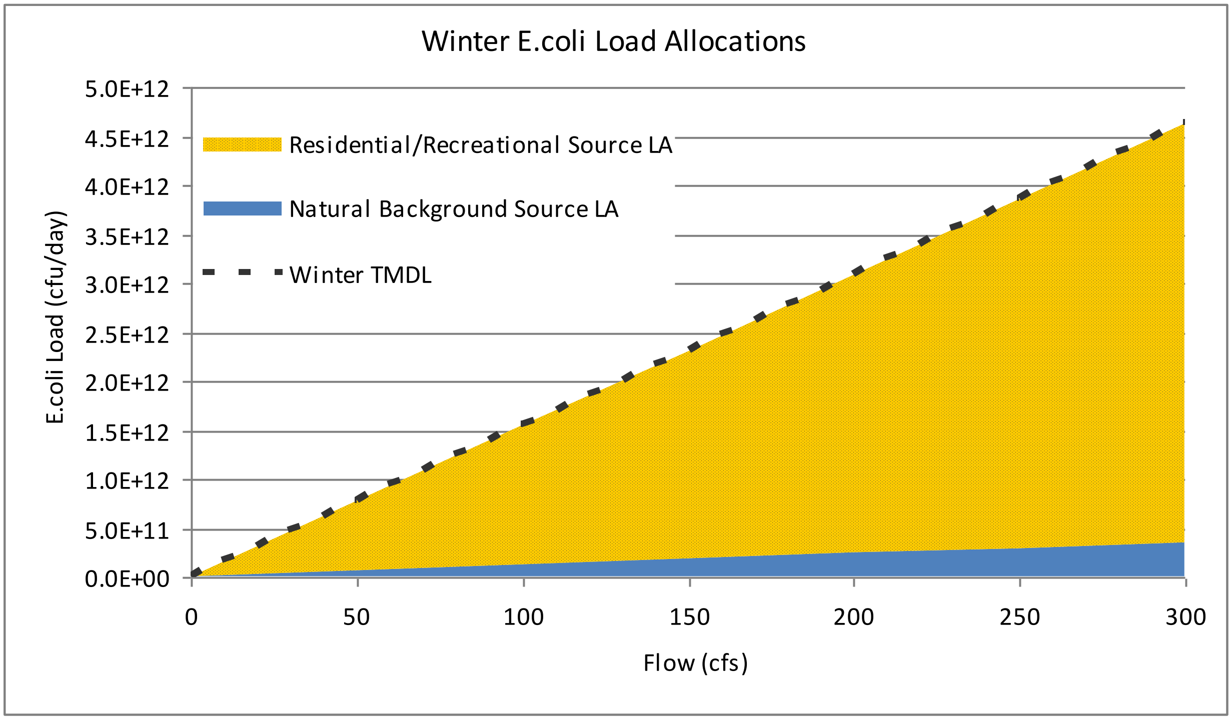

Figure 7-14. Winter E. Coli TMDL and Load Allocations

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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