5.0 - SEDIMENT TMDL COMPONENTS

This section focuses on sediment as a cause of water quality impairment in the Lower Gallatin TMDL Planning Area (TPA). This section: (1) describes how sediment can impair beneficial uses; (2) lists the specific stream segments of concern; (3) discusses the current available data pertaining to sediment impairment in the watershed, including target development and a comparison of existing water quality with targets; 4) describes the approaches used to quantify the various contributing sources of sediment; and 5) identifies and justifies the sediment TMDLs and their allocations.

5.1 THE 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 enters the system from increased bank erosion or other sources, it may alter channel form and function and affect fish and other aquatic life. Increased turbidity and excess sediment can accumulate in critical aquatic habitat areas not naturally characterized by high levels of fine sediment.

More specifically, sediment may block light and reduce 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 citation sediment are not limited to suspended or fine sediment; an accumulation of larger sediment (e.g., cobbles) can fill pools, reduce the amount of desirable particle sizes for fish spawning, and overwiden channels, which may lead to additional sediment loading and/or increased temperatures. Larger sediment can also reduce or eliminate flow in some stream reaches where sediment builds up in the channel, causing flow to go subsurface (May and Lee, 2004). Although fish and aquatic life are typically the most sensitive beneficial uses for sediment, excess sediment may also affect other uses. For instance, high concentrations of suspended sediment in streams can also discolor or turn water murky, negatively effecting recreational use. Excessive sediment can also increase filtration costs for water treatment facilities that provide safe drinking water.

5.2 STREAM SEGMENTS OF CONCERN

A total of 11 waterbody segments in the Lower Gallatin TPA appeared on the 2012 Montana 303(d) List for sediment impairments (**Table 5-1**): Bear, Bozeman, Camp, Dry, Godfrey, Jackson, Reese, Rocky, Smith, Stone, and Thompson Creeks. Most waterbody segments listed for sediment impairment are also impaired for various forms of habitat alterations (**Table 5-1**), which are non-pollutant causes commonly associated with sediment impairment. TMDLs are limited to pollutants, but implementation of land, soil, and water conservation practices to reduce pollutant loading will inherently address some non-pollutant impairments.

12 sediment impairments

Table 5-1. Waterbody segments in the Lower Gallatin TPA with sediment listings on the 2012 303(d) List

Stream Segment	Waterbody ID	Sediment Pollutant Listing	Non-Pollutant Causes of Impairment Potentially Linked to Sediment Impairment
BEAR CREEK, headwaters to the mouth (Rocky Creek MT41H003_080)	MT41H003_081	Sedimentation/Siltation; Solids (Suspended/Bedload)	Alteration in streamside or littoral vegetative covers
BOZEMAN (aka SOURDOUGH) CREEK, Limestone Creek to the mouth (East Gallatin River)	MT41H003_040	Sedimentation/Siltation	Alteration in streamside or littoral vegetative covers
CAMP CREEK, headwaters to the mouth (Gallatin River)	MT41H002_010	Sedimentation/Siltation	Alteration in streamside or littoral vegetative covers; Physical substrate habitat alterations; Other anthropogenic substrate alterations; Low flow alterations
DRY CREEK, headwaters to the mouth (East Gallatin River)	MT41H003_100	Sedimentation/Siltation	Alteration in streamside or littoral vegetative covers; Physical substrate habitat alterations
GODFREY CREEK, headwaters to White Ditch	MT41H002_020	Sedimentation/Siltation	Alteration in streamside or littoral vegetative covers
JACKSON CREEK, headwaters to the mouth (Rocky Creek)	MT41H003_050	Sedimentation/Siltation	Alteration in streamside or littoral vegetative covers
REESE CREEK, headwaters to the mouth (Smith Creek)	MT41H003_070	Solids (Suspended/Bedload)	
ROCKY CREEK, confluence of Jackson and Timberline Creeks to mouth (East Gallatin River)	MT41H003_080	Sedimentation/Siltation	Alteration in streamside or littoral vegetative covers; Physical substrate habitat alterations; Other anthropogenic substrate alterations
SMITH CREEK, confluence of Ross and Reese Creeks to the mouth (East Gallatin River)	MT41H003_060	Sedimentation/Siltation	Alteration in streamside or littoral vegetative covers; Physical substrate habitat alterations
STONE CREEK, headwaters to the mouth (Bridger Creek)	MT41H003_120	Sedimentation/Siltation	Alteration in streamside or littoral vegetative covers
THOMPSON CREEK (or Thompson Spring), headwaters to mouth (East Gallatin River)	MT41H003_090	Sedimentation/Siltation	Alteration in streamside or littoral vegetative covers

5.3 Information Sources and Assessment Methods to Characterize Sediment Conditions

For TMDL development, information sources and assessment methods fall within two general categories. The first category, discussed in this section, characterizes overall stream health with a focus on sediment and related water quality conditions. The second category, discussed in **Section 5.6**, quantifies sediment sources in the watershed.

To characterize sediment conditions for TMDL development, sediment data was compiled and additional monitoring took place in 2009. Unless significant changes have occurred in a watershed, data collected

by whom? cite this policy.

within the past 10 years is considered representative of the current condition; data older than 10 years may be discussed to provide historical context for land management practices within a watershed and/or to compare with current conditions. These data sources represent the primary information used to characterize water quality and/or develop TMDL targets:

- DEQ assessment files
- DEQ 2009 sediment and habitat assessments
- PACFISH/INFISH Biological Opinion Effectiveness (PIBO) Monitoring Program reference and non-reference data
- USFS regional reference data
- other monitoring data and reports (e.g., USFS and Greater Gallatin Watershed Council)

5.3.1 DEQ Assessment Files

DEQ assessment files contain information used to make the existing sediment impairment determinations. Many of the impairment listings are based on data and stream condition summaries from the late 1970s compiled as part an EPA-funded Water Quality Management Plan by the Blue Ribbons of the Big Sky Country Areawide Planning Organization (APO)(Blue Ribbons of the Big Sky Country Areawide Planning Organization, 1979; 1977; 1978). In addition to summarizing the information in the APO reports, the DEQ assessment files include a summary of physical, biological, and habitat data collected between 1990 and 2011, as well as other historical information collected or obtained by DEQ. The most common quantitative data that will be incorporated from the assessment files are pebble counts and macroinvertebrate index scores. The files also include information on sediment water quality characterization and potentially significant sources of sediment, as well as information on non-pollutant impairment determinations and associated rationale. Files are available electronically on DEQ's Clean Water Act Information Center website: http://cwaic.mt.gov/.

5.3.2 DEQ 2009 Sediment and Habitat Assessments

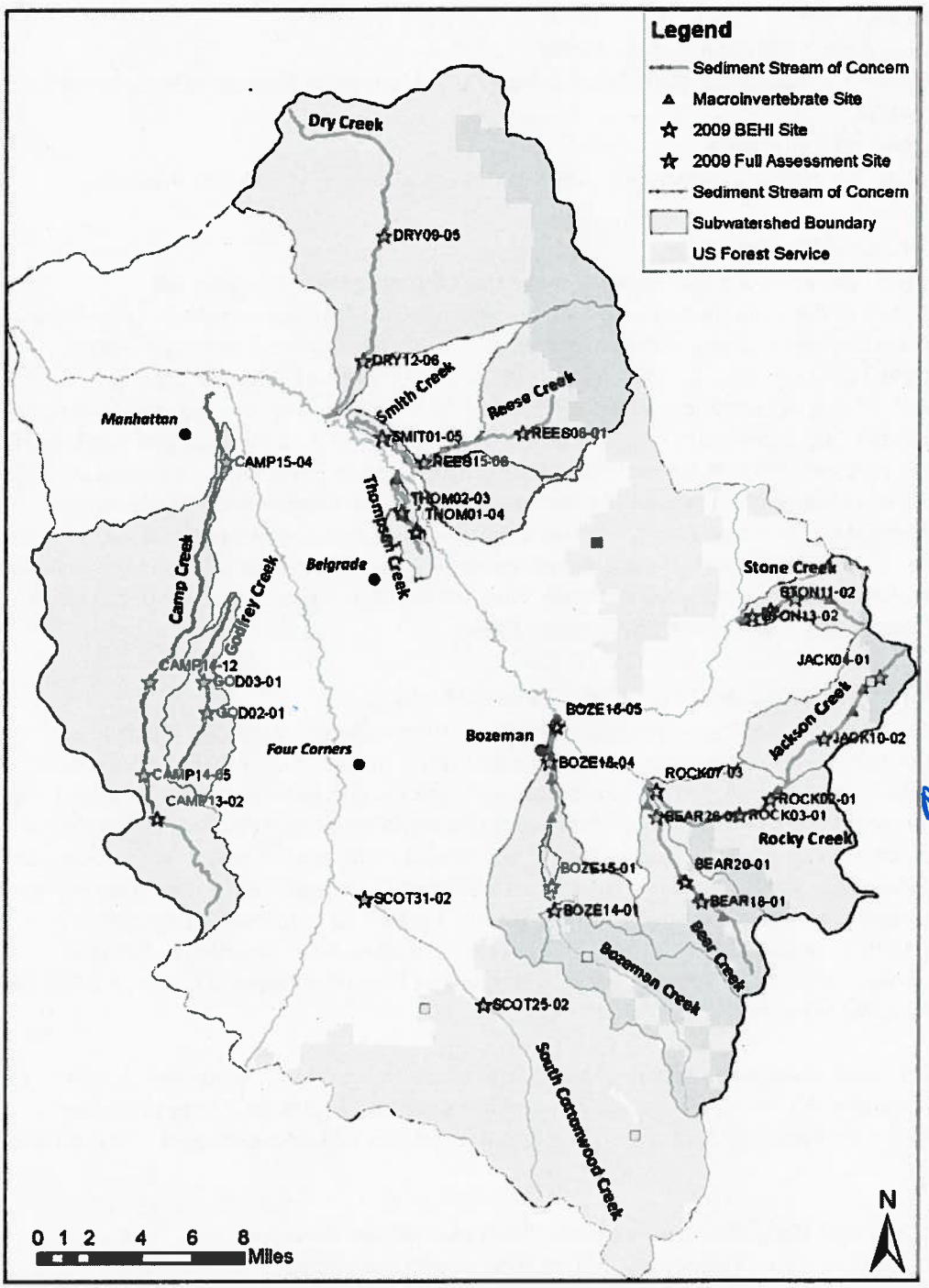
To aid in TMDL development, field measurements of channel morphology and riparian and instream habitat parameters were collected in August 2009 from 23 reaches (**Figure 5-1**). An additional seven reaches were assessed in 2009 to determine the severity of bank erosion and identify the source. These seven reaches are represented by the bank erosion hazard index (BEHI) sites in **Figure 5-1**. Reaches were dispersed among the 11 segments of concern listed in **Section 5.2**, with two full assessment reaches on most streams. Additionally, one reach was evaluated on Bozeman Creek upstream of the listed segment, and two reaches were assessed on South Cottonwood Creek (**Figure 5-1**) to broaden the range of conditions in the sample dataset and serve as potential reference sites. After sampling and closer evaluation of human-induced sediment sources, only one site on South Cottonwood Creek (SCOT25-02) was determined a suitable reference site.

Initially, all streams were assessed aerially to characterize reaches by four main attributes not linked to human activity: stream order, valley gradient, valley confinement, and ecoregion. These attributes represent main factors influencing stream morphology, which in turn influence sediment transport and deposition.

The next step in the aerial assessment involved identifying near-stream land uses, since land management practices can have a significant influence on stream morphology and sediment characteristics. The result was stratifying 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, allowed DEQ to select the above-referenced monitoring reaches. Although ownership is not part of the reach type category (because of the distribution of private and federal land within the watershed), most reach type categories contain predominantly either private or public lands.

Sentence doesn't make sense. Public + private lands => what other kind of lands are there?



Streams aren't labeled very well.

Figure 5-1. Sediment streams of concern and sediment-related sampling sites.

"Since one step in the TMDL process is to further characterize..."

Monitoring reaches on sediment-listed streams were chosen to represent various reach characteristics, land-use categories, and human-caused influences. There was a preference toward sampling those reaches where human 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 303(d) listed waterbody with potential sediment 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, DEQ acknowledges this approach results in less certainty regarding conditions in 1st order streams and higher-gradient reaches, and that conditions within sampled reaches do not necessarily represent conditions throughout the entire stream.

Table 5-2. Reach Types and Monitoring Sites

(Type = Ecoregion-Valley Slope-Stream Order-Valley Confinement; MR = Middle Rockies). Sites denoted with an asterisk were streambank erosion sites.

Reach Type	Number of Reaches	Number of Monitoring Sites	Monitoring Sites
MR-0-4-C	1		
MR-2-3-C	1		
MR-4-3-U	1		
MR-10-2-U	1		
MR-0-3-C	2		
MR-2-4-U	2		
MR-10-1-C	3		
MR-0-1-U	4	1	THOM01-04*
MR-2-2-C	4	2	BEAR18-01, STON08-01
MR-2-1-U	5		
MR-4-1-C	5	1	JACK04-01
MR-4-2-C	5		
MR-2-3-U	6	2	SCOT25-02, CAMP13-02*
MR-10-1-U	7		
MR-0-4-U	8	6	CAMP15-04, DRY12-06, REES15-06, ROCK03-01, SMIT01-05, ROCK07-03*
MR-4-1-U	10		
MR-4-2-U	10	1	BEAR20-01
MR-0-3-U	13	9	BEAR26-02, BOZE18-04, CAMP14-05, CAMP14-12, DRY09-05, GOD03-01, ROCK02-01, SCOT31-02, BOZE18-05*
MR-0-2-U	14	5	BOZE14-01, GOD02-01, REES06-01, THOM02-03, BOZE15-01*
MR-2-2-U	19	3	JACK10-02, STON13-02, STON11-02*

The field parameters assessed in 2009 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 2,000 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,

Cite the formal protocol (is there one?) See Att A

this all begs the question: WHY? How is it decided what is [illegible] need a methodology!

riparian, and bank erosion measures were performed in all cells. Field parameters are briefly described in **Section 5.4**, and summaries of all field data and sampling protocols are contained in the 2009 Sediment and Habitat Assessment report (**Attachment A**).

5.3.3 PIBO Data

The PACFISH/INFISH Biological Opinion Effectiveness (PIBO) monitoring program collects data from reference and managed (i.e., non-reference) stream sites on US Forest Service (USFS) and Bureau of Land Management (BLM) land within the Columbia and Upper Missouri River basins. Reference sites are defined as having catchment road densities less than 0.5 km/km^2, riparian road densities less than 0.25 km/km^2, no grazing within 30 years, and no known in-channel mining upstream of the site. Within sediment-impaired watersheds of the Lower Gallatin TPA, data were collected in 2007 at two managed sites in the Gallatin National Forest: Bozeman Creek upstream of the listed segment and Jackson Creek (**Figure 5-1**). There are 15 reference sites in the Gallatin National Forest, including one in the Lower Gallatin TPA (**Figure 5-1**). However, because that is a small dataset for target development, and ecoregion is a primary stratification category, all PIBO reference data from the Middle Rockies ecoregion were used for target development. This consists of all sites in the Gallatin National Forest as well as data from 58 other sites collected between 2001 and 2010.

State this up front

Data ~~was~~ were collected following protocols described in "Effectiveness Monitoring for Streams and Riparian Areas within the Pacific Northwest: Stream Channel Methods for Core Attributes" *(USDA Forest Service, 2006)*. Relevant data collected during these assessments include width/depth ratios, residual pool depths, pool frequency, large woody debris frequency, pebble counts, and the percentage of fine sediment in pool tails <6mm via grid toss.

What does that mean? relevant to this project

5.3.4 USFS Regional Reference Data

Regional reference data are available from the Beaverhead Deerlodge National Forest (BDNF). BDNF data were collected between 1991 and 2002 from approximately 200 reference sites: 70 of the sites are located in the Greater Yellowstone Area and the remaining sites are in the BDNF, which is also located in southwestern Montana (Bengeyfield, 2004). Reference sites were selected by USFS hydrologists and fish biologists and were defined as representing the current climate and tectonic regime and without having significant human influence. The sites were primarily located in lower-gradient areas where the effects of land management practices are most likely to be seen (Bengeyfield and Hickenbottom, 2005). Applicable reference data from this resource used for TMDL target development are width/depth ratios, entrenchment ratios, and fine sediment <6mm from pebble counts.

5.3.5 Other Monitoring Data and Reports

Additional sources of monitoring data are primarily limited to Bear and Bozeman Creeks. Largely because of concerns related to sediment loading from road and trail conditions, the USFS collected data on Bear Creek in 2003; additional monitoring was conducted in 2011 to evaluate the effectiveness of decommissioning and improvement projects conducted in 2007–2008. Data collection in 2003 included total suspended solids, bedload, and streamflow (Story and Taylor, 2004), as well fish abundance via electroshocking and fish habitat metrics (e.g., percent fine sediment <2mm in pool tails, large wood debris, residual pool depth, pool frequency, and unstable banks) (Barndt and Bay, 2004). Data collection in 2011 was conducted at fewer sites and limited to total suspended solids, bedload, and streamflow (Story and Hancock, 2011).

* PIBO/USFS – you're mixing/matching this section w/ "targets". I would stick primarily with ~~target development~~ data descriptions only.

For Bozeman Creek, the Bozeman Watershed Council (now defunct) conducted a watershed assessment in August 2002 using a modified version of the USFS R1/R4 Habitat Inventory (Overton et al., 1997) that included measurements of pools and riffles, large woody debris, undercut/unstable streambanks, width/depth ratio, visual substrate composition, and percent canopy along the entire stream (Bozeman Watershed Council, 2004). The stream was broken into ten zones, which were subdivided in assessment reaches. For each reach the report includes a summary of land use, geomorphology, channel character, fish habitat, limiting factors, wetlands, and recommendations for improvement. A study was conducted using this data in combination with a GIS analysis of land cover and land use to study the relationship between land use, geomorphology, and aquatic habitat (McIlroy et al., 2008). Additionally, the Greater Gallatin Watershed Council conducted pebble counts and collected macroinvertebrates at two sites on Bozeman Creek in August 2009.

USFS planning documents, including the Gallatin National Forest Travel Plan Final Environmental Impact Statement (U.S. Department of Agriculture, Forest Service, 2006), North Bridgers Grazing Allotment Management Plan Update Environmental Assessment (U.S. Forest Service, 2007), Bangtail Allotment Management Plan Update Environmental Assessment (U.S. Forest Service, 2009), and Bozeman Municipal Watershed Supplemental Environmental Impact Statement (U.S. Department of Agriculture, Forest Service, Gallatin National Forest, 2011) contain information such as descriptions of soil sensitivity to disturbance, intensity and effects of grazing and timber harvest, evaluation of riparian health via a Proper Functioning Condition assessment (Prichard, 1998), and an evaluation of sediment sources, such as roads. Where applicable, this information is incorporated into the existing condition discussion. The planning documents also include estimates of sediment loading under different management scenarios; however, because the estimates were intended to compare relative differences among scenarios, and were conducted at a different scale using different methods than source assessments used for TMDL development, the loads are not presented in this document.

Lastly, as part of the TMDL development effort for nutrient and *E. coli* impairment in the Lower Gallatin TPA, a source assessment was performed in 2009. Because nutrient sources are commonly associated with sediment, the source assessment report (**Attachment B**) was reviewed for information regarding sediment sources. The report contains source assessment information for Bear, Camp, Dry, Godfrey, Jackson, Reese, Smith, Sourdough, and Thompson Spring Creeks.

5.4 Water Quality Targets

The concept of water quality targets was presented in **Section 4.1**. This section provides the rationale for each sediment-related target parameter and discusses the basis of the target values.

In developing targets, natural variation throughout the river ~~continuum~~ must be considered. As discussed in more detail in **Section 3.0** 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 using reference site data, but modeling, professional judgment, and literature values may also be used. DEQ defines "reference" as the condition of a waterbody capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, the reference condition reflects a waterbody's greatest potential for water quality given past and current land use. Although sediment water quality targets typically relate most directly to the aquatic life use, the targets protect all designated beneficial uses because they are based on the reference approach, which strives for the highest achievable condition.

Waterbodies used to determine reference conditions are not necessarily pristine. The reference condition approach is intended to accommodate natural variations from climate, bedrock, soils, hydrology, and other natural physiochemical differences, yet it allows differentiation between natural conditions and widespread or significant alterations of biology, chemistry, or hydrogeomorphology from human activity.

The basis for each water quality target value varies depending on the availability of reference data and sampling method comparability to 2009 DEQ data. As discussed in **Appendix B**, there are several statistical approaches DEQ uses for target development. They include using percentiles of reference data ~~of~~ of the entire sample dataset, if reference data are limited. For example, if low values are desired (like with fine sediment), and there is a high degree of confidence in the reference data, the 75th percentile of the reference dataset is typically used.

If reference data are not available, and the sample streams are predominantly degraded, the 25th percentile of the entire sample dataset is typically used. However, percentiles may be used differently depending on whether a high or low value is desirable, how much the representativeness and range of data varies, how severe human disturbance is to streams in the watershed, and the size of the dataset.

In general, stream sediment and habitat conditions within the streams evaluated by DEQ in 2009 reflected a minimal to moderate level of human disturbance (i.e., not severely disturbed). For each target, descriptive statistics were generated relative to any available reference data (e.g., BDNF or PIBO) as well as for the entire sample dataset. The preferred approach for setting target values is to use reference data, where preference is given to the most protective reference dataset.

Additionally, the target value for some parameters may apply to all streams in the Lower Gallatin watershed, whereas others may be stratified by bankfull width, reach type characteristics (e.g., ecoregion, gradient, stream order, and/or confinement), or by Rosgen stream type, if those factors are determined to be important drivers for certain target parameters. Although the basis for target values may differ by parameter, the goal is to develop values that incorporate an implicit margin of safety (MOS) and that are achievable. MOS is discussed in additional detail in **Section 5.8.2**. Field data from the reference site on South Cottonwood Creek are not discussed within this section but were compared with target values during the target development process to help evaluate the appropriateness and achievability of target values.

5.4.1 Water Quality Target Summary

The sediment water quality targets for the Lower Gallatin watershed are summarized in **Table 5-3** and described in detail in the sections that follow. Consistent with EPA guidance for sediment TMDLs (U.S. Environmental Protection Agency, 1999b), water quality targets for the Lower Gallatin watershed comprise a combination of measurements of instream siltation, channel form, biological health, and habitat characteristics that contribute to loading, storage, and transport of sediment or that demonstrate those effects. Fine sediment targets and biological data, in conjunction with indicators of excess sediment (i.e., fine sediment, residual pool depth, and field observations), are given the most weight. what?

Target parameters and values are based on the current best available information, but they will be assessed during future TMDL reviews for their applicability and may be modified if new information

Not a formal assessment

* its implied that you are re-assessing the stream, but not stated. think about adding this language.

provides a better understanding of reference conditions or if assessment metrics or field protocols are modified. For all water quality targets, future surveys should document stable (if meeting criterion) or improving trends. The exceedance of one target value does not necessarily equate to a determination that the information supports impairment; the degree to which one or more targets are exceeded are taken into account (as well as the current 303(d) listing status), and the combination of target analysis, qualitative observations, and sound, scientific professional judgment is crucial when assessing stream condition. Site-specific conditions such as recent wildfires, natural conditions, and flow alterations in a watershed may warrant selecting unique indicator values that differ slightly from those presented below, or special interpretation of the data relative to the sediment target values.

Table 5-3. Sediment Targets for the Lower Gallatin TPA

Parameter Type	Target Description	Criterion
Fine Sediment	Percentage of fine surface sediment <6mm and <2mm in riffles via pebble count (reach average)	<6mm: B/C stream types: < 11%, E stream types: < 30% <2mm: B/C stream types: < 9%, E stream types: < 16%
	Percentage of fine surface sediment <6 mm in pool tails via grid toss (reach average)	B/C stream types: ≤ 8% E stream type: ≤ 14%
Channel Form and Stability	Bankfull width/depth ratio (reach average)	B stream types: < 17 C stream types: < 23 E stream types: < 12
	Entrenchment ratio (reach average)	B stream types: > 1.4
		C and E stream types: > 2.2
Instream Habitat	Residual pool depth (reach average)	< 15 ft bankfull width : > 0.7 ft
		> 15 ft bankfull width : > 1.2 ft
	Pools/mile	< 15 ft bankfull width : ≥ 84
		> 15 ft bankfull width : ≥ 52
	LWD/mile	All bankfull widths: 143
Human Sediment Sources	Significant and controllable sediment sources	Presence of significant and controllable man-caused sediment sources throughout the watershed
Biological Index	Macroinvertebrate bioassessment impairment threshold	O/E: ≥ 0.80

5.4.2 Fine Sediment

The percent of surface fines <6 mm and <2 mm is a measurement of the fine sediment on the surface of a streambed and is directly linked to the support of the coldwater fish and aquatic life beneficial uses. Increasing concentrations of surficial fine sediment can negatively affect salmonid growth and survival, clog spawning redds, and smother fish eggs by limiting oxygen availability (Irving and Bjorn, 1984; Weaver and Fraley, 1991; Shepard et al., 1984; Suttle et al., 2004). Excess fine sediment can also decrease macroinvertebrate abundance and taxa richness (Mebane, 2001; Zweig and Rabeni, 2001). Because similar concentrations of sediment can cause different degrees of impairment to different species (and even age classes within a species), and because the particle size defined as "fine" is variable (and some assessment methods measure surficial sediment while other measures 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% to 40% fine sediment (Bjorn and Reiser, 1991; Mebane, 2001; Relyea et al.,

2000). Bryce et al. (2010) evaluated the effect of surficial fine sediment (via reach transect pebble counts) on fish and macroinvertebrates and found that the minimum effect level for sediment <2 mm is 13% for fish and 10% for macroinvertebrates. Literature values are taken into consideration during fine sediment target development; however, because increasing concentrations of fine sediment are known to harm aquatic life, targets are developed using a conservative statistical approach consistent with **Appendix B** and consistent with Montana's water quality standard for sediment as described in **Section 3.2.1**.

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

Surface fine sediment measured in riffles by the modified Wolman (1954) pebble count indicates the particle size distribution across the channel width and is an indicator of aquatic habitat condition that can point to excessive sediment loading. Pebble counts in 2009 were performed in three riffles per sampling reach, for a total of at least 300 particles. For DEQ data collected independently of the TMDL development process (i.e., before 2009) and the data collected by the GGWC for Bozeman Creek, pebble counts at each reach were performed from bankfull to bankfull in a single representative riffle, for a total of at least 100 particles.

Less than 6 mm

The BDNF reference dataset is broken out by Rosgen channel type and dominant particle size, but the PIBO reference dataset is not. Because the streams in the Lower Gallatin TPA contain a variety of channel types, including E channels (which tend to have higher levels of fine sediment than other channels), the fine sediment target for particles <6 mm is based on BDNF reference data according to Rosgen channel type.

Although the percentage of fine sediment may vary depending on the dominant particle size in a stream, all gravel- and cobble-dominated B and C channels in the project area had a similar level of fine sediment during sampling in 2009; therefore, the target for riffle substrate fine sediment is expressed as one value for B/C channels and another value for E channels. The target for riffle substrate percent fine sediment <6 mm is set at less than or equal to the median of the reference value based on the BDNF reference dataset (**bold** in **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. The latter was the method used for TMDL-related data collection in the Lower Gallatin watershed.

The 2009 DEQ data are also summarized in **Table 5-4**, and in general, the 75th percentile of the sample dataset is comparable or less than the median of the reference dataset, indicating much of the sample dataset has low percent fines <6 mm in riffles.

Table 5-4. 2009 DEQ Data Summary and BDNF Reference Dataset Median Percent Fine Sediment <6 mm.

Target values are indicated in bold.

Data Source	Parameter	All	B3/C3	B4/C4	B/C	E4
BDNF	Sample Size (n)	129	37	31	68	63
	Median	20	8	21	**11**	**30**
Sample Data	Sample Size (n)	23	4	8	12	12
	Median	10	6	6	6	19
	75th	20	8	9	8	21

Less than 2 mm

For fine sediment <2 mm, PIBO is the only reference data currently available. Like the BDNF data, the PIBO pebble count data are collected from multiple channel types (including E channels) and are also a composite of riffle and pool particles, which are likely to be higher in fines than the DEQ riffle-only pebble count. The median of the PIBO reference dataset is slightly greater than the median of the sample dataset (**Table 5-5**). Because of the tendency of E channels to have a higher percentage of fine sediment than B and C channels, and because the sample dataset is broken out by channel type, the target is based the sample dataset.

As discussed in the target development rationale in **Section 5.4**, the sampled streams ranged from being minimally to moderately disturbed, which indicates the median is likely the most appropriate percentile for target development. Because the median percentile of fine sediment <2mm in riffles of B and C channels (of the sample dataset) is much lower than the most conservative literature values shown to cause harm to fish and aquatic life (i.e., 10-13%) (Bryce et al., 2010), the median value for the entire sample dataset (i.e., 9%) will be set as the riffle fine sediment <2mm target for B and C channels. The median value for E4 streams of 16% from the sample dataset will be applied as the target for E4 channels.

Table 5-5. 2009 DEQ Data Summary and PIBO Reference Dataset Percent Fine Sediment <2 mm.
Target values are indicated in bold.

Data Source	Parameter	All	B3/C3	B4/C4	B/C	E4
PIBO	Sample Size (n)	64	Data not broken out by channel type			
	Median	11				
	75th	21				
Sample Data	Sample Size (n)	23	4	8	12	11
	Median	**9**	4	4	4	**16**
	75th	16	5	7	6	19

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

Grid toss measurements in pool tails is an alternative measure to pebble counts that assesses the level of fine sediment accumulation in macroinvertebrate habitat and potential fish spawning sites. A 49-point grid toss (Kramer et al., 1993) was used to estimate the percent surface fine sediment <6 mm in pool tails in the Lower Gallatin watershed. Three tosses, or 147 points, were performed then averaged for each pool tail assessed.

For pool tail grid toss values, PIBO is the only reference data currently available. The 75th percentile of the PIBO reference data for pool tails is 18% and the median is 9% (**Table 5-6**). In the 2009 Lower Gallatin sample dataset, pool tail grid toss values for the 25th percentile of the sample dataset for all sites, as well as B and C channels, was similar to the median of the PIBO dataset. This indicates fine sediment levels in pools within the watershed reflect a more severe level of disturbance than riffles. Therefore, the more conservative 25th percentile of the sample dataset (versus the median) is the most appropriate percentile for pool tail grid toss targets. The pool tail grid toss target is 8% for B/C channels and 14% for E channels and should be assessed based on the reach average grid toss value.

↳ the discussion of 25th/75th/median reference values for each of these is confusing + difficult to follow from parameter to parameter. It comes across as if you are cherry picking data.

Table 5-6. PIBO Reference and 2009 DEQ Data Percentiles for Percent Fine Sediment <6 mm via Grid Toss in Pool Tails.

Pool tail target values are indicated in bold.

Data Source	Parameter	All	B/C	E
PIBO Pool Tail	Sample Size (n)	70	Data not broken out by channel type	
	Median	9		
	75th	18		
Sample Data Pool Tail	Sample Size (n)	20	11	9
	25th	11	**8**	**14**
	Median	16	14	24
	75th	25	20	29

5.4.3 Channel Form and Stability

Parameters related to channel form indicate a stream's ability to store and transport sediment. Stream gradient and valley confinement are two significant controlling factors that determine stream form and function, however, alterations to the landscape and sediment input beyond naturally occurring amounts can affect channel form. Numerous scientific studies have found trends and common relationships between channel dimensions in properly functioning stream systems and those with a sediment imbalance. Two of those relationships are used as targets in the Lower Gallatin TPA and are described below.

5.4.3.1 Width/Depth Ratio and Entrenchment Ratio

badly worded

The width/depth ratio and the entrenchment ratio ~~are fundamental aspects of channel morphology. Each provides a~~ provide 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 (e.g., riffles, pools, and near-bank zones).

Changes in both the width/depth ratio and entrenchment ratio can be used as indicators of change in the relative balance between the sediment load and the transport capacity of the stream channel. As the width/depth ratio increases, streams become wider and shallower, suggesting an excess sediment load (MacDonald et al., 1991). As sediment accumulates, the depth of the stream channel decreases, which is compensated for by an increase in channel width when the stream attempts to regain a balance between sediment load and transport capacity.

Conversely, a decrease in the entrenchment ratio signifies a loss of access to the floodplain. Low entrenchment ratios indicate that stream energy is concentrated in-channel during flood events versus having energy dissipate to the floodplain. Accelerated bank erosion and an increased sediment supply often accompany an increase in the width/depth ratio and/or a decrease in the entrenchment ratio (Rosgen, 1996; Knighton, 1998; Rowe et al., 2003). Width/depth and entrenchment ratios were calculated for each 2009 assessment reach based on five riffle cross-section measurements.

Width/Depth Ratio Target Development

it was not used because Rosgen channel type was not available

Although PIBO reference data exists for width/depth ratio, ~~because channel morphology tends to vary by Rosgen channel type,~~ only the BDNF reference dataset was considered for width/depth ratio target development. Because many of the streams in the Lower Gallatin TPA have been historically altered to the extent that reference channel form and floodplain access may not be achievable without extensive channel reconstruction (or the greatest potential may be a combination of channel types), the Rosgen

What does this mean? Rosgen def by stream type

delineative criteria were also used during target development (**Table 5-7**). Width/depth ratios are measured the same way for the reference and sample dataset: in comparing the reference data with the 2009 sample dataset, the 75th percentile of the reference values are similar to the corresponding percentile in the sample dataset for B and C channels but is almost half the 75th percentile ratio for E channels in the sample dataset. This indicates the 75th percentile of reference is an appropriate target for B and C channels but not for E channels. Given that the Rosgen criterion for an E channel is a width/depth ratio less than 12, which is equal to the median of the sample dataset, less than or equal to 12 will be applied as the width/depth ratio target for E streams in the Lower Gallatin TPA. Summary statistics and target values by Rosgen channel type are provided in **Table 5-7**. The target value applies to the average value for each sample reach.

Table 5-7. BDNF Reference and Other Data used for Width/Depth Ratio Targets.
Width/depth ratio target values are indicated in bold.

Data Source	Parameter	B	C	E
BDNF	Sample Size (n)	40	30	115
	75th	**17**	**23**	**8**
Sample Data	Sample Size (n)	18	38	46
	25th	11	13	10
	Median	13	16	12
	75th	16	20	15
Rosgen Criteria	Width/Depth Ratio	>12	>12	**<12**

Entrenchment Ratio Target Development

The BDNF reference dataset is the only reference data currently available to help develop entrenchment targets. For entrenchment ratio, because it is desirable to have a greater value, the 25th percentile of the BDNF reference dataset was evaluated for target development. For both B and C channels, the median of the sample dataset is comparable to the 25th percentile of the BDNF reference value and in line with the Rosgen delineative criteria (**Table 5-8**). However, for E channels the median of the sample dataset is meeting the Rosgen criteria but well below the 25th percentile of the BDNF reference dataset, indicating the 25th percentile of reference may not be a reasonable target for E channels.

Although having a greater entrenchment value (i.e., more floodplain access) is desirable for C and E channels, because the potential (after implementation of all reasonable land, soil, and water conservation practices) is likely less than the 25th percentile of reference, the Rosgen delineative criteria will be applied as the target for entrenchment ratio (**Table 5-8**). The target value applies to the average value for each sample reach.

Table 5-8. BDNF Reference and Other Data used for Entrenchment Ratio Targets.
Entrenchment ratio target values are indicated in bold.

Data Source	Parameter	B	C	E
BDNF	Sample Size (n)	40	30	115
	25th	1.4	3.2	3.7
Sample Data	Sample Size (n)	18	38	46
	25th	1.4	1.7	1.9
	Median	1.9	3.9	2.5
	75th	2.8	8.0	4.4
Rosgen Criteria	Entrenchment Ratio*	**1.4-2.2**	**>2.2**	**>2.2**

*Values are ± 0.2

5.4.4 Instream Habitat Measures

For all instream habitat measures (i.e., residual pool depth, pool frequency, and large woody debris frequency), PIBO is the only reference data currently available. Because these parameters are largely influenced by stream size, target values will be expressed by bankfull width category. Because all but one reach evaluated by DEQ in 2009 had a mean bankfull width less than 36, and the majority of streams were less than 25 feet wide, instream habitat targets are broken into bankfull width categories of less than and greater than 15 feet. — why? explain.

All of the instream habitat measures are important indicators of sediment input and movement, as well as fish and aquatic life support, but they may be given less weight in the target evaluation if they do not seem to be directly related to the effects of sediment. The use of instream habitat measures in evaluating or characterizing impairment must be considered from the perspective of whether these measures are linked to fine, coarse, or total sediment loading. → so you do or don't use them? Confusing. yes, they're used

5.4.4.1 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 pool habitat quality. Deep pools are important resting and hiding habitat for fish, and provide refuge during temperature extremes and high-flow periods (Nielson et al., 1994; Bonneau and Scarnecchia, 1998; Baigun, 2003). Similar to channel morphology measurements, residual pool depth integrates the effects of several stressors; pool depth can be decreased as a result of filling with excess sediment (fine or coarse), a reduction in channel obstructions (such as large woody debris), and changes in channel form and stability (Bauer and Ralph, 1999).

A reduction in pool depth from channel aggradation may not only alter surface flow during the critical low flow periods, but may also harm fish by altering habitat, food availability, and productivity (May and Lee, 2004; Sullivan and Watzin, 2010). Residual pool depth is typically greater in larger systems. During DEQ sampling in 2009, pools were defined as depressions in the streambed bounded by a "head crest" at the upstream end and "tail crest" at the downstream end, with a maximum depth that was 1.5 times the pool-tail depth (Kershner et al., 2004).

The definition of pools for the PIBO protocol is fairly similar to the definition used for the 2009 Lower Gallatin sample dataset: both use the same criterion to calculate the difference between the maximum depth and pool tail depth. However, the DEQ dataset could potentially have a greater pool frequency and more pools with a smaller residual pool depth because DEQ's protocol has no minimum pool size requirement, whereas the PIBO protocol only counts pools greater than half the wetted channel. } why the difference?

In comparing the PIBO reference data with the sample data, the PIBO 25th percentile residual pool depth values are all less than the median and similar to the 25th percentile from the sample dataset (**Table 5-9**), indicating the protocol differences likely did not result in smaller residual pool depths in the DEQ dataset. Therefore, the residual pool depth target is equal to or greater than the PIBO 25th percentile value (**bold** in **Table 5-9**).

Target comparisons should be 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 2009 as a baseline. Future monitoring should document an improving trend (i.e., deeper pools) at sites that fail to meet the target criteria,

while a stable trend should be documented at established monitoring sites that are currently meeting the target criteria.

Table 5-9. PIBO Reference and 2009 DEQ Sample Data Percentiles for Residual Pool Depth (ft).
Targets are shown in bold.

Category	PIBO Reference			DEQ Sample Data			
	n	25th	Median	n	25th	Median	75th
< 15 ft bankfull width	10	**0.7**	0.9	9	0.7	0.9	1.4
> 15 ft bankfull width	56	**1.2**	1.4	14	1.1	1.3	1.4

5.4.4.2 Pool Frequency

Pool frequency is another indicator of sediment loading that relates to changes in channel geometry and is an important component of a stream's ability to support the fishery beneficial use (Muhlfeld and Bennett, 2001). Sediment may limit pool habitat by filling in pools with fines. Alternatively, the build-up 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.

The PIBO 25th percentile pool frequency value for streams with a bankfull width less than 15 feet compare favorably with the median of sample dataset; however, the PIBO 25th percentile value for streams with a bankfull width greater than 15 feet is less than all percentiles for the sample dataset. This indicates that either that protocol differences may have resulted in a greater pool frequency in the DEQ dataset for wider streams, or that wider streams in the Lower Gallatin have a greater pool frequency potential than the 25th percentile of reference (**Table 5-10**). Although the Lower Gallatin TPA is slightly east of the area where the USFS Inland Native Fish (aka INFISH) Riparian Management Objectives apply (west of the Continental Divide), the INFISH values were evaluated in addition to the sample dataset to determine the most appropriate reference percentile for target development (**Table 5-10**).

Although streams with a bankfull width greater than 50 feet have an INFISH value close to the PIBO reference 25th percentile, all but one reach (SMITH01-05) from the Lower Gallatin watershed had a mean bankfull width less than 36 feet. Therefore, the PIBO 25th percentile for streams with a bankfull width greater than 15 feet is much too low to be used as a target value. The pool frequency target for streams with a bankfull width less than 15 feet is set at greater than or equal to the 25th percentile of PIBO reference; the target for streams with a bankfull width greater than 15 feet is set at greater than or equal to the median of PIBO reference (**bold** in **Table 5-10**). Pools per mile should be calculated based on the number of measured pools per reach and then scaled up to give a frequency per mile.

Table 5-10. PIBO Reference and 2009 DEQ Sample Data Percentiles for Pool Frequency (pools/mile) and INFISH Riparian Management Objective Values.
Targets are shown in bold.

Category	PIBO Reference			DEQ Sample Data			
	N	Median	25th	n	25th	Median	75th
< 15 ft bankfull width	10	101	**84**	9	74	84	95
> 15 ft bankfull width	56	**52**	22	14	28	55	76
INFISH Riparian Management Objectives	< 20 ft bankfull width: 96-56 25 ft bankfull width: 47			50 ft bankfull width: 26 100 ft bankfull width: 18			

5.4.4.3 Large Woody Debris

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 numbers generally are greater in smaller low-order streams and decrease as streams get larger and the composition of the riparian vegetation shifts. The application of an LWD target will carry very little weight in verifying sediment impairment but may have significant implications as an indicator of a non-pollutant type of impairment.

For DEQ sampling in 2009, wood was counted as LWD if it was greater than 9 feet long, or two-thirds of the wetted stream width, and 4 inches in diameter at the small end (Overton et al., 1997). The LWD count for PIBO was compiled using a different definition of LWD; if measurements were conducted by DEQ and PIBO protocols within the same reach, the PIBO LWD count would likely be greater because it includes pieces 3 feet long and 4 inches in diameter. For streams with a bankfull width of less than 15 feet, the DEQ sample dataset median was equal to the 25th percentile of the PIBO reference data; however, for wider channels, the sample dataset had much lower LWD counts than the PIBO dataset (**Table 5-11**). This difference for larger channel widths may partially be a result of different measurement protocols but is also likely a result of past land conversion and riparian vegetation removal within the wider valley sections of streams. An additional factor is that the typical trend of less LWD in larger streams is not reflected in the PIBO dataset. Given that the 75th percentile of the sample dataset does meet the reference 25th percentile for both bankfull width categories, an appropriate target frequency is likely between the 25th percentile reference values (i.e., 143–239) (**Table 5-11**). The target for all streams will be set at 143 LWD/mile.

Table 5-11. PIBO Reference and 2009 DEQ Sample Data Percentiles for Large Woody Debris Frequency (LWD/mile).

Target value is shown in bold.

Category	PIBO Reference			DEQ Sample Data		
	n	Median	25th	n	Median	75th
< 15 ft bankfull width	11	281	**143**	9	143	216
> 15 ft bankfull width	55	343	239	14	53	257

5.4.5 Human Sediment Sources

The presence of human sediment sources does not always result in sediment impairment of a beneficial use. When there are no significant identified human 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; however, the overall extent of human sources will be used to supplement any characterization of impairment conditions. This includes evaluating human-caused and natural sediment sources, along with field observations and watershed-scale source assessment information obtained using aerial imagery and GIS data layers.

Because sediment transport through a system can take years or decades, and because channel form and stability can influence sediment transport and deposition, any evaluation of human-caused sediment sources must consider both current and historical sediment loading as well as historical alterations to channel form and stability because those changes still have the potential to contribute to sediment and/or habitat impairment. Source assessment analysis will be provided by 303(d) listed waterbody in **Section 5.6**, with additional information in **Appendix C** and **Attachments A, B, and C.**

5.4.6 Biological Index

Siltation exerts a direct influence on benthic macroinvertebrate communities by filling in spaces between gravel and by limiting attachment sites. Macroinvertebrate communities respond predictably to siltation by shifting from natural or expected taxa to a prevalence of sediment-tolerant taxa (as opposed to those that require clean gravel substrates). Macroinvertebrate bioassessment scores are an assessment of the macroinvertebrate assemblage at a site. DEQ uses one bioassessment methodology to evaluate stream condition and aquatic life beneficial-use support. Aquatic insect communities 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.

DEQ uses the Observed/Expected Model (O/E) to assess macroinvertebrate communities. The rationale and methodology for the index is presented in the DEQ Benthic Macroinvertebrate Standard Operating Procedure (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2006). The O/E Model compares the taxa that are expected at a site under a variety of environmental conditions with the actual taxa that were found when the site was sampled. It is expressed as a ratio of the Observed/Expected taxa (O/E value). The O/E community shift point toward a more sediment-tolerant taxa for all Montana streams is any O/E value <0.80. Therefore, an O/E score of ≥0.80 is established as a sediment target in the Lower Gallatin TPA.

is this true? Can O/E identify causes of biological impairment? if not, reword.

Unless noted otherwise, macroinvertebrate samples discussed in this document were collected according to DEQ protocols. DEQ protocols have changed some within the last 10 years. All available data collected within that time are presented in this document; however, the current protocol, MAC-R-500, which is a reach-wide composite from both riffles and pools, is considered the most reliable for use with the O/E model. USFS data were collected according to the PIBO protocol, which is done with a kick net in two sections of the first four riffles/runs within a reach (Heitke et al., 2010); it is comparable to the MAC-R-500 method. (reference).

An index score greater than the threshold value is desirable, and the result of each sampling event is evaluated separately. Because index scores may be affected by other pollutants or forms of pollution, such as habitat disturbance, they will be evaluated in consideration of more direct indicators of excess sediment. In other words, not meeting the biological target does not automatically equate to sediment impairment. Additionally, because the macroinvertebrate sample frequency and spatial coverage is typically low for each watershed, and because of the extent of research showing the harm of excess sediment to aquatic life, meeting the biological target does not necessarily indicate a waterbody is fully supporting its aquatic life beneficial use. For this reason, macroinvertebrate data are not required ~~for a~~ "TMDL development determination", and available data will evaluated in conjunction with values for other target parameters.

to perform a stream assessment for sediment impairment.

~~[illegible] the biological target = fully supporting?~~

5.5 Existing Condition and Comparison to Water Quality Targets

This section includes a comparison of existing data with water quality targets, along with a "TMDL development determination" for each stream segment of concern in the Lower Gallatin watershed (**Section 5.2**). All waterbodies reviewed in this section are listed for sediment impairment on the 2012 303(d) List. Although inclusion on the 303(d) list indicates impaired water quality, a comparison of water quality targets with existing data helps define the level of impairment and establishes a benchmark to help evaluate the effectiveness of restoration efforts.

define "TMDL development determination"

5.5.1 Bear Creek (MT41H003_081)

Bear Creek (MT41H003_081) is listed for sedimentation/siltation and solids (suspended/bedload) on the 2012 303(d) List. In addition, this segment is also listed for alteration in streamside or littoral vegetative covers, which is a non-pollutant listing commonly linked to sediment impairment. Bear Creek was initially listed for sediment impairment in 2006 based on data collected in 2003 indicating the watershed has naturally erosive soil but that the sediment supply was elevated from disturbances associated with livestock and unpaved recreational vehicle trails/roads. Additionally, a water quality report from 1978 (APO) indicated residential development could be a factor, since home construction in the canyon had decreased bank vegetation and driveway culverts were undersized. Bear Creek flows 10.2 miles from its headwaters to its mouth at Rocky Creek.

Physical Condition and Sediment Sources

During data collection in 2003, the Gallatin National Forest coordinated with the Gallatin Local Water Quality District, DEQ, and the Montana Water Center to collect measurements of bedload, turbidity, suspended sediment, channel form, riffle fine sediment (via pebble count), macroinvertebrates, and stream discharge. Concurrently, the Gallatin National Forest conducted a fish habitat and abundance study that included percent fines <2mm (via visual estimate with a grid), pool and large woody debris frequency, residual pool depth, and identification of unstable streambanks.

There were eight turbidity/suspended sediment/bedload sites, four channel form/pebble count/macroinvertebrate sites, and four fish sites that captured a range of potential human effects. The uppermost site was upstream of most trails, another site was downstream of two trail fords and a landslide area, and the most downstream extent was downstream of the USFS boundary in an agricultural area near the Bozeman Trail Road. The monitoring conclusions are discussed here, and results were reviewed in comparison with the 2009 DEQ data. However, no data are presented because conditions from 2003 are no longer representative of conditions within the watershed: in 2007 and 2008 the most erosive section of trail was relocated and extensive rehabilitation work was conducted (**Figure 5-2**), drainage was improved, and new trail bridges were installed. In total, the USFS decommissioned approximately 5 miles of road in the watershed in 2007–2008.

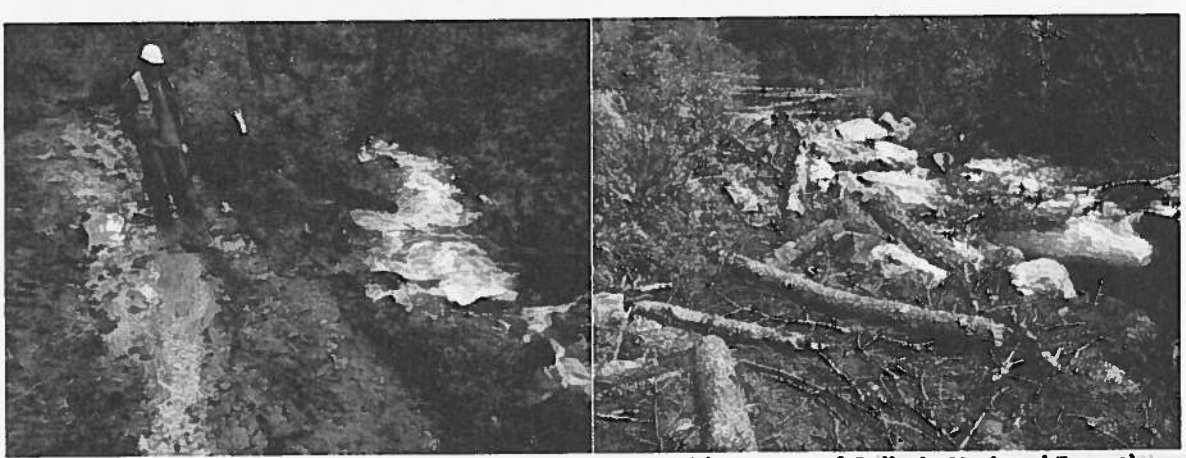


Figure 5-2. 2007–2008 photos of obliterated section of trail (courtesy of Gallatin National Forest).

During the sampling in 2003, pool habitat quality was variable, but both quality and abundance were lowest at sites that were downstream of the most erosive sections of trail. Unstable streambanks were

common at all sites; causes were cited as natural geology, varying degrees of cattle access on federal and private land, trail crossings, and channel readjustment resulting from an old lumber mill. Fine sediment was elevated at all sites, including those with a minimal level of upstream disturbance. Soils were noticeably destabilized by even the single pass of a cow (Barndt and Bay, 2004).

Fish abundance was high, but the report noted observations were limited to a single year and emphasized the reduced quantity of fish rearing habitat, high levels of fine sediment, and sensitivity of soils to disturbance. Evaluation of trail-related effects to turbidity were limited by a lack of runoff. Elevated fine sediment was noted during periods of active stream fording and in association with irrigation return flows and near-channel grazing, but much sediment was also attributed to the natural instability of the system and fine soil texture.

The Gallatin National Forest followed up with sediment sampling in 2011 at four of the sites from 2003. The sampling locations ranged from just upstream of the former trail ford area to the same downstream extent used in 2003, which represents agricultural land downstream of the USFS boundary. Runoff in 2011 was above average, and sediment and turbidity levels were the highest measured since monitoring was initiated in 1989, making a comparison with 2003 difficult. The 2011 data indicated the trail relocation and improvement efforts eliminated a sediment hotspot; however, similar to the 2003 data, the monitoring results did not allow for separation of the natural versus human contribution to elevated fine sediment (Story and Hancock, 2011). Although conditions at the most downstream site were somewhat improved in 2011 from the bare eroding streambanks observed in 2003, grazing along the stream and irrigation return flows were cited as remaining significant sediment sources from human activity.

In 2009 DEQ assessed sediment and habitat on two sites on Bear Creek (**Figure 5-1**). The uppermost site (BEAR18-01) was on USFS-administered land upstream of the Bear Canyon trailhead and overlapped with part of the trail section that was rehabilitated in 2007. It appeared that the relocation and rehabilitation work mitigated direct sediment inputs from the trail network, but some localized streambank erosion was attributed to the former trail network, particularly near historic stream crossings. Evidence of past riparian logging was observed along the channel, but the reach was lined with dense riparian shrubs that limited bank erosion. Pools were primarily at the outside of meander bends, the substrate was embedded, and there was silt along the channel margin.

The other assessment site (BEAR26-02) was in the lower portion of the segment, where the stream meanders through a broad valley with a mix of agriculture and rural residential development. A fence bordering a hayfield along the reach was falling into the channel, indicating active bank erosion. The channel was overwidened in sections, especially downstream of large eroding banks. Pools were primarily formed by woody debris from riparian shrubs, which were dense on the inside of meander bends. Vegetation on the outside of meander bends was primarily limited to grasses, and bank erosion was attributed to encroachment by cropland.

In 2009 DEQ evaluated one additional site for streambank erosion (BEAR20-01). The site was a confined section of stream located upstream of the Bear Canyon trailhead and had a limited amount of rural residential development. Bank erosion was primarily limited to sections where the stream was eroding away at the base of the hillslope, and all erosion at this site was attributed to natural sources. Streambanks at all sites corresponded with observations from the USFS reports in that they were primarily composed of highly erodible fine sediment.

During reconnaissance work for the sediment and habitat assessments in July 2009, a storm event occurred and a gully was observed at the edge of the road that started above the trailhead parking lot and continued to pick up sediment until it discharged near a culvert into New World Gulch, a tributary to Bear Creek (**Figure 5-3**).

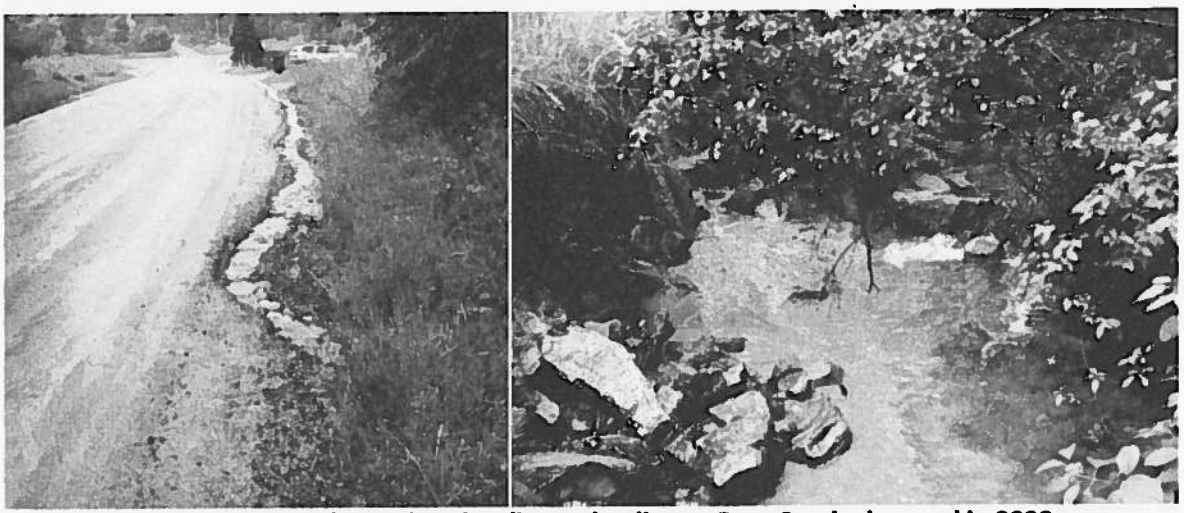


Figure 5-3. Road erosion and associated sediment loading to Bear Creek observed in 2009.

The nutrient source assessment report (**Attachment B**) corresponds with observations from the 2009 sediment and habitat assessments as well as observations from the USFS sampling: riparian vegetation was typically dense and sediment sources were from naturally erosive soils, streambank and trail erosion, unpaved road crossings, and grazing on public and private land.

Comparison with Water Quality Targets

The existing data in comparison with the targets for Bear Creek are summarized in **Table 5-12**. The macroinvertebrate bioassessment data are located in **Table 5-13**. Four macroinvertebrate samples were collected in 2003 but are not included in **Table 5-13** because of the extensive trail rehabilitation work conducted in 2007 and 2008. All 2003 samples met the target. All bolded cells are beyond the target threshold; depending on the target parameter, this may equate to being below or above the target value.

Table 5-12. Existing sediment-related data for Bear Creek relative to targets.

Values that do not meet the target are in bold.

Reach ID	Assessment Year	Mean BFW (ft)	Existing Stream Type	Potential Stream Type	Riffle Pebble Count (mean)		Grid Toss (mean)	Channel Form (mean)		Instream Habitat		
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / Mile	LWD / Mile
BEAR18-01	2009	15.5	C4b/E4b/B4	B4/C4b	4	2	**23**	12.7	5.6	1.4	58	143
BEAR26-02	2009	22.1	B4c/C4	C4	6	4	**21**	19.5	3.0	1.2	79	**69**

Table 5-13. Macroinvertebrate bioassessment data for Bear Creek.
Values that do not meet the target threshold (0.80) are in bold.

Station ID	Location	Collection Date	Collection Method	O/E
M05BEARC05	0.2 mile downstream of USFS boundary	8/22/2011	MAC-R-500	1.08

Summary and TMDL Development Determination
Both sites met the riffle fine sediment targets but both failed to meet the pool tail grid toss target. Although some localized channel overwidening was observed, both sites met channel form targets. Additionally, pool frequency and residual pool depth targets were met. Likely as a result of past harvest practices in the forest and the valley, the lower site was well below the LWD target. The macroinvertebrate sample met the target.

Although field methods varied slightly between sampling events in 2003 and 2009, general comparisons were made to help evaluate instream changes resulting from the trail rehabilitation project. In 2009 fine sediment values were less, channel form measurements and residual pool depths were similar, pool frequency was greater in the valley portion of the segment, and LWD was greater but still very limited in the valley portion of the segment. Recent data and field observations, along with data collected before the trail rehabilitation project, indicate the work conducted in 2007–2008 addressed a substantial human source of sediment to Bear Creek and that the system is recovering. Although the silt observed at the channel margins and substrate embeddedness at the upper site may be partially to entirely natural, the elevated fine sediment in pool tails, in combination with remaining human sources and the sensitivity of the watershed to disturbance, support the listing. A sediment TMDL will be developed for Bear Creek.

5.5.2 Bozeman Creek (aka Sourdough Creek) (MT41H003_040)

Bozeman Creek (MT41H003_040) is listed for sedimentation/siltation on the 2012 303(d) List. In addition, this segment is also listed for alteration in streamside or littoral vegetative covers, which is a non-pollutant listing commonly linked to sediment impairment. Bozeman Creek was initially listed for sediment impairment in 1990 based on reports from the late 1970s documenting sedimentation associated with agricultural and urban runoff as well as logging. Bozeman Creek forms within the Gallatin National Forest, but the listed segment extends 4.9 miles from the confluence of Limestone Creek to its mouth at the East Gallatin River. The portion of Bozeman Creek from its headwaters to the water supply intake for Bozeman near the USFS boundary is designated as A-Closed. It is commonly called Sourdough Creek upstream of the USFS boundary and Bozeman Creek downstream of the USFS boundary; as explained in the **Table ES-1** of the Executive Summary, the stream will be referred to as Bozeman Creek throughout this document.

Physical Condition and Sediment Sources
In addition to past sediment inputs from logging and associated roads, one potential sediment source to Bozeman Creek from the upper watershed is from the breach of the Mystic Lake Dam, which was conducted during low flow in 1985. After the breach, sediment within the reservoir was left undisturbed, and restoration work was conducted in a 100-meter segment of stream channel and riparian downstream of the dam. Although sediment from the reservoir has likely been flushed downstream since the breach, a study of the ecological response of the dam removal concluded the nature of the dam operation and removal resulted in no noticeable downstream geomorphologic or riparian changes (Schmitz et al., 2008).

In 2002 the Bozeman Watershed Council (now defunct) conducted an assessment of watershed health that involved collecting sediment and habitat data along the entire stream. The stream was broken into 10 zones, which were then broken into sampling reaches. Zones 8 through 10 roughly correspond to the segment of Bozeman Creek listed for sediment impairment; zone 8 was indicated as the area where urban influences become more concentrated.

The assessment concluded that the upper watershed lacked LWD, had steep slopes and highly erodible soils (which are prone to landslides), and contained limited spawning habitat. It cited roads and upland erosion near the city's water supply intake as potential sediment sources within the upper watershed. Sediment inputs in the upper watershed were estimated to be near the pre-logging level, and although erosion from a severe fire was noted as a risk, the predominant issues were nonpoint sources associated with urbanization in the lower watershed. Reaches within zones 8 through 10 were the only sections identified as having low habitat integrity. Limiting factors were noted as channelization and entrenchment, sediment accumulation from streambank erosion and low flow, unstable streambanks, barriers and riprap, and lack of riparian vegetation and LWD.

Increased streamflow velocity from riprap, lack of riparian vegetation, and the orientation of a residential storm water drain were cited as sources of streambank erosion. In addition to these limitations, the USFS fisheries biologist, Scott Barndt, noted that pool habitat was lacking and there were high levels of fine sediment. At the assessment reaches within zones 8 through 10, fine sediment was estimated at 30% and 40%, respectively, LWD frequency ranged from 2 to 52 pieces per mile, and pool frequency ranged from 3 to 39 pools per mile.

The data from 2002 were used in a study that evaluated the differences in geomorphology and habitat among different land-use classes (McIlroy et al., 2008). The study area started near the USFS boundary at the city's diversion dam and contained five land use classes: agriculture, forest, industrial, high density, and low density (which had a municipal park broken out for the analysis). Channel sinuosity was significantly different between high density and agricultural, low density, and park classes. The agricultural class had more undercut and unstable streambanks and the greatest pool length and pocket pool abundance. Pocket pool abundance was lowest, and the percentage of silt/clay was greatest, in the high density areas. The percentage of sand and gravel were similar across land-use categories. Overall, the study concluded that LWD abundance was low; values ranged from 0 to 264 pieces per mile, with an average of 54 pieces per mile and a median of 83 pieces per mile. Intentional wood removal was determined to be a factor, and the importance of public education and outreach was emphasized.

In 2004 DEQ conducted an assessment at two sites. The upper site (M05SOURC01) was located at the top of the listed segment. The substrate was gravel and cobble, and fine sediment deposition was observed in pools. There were some actively eroding streambanks, particularly where the channel abutted a pasture/hayfield. LWD was abundant at the site. Most of the riparian vegetation was contained within a city-owned recreational trail and was well conserved. The other site (M05SOURC02) was approximately 0.25 mile upstream of the mouth. The stream was channelized and incised but typically had a healthy riparian zone with regenerating willows. The streambanks were frequently armored, and the site was lacking pools because of the channelization. Accumulations of fine sediment were mostly limited to the channel margin.

In 2009 DEQ assessed sediment and habitat at two monitoring sites on Bozeman Creek (**Figure 5-1**). The upper site (BOZE14-01) was upstream of the listed segment but was evaluated as part of the source assessment and to assess instream conditions upstream of the listed segment. The site was just

upstream of the Sourdough Canyon trailhead (the trail was formerly a road, and there was occasional riprap along the channel where the stream abutted the trail). Riparian vegetation was dense at the site and included alders, red-osier dogwoods, and willows in the understory, with cottonwoods in the overstory. The substrate was mostly small cobble and coarse gravel, and the majority of the site was riffle habitat. Pools were formed by lateral scour and LWD aggregates; one large LWD jam was observed. Spawning potential was estimated to be limited because of the large substrate. Some fine sediment accumulations were observed along the channel margin, and the substrate in pool tails was embedded. Streambank erosion was fairly limited but was observed in a couple places where the trail encroached on the channel. It appeared silt fencing had been used to limit trail sediment inputs to the stream but was inadequately maintained because fencing was tangled with LWD in the channel at this site and the next site downstream (BOZE15-01). On a side note, the Gallatin Valley Land Trust completed an improvement project in October 2011 that included moving the trail access road farther from the stream to reduce sedimentation (Flandro, 2011).

The lower site (BOZE18-04) was in a channelized section of stream near downtown Bozeman and is bordered by houses on the left and Bogert Park on the right. There were a few small pocket pools with spawning sized gravels along the channel margin, but habitat was mostly riffle. The left side of the channel was hardened in many places by retaining walls and riprap; the right side was mostly lined with a narrow band of large deciduous trees. One large eroding streambank was associated with recreational access from the park. Although there was a fair amount of bare ground along the channel, streambank erosion was typically limited because of stabilization by roots from the trees and the extensive use of riprap.

In 2009 DEQ evaluated two additional sites for streambank erosion. The upper site (BOZE15-01) was well upstream of the listed segment approximately 1 mile downstream of BOZE14-01 and near the Nash Road crossing. Some old riprap was observed, but surrounding land-use practices appeared to have minimal effects on the site. Bank erosion was limited as a result of cobbles armoring the streambanks and roots from cottonwood trees in the riparian zone. All erosion was attributed to natural sources. The other site (BOZE18-05) was located near the downstream end of the segment in an industrial area north of I-90 and just upstream of M05SOURC02, which DEQ sampled in 2004. Streambank erosion was limited as a result of extensive riprap that had been strategically placed along meander bends. A component of the bank erosion was attributed to natural sources but the majority was attributed to urban development. Riparian vegetation consisted of a dense band of willows and alders along the channel margin with some cottonwoods in the overstory.

The nutrient source assessment report (**Attachment B**) noted minimal sources within the Gallatin National Forest associated with recreational trails but increasing sources in a downstream direction as residential and urban development intensifies. Downstream of the forest boundary, riparian buffers along pastureland were typically dense and wide. In residential areas upstream of Bogert Park, riparian vegetation was predominantly dense and healthy, and bank erosion was limited to areas of pasture and lawn encroachment. Riparian quality was much lower and streambank trampling and erosion much more common in residential and industrial areas downstream of Bogert Park. However, streambank erosion was limited along many residences because of extensive riprap. Riparian quality improved and bank erosion was much lower near the bottom of the segment downstream of Tamarack Street; however, fine sediment accumulations were observed in areas with slower moving water. Recreational trails and roads were noted as a minor source, but storm water was identified as a potentially significant source.

The USFS has recently identified Bozeman Creek as a priority watershed for restoration. Some sediment-related items identified as key issues in the restoration action plan include five splash dams that were in the channel between 1878 and 1910, which caused considerable damage to the channel, as well as road density and deferred road/trail maintenance (U.S. Forest Service, 2011). Additionally, approximately 50 feet of road/trail slumpage occurred near the Mystic Lake rental cabin in 2011. The USFS estimates that sediment yields are barely over a pristine baseline (3.4%); however, the action plan includes projects aimed to reduce sediment inputs to the creek, such as repairing the road slump and storm-proofing the road and trail system. Also, because of the estimated risk of a large-scale wildfire and associated resulting ash and fine sediment loads that would end up in Bozeman Creek (and the city's water supply intake), the USFS will be conducting a harvesting and thinning project. The project is not anticipated to affect water yield and will not involve any harvesting within the riparian zone. Further, the USFS estimates it will increase the short-term sediment yield by 1.3% (for a total of 4.7% over pristine) (U.S. Department of Agriculture, Forest Service, Gallatin National Forest, 2011).

Comparison with Water Quality Targets

The existing data in comparison with the targets for Bozeman Creek are summarized in **Table 5-14**. The macroinvertebrate bioassessment data for Bozeman Creek is in **Table 5-15**. All bolded cells are beyond the target threshold; depending on the target parameter, this may equate to being below or above the target value.

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

Reach ID	Assessment Year	Mean BFW (ft)	Existing Stream Type	Potential Stream Type	Riffle Pebble Count (mean)		Grid Toss (mean)	Channel Form (mean)		Instream Habitat		
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / Mile	LWD / Mile
M05SOURC 01	2004		C4	–	8	7	–	16.8	2.7	–	–	–
M05SOURC 02	2004	22	G4/F4	–	14	8	–	15.7	1.6	–	–	–
PIBO2316*	2007	19.7	–	–	6	3	3	16.9	–	1.0	**49**	264
BOZE14-01*	2009	22.3	C3/C4/E3	C3	8	4	**10**	14.2	5.5	1.3	53	158
BOZE18-04	2009	23.8	B4c/F4/G4c	B4c	10	8	**14**	12.8	1.4	1.3	**11**	**37**

*Upstream of listed segment

Table 5-15. Macroinvertebrate bioassessment data for Bozeman Creek.
Values that do not meet the target threshold (0.80) are in bold.

Station ID	Location	Collection Date	Collection Method	O/E
BOZMC02	E. Lincoln St. below storm outfall	7/24/2008	MAC-R-500	1.14
		7/19/2009	MAC-R-500	1.01
		7/12/2010	MAC-R-500	1.14
		8/20/2011	MAC-R-500	1.27
BOZMC01	1.4 miles upstream of mouth near the old library	7/24/2008	MAC-R-500	1.14
		7/19/2009	MAC-R-500	0.89
		7/12/2010	MAC-R-500	0.89
		8/20/2011	MAC-R-500	1.14
M05BOZMC01	At the mouth	8/30/2005	KICK	1.14
M05SOURC02	0.25 mile upstream of the mouth	8/2/2004	KICK	1.26
M05SOURC01	Upper end of segment just downstream of confluence with Limestone Creek	8/2/2004	KICK	1.15

Summary and TMDL Development Determination
All sites met the target for fine sediment in riffles. Although BOZE14-01 is upstream of the listed segment and had less fine sediment in riffles and pools than BOZE18-04, both DEQ sites from 2009 exceeded the pool tail grid toss target for fine sediment. The sediment assessment procedure performed for the 2002 watershed assessment varied from the more recent assessment procedures; however, in 2002 excess fine sediment was noted as a widespread problem throughout the segment.

Both channel form targets were met at all sites; however, the channel was more entrenched within the listed segment, which corresponds with observations from the assessments performed in 2002 and 2004. The residual pool depth target was met at all sites, but the PIBO site was just short of the pool frequency target, and BOZE18-04 was well below the pool frequency target. Both sites upstream of the listed segment met the LWD frequency target; however, BOZE18-04 was well below the target. Although all macroinvertebrate samples met the target value, fine sediment and habitat parameters, as well as observations about the effects of urbanization, are consistent with the 2002 watershed assessment and sampling conducted in 2004. This information supports the 303(d) listing; a sediment TMDL will be developed for Bozeman Creek.

5.5.3 Camp Creek (MT41H002_010)

Camp Creek (MT41H002_010) is listed for sedimentation/siltation on the 2012 303(d) List. In addition, this segment is also listed for alteration in streamside or littoral vegetative covers, physical substrate habitat alterations, other anthropogenic substrate alterations, and low-flow alterations, which are non-pollutant listings commonly linked to sediment impairment. Camp Creek was initially listed for sediment impairment in 1988 based on reports going back to the late 1970s documenting sedimentation and limitation of the fishery associated with channel changes, realignment due to road construction, irrigation runoff, bank erosion and removal of riparian vegetation associated with cattle grazing, and increased flow from irrigation returns. Camp Creek flows 29.6 miles from its headwaters to the mouth at the Gallatin River.

Physical Condition and Sediment Sources

In 2001 DEQ assessed two sites on Camp Creek: one was about a mile upstream of Anceney and the other was approximately 1 mile upstream of the confluence with Baker Creek. The site near Anceney had all sizes of rock and gravel but was choked by sand and silt. The site had been heavily grazed for generations, resulting in over-browsed riparian vegetation and an overwidened channel. Undercut streambanks and overhanging willows were providing some good pools and cover for fish.

The lower site near Baker Creek had been formerly overgrazed but had recently changed ownership, and conditions appeared to be improving. Large accumulations of sand, silt, and clay were prevalent and noted to be filling pools and reducing fish habitat. LWD was rare, and an altered flow regime was causing lateral downcutting and channel incisement. Soils at both sites were noted as naturally erosive, but loading was being increased by grazing and dryland agriculture.

In 2009 DEQ assessed sediment and habitat on three sites on Camp Creek. The uppermost site (CAMP14-05) was highly entrenched with large eroding streambanks where the stream meandered into the valley wall. The channel entrenchment, as well as much of the streambank erosion, was attributed to past vegetation removal and agricultural practices. Other human sources of bank erosion were riparian grazing and cropland. The site was used for livestock grazing and had a hayfield along the right side of the channel. The channel margin contained wetland vegetation, grasses, and periodic shrubs, with junipers and rose growing beyond the bankfull zone. The streambanks and streambed were composed of sand and silt. The channel contained dense aquatic vegetation, and fine sediment in pool tails was likely limiting spawning potential. Camp Creek conveys irrigation water drawn from the Gallatin River, and it appeared that streamflows increased between this site and the next downstream site (CAMP14-12).

CAMP14-12 was very similar in character to the upper site in that it was highly entrenched with large eroding streambanks composed of sand and silt. The stream was fairly close to the road on the right side and had a hayfield on the other side that extended to the valley terrace. The upstream addition of irrigation return flows were apparent, since the channel was near bankfull in late August; the landowner commented that the high flows appeared to be accelerating streambank erosion. Additionally, the landowner said that the stream was historically in the center of the hayfield but was relocated. Streambank erosion was primarily attributed to past irrigation water management but also to cropland management. Wetland vegetation lined much of the channel, which was narrow and deep, but the upper end of the site had a wider and shallower channel lined with large willows and grasses. The streambed was primarily fine sediment and likely limits the spawning potential. Although pools were numerous, the elevated flows in the narrow channel and easily disturbed fine grain sediment prevented the field crew from performing pool tail grid toss measurements.

The most downstream site (CAMP15-04) was just downstream of I-90 in a section that resembles a spring creek. This section of stream is within the floodplain of the Gallatin River and receives numerous groundwater and spring inputs. The channel was wide with low streambanks that contained much less silt than the other assessment sites. Streambank erosion was limited to places historically used for livestock access. During the assessment, the site appeared to be used lightly for grazing, but cattle were observed there in December, indicating it may be used as a winter pasture. The reach was primarily a riffle but contained large deep pools with poorly defined tails at the outside of meander bends. There was little shrub cover, and riparian vegetation was primarily wetland vegetation and grasses.

In 2009 DEQ evaluated one additional site for streambank erosion (CAMP13-02). The site was near the Anceney site from 2001 in an area used for grazing, but a portion of the stream was partially fenced off. Streambank erosion at the site was primarily attributed to natural sources, and the erosion rate was limited by dense riparian shrubs.

The nutrient source assessment report (**Attachment B**) documented extensive agricultural sources downstream of Norris Road, which is just upstream of CAMP14-05. Sources included bank erosion associated with overgrazing and pasture encroachment on the stream channel, livestock confinement areas near the stream, and unpaved road crossings.

Comparison with Water Quality Targets

The existing data in comparison with the targets for Camp Creek are summarized in **Table 5-16.** No macroinvertebrate data are available for Camp Creek. All bolded cells are beyond the target threshold; depending on the target parameter, this may equate to being below or above the target value.

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

Reach ID	Assessment Year	Mean BFW (ft)	Existing Stream Type	Potential Stream Type	Riffle Pebble Count (mean)		Grid Toss (mean)	Channel Form (mean)		Instream Habitat		
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / Mile	LWD / Mile
CAMP14-05	2009	12.3	E4/B4c/5c	E4	**61**	**36**	**83**	11.1	**1.7**	1.1	95	216
CAMP14-12	2009	17.1	B4c	E4	14	10	No Data	**14.0**	**2.1**	**1.1**	90	**26**
CAMP15-04	2009	36.6	C3/C4	C4/E4	9	9	**24**	22.2	6.4	1.9	**16**	**26**

Summary and TMDL Development Determination

The upper site was well over the riffle pebble count targets, and both sites with grid toss data exceeded the target. Reflecting the entrenched nature of the channel at the middle and upper site, both sites failed to meet the entrenchment ratio target. The middle site exceeded the target for width/depth ratio, which is likely a factor of irrigation water management and prolonged elevated flows. The middle site was just below the target for residual pool depth. Although the most downstream site had deep pools, it was well below the target for pool frequency. Both the middle and most downstream site were well below the target for LWD. Soils in the Camp Creek watershed are sensitive to disturbance, and based on the recent data, excess sediment loading associated with channel realignment, overgrazing, and irrigation continue to overwhelm the system's sediment transport capacity. This information supports the 303(d) listing; a sediment TMDL will be developed for Camp Creek.

5.5.4 Dry Creek (MT41H003_100)

Dry Creek (MT41H003_100) is listed for sedimentation/siltation on the 2012 303(d) List. In addition, this segment is also listed for alteration in streamside or littoral vegetative covers and physical substrate habitat alterations, which are non-pollutant listings commonly linked to sediment impairment. Dry Creek was initially listed for sediment impairment in 1992 based on data from the late 1970s noting channel realignment associated with transportation, as well as a 1991 DEQ assessment that

documented reduced riparian vegetation and siltation and streambank failure associated with agriculture. Dry Creek flows 20.1 miles from its headwaters to the mouth at the East Gallatin River.

Physical Condition and Sediment Sources

A small portion of the upper watershed containing tributary headwaters is on land administered by the USFS and contains a grazing allotment (**Figure 5-1**). In an evaluation for the North Bridgers Allotment Management Plan Update Environmental Impact Statement (U.S. Forest Service, 2007), the riparian vegetation for all sites within the allotment was rated as in proper functioning condition (Prichard, 1998). No potential grazing-related effects to water quality were noted for this allotment.

In 2009 DEQ assessed sediment and habitat at two monitoring sites on Dry Creek (**Figure 5-1**). The upper site (DRY09-05) was near the Menard Road crossing in an entrenched section of stream, with large eroding streambanks at the outside of meander bends, and was surrounded by grazing pasture. Streambanks were composed almost entirely of sand/silt, and bank erosion was attributed to grazing. A meander scar was observed on the abandoned floodplain, indicating the stream was not historically entrenched. Woody shrubs were sparse, but the channel appeared to be recovering: it was establishing a new floodplain within the entrenched valley and had wetland vegetation stabilizing the inside of meander bends. Pools predominantly occurred at the outside of meander bends and were deep. Fine sediment deposition was observed in some pool tails.

The lower site (DRY12-06) was approximately 3 miles upstream from the mouth. The stream was entrenched at the upper end of the site but had better floodplain access at the lower end of the site; the source of entrenchment was unclear. The streambanks had some coarse and fine gravel but were predominantly sand/silt. Bank erosion was attributed to past agriculture and vegetation removal. The landowner identified several areas of active bank retreat. Willows, wetland vegetation, and other streambank-stabilizing plants were colonizing the newly forming floodplain at the lower end of the site, indicating the site is recovering. However, most of the streambanks were lined with reed canary grass (which has deep roots but tends to out-compete native vegetation). Riffles were predominantly cobbles, but fine sediment accumulations were noted at the bottom of deep pools under eroding streambanks. Because of turbidity, no grid tosses were performed in pool tails (potential spawning locations could not be identified).

The nutrient source assessment report (**Attachment B**) documented healthy riparian vegetation and stable streambanks throughout most of Dry Creek but did note several areas with large eroding banks because of either grazing or encroachment of pastureland onto the channel. Unpaved road crossings, particularly where gravel was accumulating on bridge decking, were also noted as a potential sediment source.

Comparison with Water Quality Targets

The existing data in comparison with the targets for Dry Creek are summarized in **Table 5-17**. No macroinvertebrate data are available for Dry Creek. All bolded cells are beyond the target threshold; depending on the target parameter, this may equate to being below or above the target value.

Table 5-17. Existing sediment-related data for Dry Creek relative to targets.
Values that do not meet the target are in bold.

Reach ID	Assessment Year	Mean BFW (ft)	Existing Stream Type	Potential Stream Type	Riffle Pebble Count (mean)		Grid Toss (mean)	Channel Form (mean)		Instream Habitat		
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / Mile	LWD / Mile
DRY09-05	2009	14.3	B4c/G4c	E4	22	**19**	**17**	**11.3**	**1.4**	1.6	**74**	**79**
DRY12-06	2009	17.1	C4/B4c	E4	15	11	No Data	**13.9**	3.5	1.5	**37**	**0**

Summary and TMDL Development Determination
The upper site failed to meet the riffle pebble count target for fine sediment <2mm and also the pool tail grid toss target. At the lower site, fine sediment accumulation was not an issue in riffles, and although no grid tosses were performed, field observations indicate excess fine sediment from eroding streambanks is accumulating in pools. The stream appeared to be recovering and narrowing at both sites but is still overwidened and failed to meet the target for width/depth ratio. Pools were quite deep at both sites but failed to meet the target for pool frequency. Also, both sites failed to meet the target for LWD, with the lower site having none. The recovery occurring at the assessment sites corresponds with observations from the nutrient source assessment: much of Dry Creek is either in good condition or in recovery. However, the source assessment and field observations also document the increase in bank erosion and downcutting that can occur when land management practices remove riparian vegetation. This information supports the 303(d) listing; a sediment TMDL will be developed for Dry Creek.

5.5.5 Godfrey Creek (MT41H002_020)

Godfrey Creek (MT41H002_020) is listed for sedimentation/siltation on the 2012 303(d) List. In addition, this segment is also listed for alteration in streamside or littoral vegetative covers, which is a non-pollutant listing commonly linked to sediment impairment. Godfrey Creek was initially listed for sediment impairment in 1996 based on reports from the late 1970s as well as the early 1990s documenting upland erosion from cropland, overgrazing on rangeland and along the stream, lack of riparian vegetation, streambank erosion, channel manipulation, and sediment from irrigation returns. Godfrey Creek is located just east of Camp Creek and flows 9 miles from its headwaters to mouth at Moreland Ditch.

Physical Condition and Sediment Sources
An extensive Section 319 (i.e., nonpoint source) project was undertaken in the early to mid-1990s to improve management practices in the watershed. Many landowners were involved in projects, including adding riparian fencing, improving grazing and manure management, and improving irrigation water management. DEQ conducted several assessments in the mid 1990s that noted minimal improvement but cited inadequate information to fully evaluate changes. The 1996 Section 319 project report mentioned roads as a source and noted that improvements may be limited by three irrigation canals crossing the watershed.

In 2009 DEQ assessed sediment and habitat at two monitoring sites on Godfrey Creek (**Figure 5-1**). The upper site (GOD02-01) was in a channelized section of stream along Churchill Road. The streambed was silty, with frequent pools and extensive macrophyte growth. The channel was lined with wetland vegetation and grass, and the limited amount of streambank erosion was attributed to channelization from the road. The lower site (GOD03-01) was located in a pasture used for grazing. The channel was sinuous, with fine substrate and compound pools at meander bends. Spawning-size gravels were observed in the pool tails. Riparian shrubs were lacking, but wetland vegetation was present along the channel margin. Streambank erosion was primarily observed at the outside of meander bends and was attributed to hoof shear and the lack of woody vegetation.

The nutrient source assessment report (**Attachment B**) identified agricultural sediment sources scattered throughout most of Godfrey Creek; however, the most significant sources were observed in a 3-mile section starting at the confluence of the east and west forks (just downstream of GOD02-01 but including GOD03-01). Sources were encroachment by pastureland, streambank erosion caused by overgrazing of riparian vegetation, the presence of near-channel livestock confinement areas, and direct disturbance of the channel by livestock. Sections of the stream that had better implementation of BMPs and dense riparian grasses had very limited bank erosion.

Comparison with Water Quality Targets

The existing data in comparison with the targets for Godfrey Creek are summarized in **Table 5-18**. No macroinvertebrate data are available for Godfrey Creek. All bolded cells are beyond the target threshold; depending on the target parameter, this may equate to being below or above the target value.

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

Reach ID	Assessment Year	Mean BFW (ft)	Existing Stream Type	Potential Stream Type	Riffle Pebble Count (mean)		Grid Toss (mean)	Channel Form (mean)		Instream Habitat		
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / Mile	LWD / Mile
GOD02-01	2009	7.9	B4c/C4/E4	E4	**34**	**27**	**45**	10.5	2.4	**0.6**	180	**0**
GOD03-01	2009	10.8	B4c/C4	E4	22	16	**29**	**13.5**	2.9	0.8	95	**11**

Summary and TMDL Development Determination

Riffle pebble count targets were exceeded at the upper site, and both sites exceeded the target for pool tail grid toss. As a result of overgrazing, the lower site was overwidened and failed to meet the target for width/depth ratio. The upper site was slightly below the target for residual pool depth but was more than double the target for pool frequency. Both sites were lacking LWD and fell short of the LWD target. Observations from the nutrient source assessment and sediment/habitat assessment sites indicate many of the significant sediment sources identified in the 1990s remain, and excess sediment continues to overwhelm the transport capacity of Godfrey Creek. This information supports the 303(d) listing; a sediment TMDL will be developed for Godfrey Creek.

5.5.6 Jackson Creek (MT41H003_050)

Jackson Creek (MT41H003_050) is listed for sedimentation/siltation on the 2012 303(d) List. In addition, Jackson Creek is also listed for alteration in streamside or littoral vegetative covers, which is a non-pollutant listing commonly linked to sediment impairment. Jackson Creek was initially listed in 1992 based on FWP data from 1975 citing siltation associated with channel alterations from the road and livestock trampling of the streambanks. Jackson Creek flows 8.6 miles from its headwaters to its mouth, where it joins Timberline Creek to form Rocky Creek.

Physical Condition and Sediment Sources

In 2004 DEQ assessed a site (M05JAKSC01) on land administered by the USFS downstream of an area that was historically logged but appeared revegetated and stable (**Figure 5-1**). The stream contained mostly runs and riffles, and some pools were associated with LWD and boulders. The substrate was dominated by small cobble and coarse gravel; there were some silt accumulations at the channel margin. The silt was attributed to past logging and possibly associated changes in water yield. The streambanks were generally stable but occasional bank erosion was noted as being potentially associated with downcutting. No evidence of grazing was observed at the site.

One PIBO non-reference site (2216) approximately 0.4 mile upstream of M05JAKSC01 was sampled in 2007 (**Figure 5-1**). Additionally, there is a grazing allotment on USFS-administered land within the upper watershed. In 2008 the Gallatin National Forest evaluated conditions in the watershed as part of the Bangtail Allotment Management Plan Update Environmental Assessment (U.S. Forest Service, 2009). According to the report, much of the Bangtail Mountains were roaded and logged in the 1980s and through the mid-1990s prior to a 1998 land exchange. In the Jackson Creek watershed, 1,050 acres were harvested by 1980, an additional 600 acres were harvested by 1988, and 598 acres were harvested by 1998.

Little commercial harvesting has occurred on public land in the watershed since that time, and many of the roads have been decommissioned; however, primary access roads were noted as potential sediment sources. A grazing allotment within the forest is another potential sediment source. The Jackson Creek Allotment includes 2,870 acres on national forest land and 2,301 acres on an adjacent lease on private land; the total number of permitted cow/calf pairs is greater than desired by the USFS (U.S. Forest Service, 2009). The allotment is managed under a single pasture two-month system that typically receives the most use in the uplands. The Environmental Assessment report noted no discernible effects to the stream as a result of grazing. In addition there was no change in channel stability relative to previous assessments, and riparian vegetation at the site was in proper functioning condition (Prichard, 1998). However, the report noted isolated pockets of overuse by livestock during drier years, the need for maintenance to stock water improvements, and conifer encroachment into rangeland.

In 2009 DEQ assessed sediment and habitat at two monitoring sites on Jackson Creek (**Figure 5-1**). The upper site (JACK04-01) was located on land administered by the USFS. Similar to observations from 2004, field notes indicated signs of past logging in the upper watershed but that extensive regrowth had occurred. The area was lightly grazed and the channel was overwidened at one cattle access point. There was a high amount of fine sediment in depositional areas, but the source was not apparent. There was extensive LWD, and fine sediment accumulation around LWD aggregates limited pool formation.

Additionally, fine sediment in pool tails likely limits spawning potential. Streambanks were predominantly composed of sand/silt, and erosion mostly occurred at the base of hillslopes and behind

LWD accumulations; sources were cited as natural, grazing, and past timber harvest. The riparian zone was composed of a mix of shrubs and grasses, with conifers in the overstory.

The lower site (JACK10-02) was in an agricultural section of the valley bottom used for haying. Riprap had been added to the right streambank to limit erosion of the hayfield. The stream had a headcut near the lower end the site, which is an indicator of instability and channel adjustment. Rock check dams were observed farther upstream and may have been a contributing factor. The channel was meandering and was locally entrenched, but the riparian vegetation was typically a dense mixture of alder and grasses. Although streambanks were similar to the upper site in composition, the substrate was dominated by coarse gravel, and fine sediment accumulations were not observed. Streambank erosion was limited to areas that did not have riprap or dense riparian vegetation and was attributed to cropland and natural sources.

The nutrient source assessment report (**Attachment B**) noted high riparian quality along much of Jackson Creek, including areas that were being actively logged in the upper watershed. Sediment sources were noted as past and current logging, unpaved roads, stream fords, stream encroachment by pasture, and livestock grazing. Some areas of streambank erosion were observed and attributed to grazing.

Comparison with Water Quality Targets

The existing data in comparison with the targets for Jackson Creek are summarized in **Table 5-19**. The macroinvertebrate bioassessment data for Jackson Creek is in **Table 5-20.** All bolded cells are beyond the target threshold; depending on the target parameter, this may equate to being below or above the target value.

Table 5-19. Existing sediment-related data for Jackson Creek relative to targets.

Values that do not meet the target are in bold.

Reach ID	Assessment Year	Mean BFW (ft)	Existing Stream Type	Potential Stream Type	Riffle Pebble Count (mean)		Grid Toss (mean)	Channel Form (mean)		Instream Habitat		
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / Mile	LWD / Mile
M05JAKSC01	2004	10.9	B4/E4b	--	12	**11**	--	10.0	7.2	--	--	--
PIBO2216	2007	10.5	--	--	5	4	**11**	**18.0**	--	**0.5**	162	**95**
JACK04-01	2009	13.7	B4/E4b/G4	B4	**20**	**16**	**64**	13.0	2.2	0.7	**53**	401
JACK10-02	2009	19.9	B4c/C4	C4	6	5	7	18.2	2.4	1.4	106	407

Table 5-20. Macroinvertebrate bioassessment data for Jackson Creek.

Values that do not meet the target threshold (0.80) are in bold.

Station ID	Location	Collection Date	Collection Method	O/E
PIBO_2216	1.9 miles downstream of the headwaters	7/29/2007	Surber	0.97
WMTP99-0749	0.5 miles upstream of the USFS boundary	9/4/2002	WEMAP-RW	1.02
M05JAKSC01	1.5 miles upstream of the USFS boundary	7/27/2004	KICK	**0.62**

Summary and TMDL Development Determination
In 2004 the macroinvertebrate sample failed to meet the target value. The percentage of riffle fine sediment <2mm exceeded the target, indicating excess fine sediment may be limiting the stream's ability to support aquatic life. Both the PIBO site and upper DEQ site from 2009 exceeded the pool tail grid toss target. The upper DEQ site from 2009 also exceeded both fine sediment targets for riffle pebble count. The PIBO site slightly exceeded the target for width/depth ratio but overall, channel form targets were met. The PIBO site also failed to meet the target for residual pool depth and LWD frequency.

However, the extremely high LWD values at both DEQ sites in 2009 indicate there is more than an adequate amount of LWD in the stream. The upper DEQ site from 2009 did not meet the target for pool frequency. Although grazing still appears to be a source of excess sediment, management practices have improved since Jackson Creek was initially listed for impairment. Recent observations also indicate logging practices have improved; however, unpaved roads remain a source of excess sediment and the stream may still be recovering from increased sediment loading, and changes in water yield associated with past harvest practices. This information supports the 303(d) listing; a sediment TMDL will be developed for Jackson Creek.

5.5.7 Reese Creek (MT41H003_070)

Reese Creek (MT41H003_070) is listed for solids (suspended/bedload) on the 2012 303(d) List. Reese Creek was originally listed in 1990 based on reports from the late 1970s identifying Reese Creek as a major sediment source to the East Gallatin as well as a 1989 study by FWP. Reese Creek flows 8.3 miles from the headwaters to its mouth, where it joins Ross Creek to form Smith Creek. Because of the irrigation network, Ross Creek intermixes with the Dry Creek Irrigation Canal (which originates at the East Gallatin River) and then flows for approximately 0.3 mile before it openly mixes with Reese Creek to form Smith Creek (see **Figure 6-9**). The flow contribution from Reese Creek to Smith Creek varies, depending on the flow volume in the irrigation canal.

Physical Condition and Sediment Sources
A small portion of the upper watershed is on land administered by the USFS and contains a grazing allotment (**Figure 5-1**). In an evaluation for the North Bridgers Allotment Management Plan Update Environmental Impact Statement (U.S. Forest Service, 2007), the riparian vegetation for all sites within the allotment was rated as in proper functioning condition (Prichard, 1998). No potential grazing-related effects to water quality were noted for this allotment.

In 2009 DEQ assessed sediment and habitat at two monitoring sites on Reese Creek (**Figure 5-1**). The upper site was upstream of Gee Norman Road in an area where flow is split among multiple channels. The assessment was performed in the largest channel, which also coincides with the NHD location of Reese Creek. The site appeared to have been channelized through a field at one time, but riparian vegetation was dense, with an alder understory and cottonwood overstory. Streambank erosion was attributed to past agriculture/channelization and natural sources. Likely because of being channelized, the stream lacked well defined pools.

The lower site (REESE15-06) was near the lower end of the segment, approximately 0.4 mile upstream of Ross Creek. The stream was quite sinuous at the site and typically had a buffer on both sides, but streambank erosion, attributed to cropland and natural sources, was observed at meander bends where the adjacent hayfield encroached on the channel. The riparian zone had occasional shrubs, but most of the reach had a buffer of reed canary grass, with wetland vegetation at the bankfull margin. There were

numerous pools at the outside of meander bends that had spawning-size gravels in the pool tails. Downstream of the site, where Reese Creek mixes with water from Ross Creek and the irrigation canal (to form Smith Creek), the resulting flow was observed to be much more turbid.

The nutrient source assessment report (**Attachment B**) identified minimal human sediment sources to Reese Creek. Riparian buffers were noted to be in good condition along most of the stream, including along cropland and pastureland, and streambank erosion was limited. Downstream of Hamilton Road, the riparian buffer narrowed but was dense and confined streambank erosion to areas of pasture encroachment at meander bends. Unpaved road crossings were noted as a minor sediment source.

Comparison with Water Quality Targets

The existing data in comparison with the targets for the Reese Creek are summarized in **Table 5-21**. No macroinvertebrate data are available for Reese Creek. All bolded cells are beyond the target threshold; depending on the target parameter, this may equate to being below or above the target value.

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

Reach ID	Assessment Year	Mean BFW (ft)	Existing Stream Type	Potential Stream Type	Riffle Pebble Count (mean)		Grid Toss (mean)	Channel Form (mean)		Instream Habitat		
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / Mile	LWD / Mile
REES06-01	2009	9.2	B4c/E4	E4	14	11	9	9.3	**1.4**	**0.6**	105	158
REES15-06	2009	14.7	C4/E4	E4	13	9	14	9.8	15.9	1.7	**79**	**37**

Summary and TMDL Development Determination

Both sites on Reese Creek met all fine sediment targets. The upper site was slightly entrenched and failed to meet the entrenchment ratio target, but the width/depth ratio target was met at both sites. The upper site failed to meet the target for residual pool depth. The lower site was slightly below the pool frequency target; however, its bankfull width was at the upper end of the category (i.e., 15 feet), and the site had deep pools that were well over the residual pool depth target. The lower site was well below the target for LWD frequency. Although pool quality was lacking at the upper site and past vegetation removal has greatly reduced the LWD supply to the lower portion of Reese Creek, recent data do not indicate fine sediment deposition is an issue in Reese Creek.

Although suspended sediment issues are typically associated with the same sources that cause excess sedimentation on the stream bottom, because recent data do not indicate a sedimentation problem, total suspended sediment (TSS) data for Reese Creek were also reviewed. In 1976–1977 samples were analyzed for TSS approximately 1 mile upstream of REES15-06 at one of the same sites DEQ sampled in September 2009 (RS01B). Values in the 1970s were collected during high and low flow and ranged from 10 mg/L to 836 mg/L, with an average concentration of 133mg/L. The 2009 sample had a concentration of 17mg/L, which was the highest value out of three samples collected along Reese Creek.

Although it is only a single sample (and additional sampling is recommended), it indicates that management improvements within the watershed have likely resulted in lower TSS concentrations.

However, given the current listing status, sediment sources (including unpaved roads), streambank erosion, and the irrigation network, and the potential for substantial increases in sediment loading if adequate riparian buffers are not maintained, a TMDL will be developed for Reese Creek.

5.5.8 Rocky Creek (MT41H003_080)

Rocky Creek (MT41H003_080) is listed for sedimentation/siltation on the 2012 303(d) List. In addition, this segment is also listed for alteration in streamside or littoral vegetative covers, physical substrate habitat alterations, and other anthropogenic substrate alterations, which are non-pollutant listings commonly linked to sediment impairment. Rocky Creek was initially listed for sediment impairment in 2000 based on fisheries abundance data and a channel stability study from the late 1970s documenting sedimentation attributed to channel straightening, armoring, and unvegetated former rights-of-way associated with construction of I-90, as well as overgrazing by livestock along streambanks. Rocky Creek extends 7.9 miles from the confluence of Jackson and Timberline Creeks to its mouth at the East Gallatin River.

Physical Condition and Sediment Sources

In 2004 DEQ assessed a site 0.25 mile upstream of I-90 and upstream of a beaver complex (M05RCKYC01). At the time of the assessment, a hayfield encroached on the riparian zone, and the land was under new ownership but appeared to have been grazed heavily in the past. The streambed was composed of cobble and coarse gravel that was embedded by silt, easily suspended, and pools were predominantly fine sediment. Streambank erosion was primarily on the outside of meander bends lacking woody vegetation and resulted in some eroding streambanks that were 3 feet high. The channel had historically downcut, but beaver dams downstream of the site were providing grade control. Point bars were vegetated with regenerating willows, and the riparian zone was narrow but vegetation appeared to be recovering.

In 2009 DEQ assessed sediment and habitat at two monitoring sites on Rocky Creek (**Figure 5-1**). The upper site (ROCK02-01) was on state-owned land upstream of I-90 and approximately 0.5 mile downstream of M05RCKYC01. The site was used for grazing, and while not being actively grazed at the time of the assessment, the growth pattern and distribution of willows indicated it has a long history of heavy livestock use. The stream was eroding the hillslope on the river's right side, and extensive erosion was observed on the left streambank (attributed to grazing). Similar to the site evaluated upstream in 2004, some of the eroding streambanks were several feet high. The channel was entrenched and overwidened in places from streambank erosion and livestock access. Willows were the primary formative feature for pools, and fine sediment accumulations were noted in pool bottoms. However, pool tails tended to have substrate that was too large for spawning. The riparian vegetation had some dense sections of willow but was largely grass with the occasional willow.

The lower site (ROCK03-01) was located in a channelized portion of stream that paralleled Trail Creek Road. Upstream and downstream of the site, the stream is confined by a steep hillslope, including bedrock outcrops along the river's left side in a narrow canyon, but the largest sources of confinement are the railroad and I-90. Downstream of the site at mile marker 315, direct road sand inputs from the westbound lane were observed. The channel was meandering and slightly entrenched with deep pools at the outside of bends. Substrate was predominantly small cobble, which likely limits spawning potential. Where streambank erosion was caused by the canyon or bedrock control, it was attributed to natural sources; however, the majority of streambank erosion was attributed to channelization from the transportation network.

In 2009 DEQ evaluated one additional site for streambank erosion (ROCK07-03). The site was located approximately 0.7 mile from the bottom of the segment. The site contained deep pools that were formed by LWD aggregates, and numerous fish were observed in the pools. The channel was slightly entrenched, with actively eroding streambanks at the outside of meander bends and indications of active streambank retreat. Streambank erosion was attributed to past agriculture and vegetation removal, residential development, and natural sources. Riparian vegetation included willow, alders, and red-osier dogwood, but eroding streambanks typically lacked woody vegetation.

Comparison with Water Quality Targets

The existing data in comparison with the targets for Rocky Creek are summarized in **Table 5-22**. The macroinvertebrate bioassessment data for Rocky Creek is in **Table 5-23**. All bolded cells are beyond the target threshold; depending on the target parameter, this may equate to being below or above the target value.

Table 5-22. Existing sediment-related data for Rocky Creek relative to targets.

Values that do not meet the target are in bold.

Reach ID	Assessment Year	Mean BFW (ft)	Existing Stream Type	Potential Stream Type	Riffle Pebble Count (mean)		Grid Toss (mean)	Channel Form (mean)		Instream Habitat		
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / Mile	LWD / Mile
ROCK02-01	2009	26.1	B4c/F4	C4	8	6	**18**	**26.5**	**1.3**	1.4	63	**90**
ROCK03-01	2009	25.2	B3c/C3/G3c	C3	8	7	No Data	17.7	**2.0**	1.8	**32**	**21**

Table 5-23. Macroinvertebrate bioassessment data for Rocky Creek.

Values that do not meet the target threshold (0.80) are in bold.

Station ID	Location	Collection Date	Collection Method	O/E
M05RCKYC01	0.4 miles downstream of Jackson and Timberline creeks	7/27/2004	KICK	1.19

Summary and TMDL Development Determination

Riffle pebble count targets were met at both sites, but the upper site exceeded the pool tail grid toss target. The macroinvertebrate sample collected near the upper end of the segment met the target. The upper site was also overwidened and entrenched and failed to meet both targets for channel form. The lower site failed to meet the target for entrenchment. Both sites had deep pools, but because channelization often results in a riffle-dominated system, the lower site was well below the pool frequency target. Both sites failed to meet the target for LWD. Based on recent observations, roads as well as bank erosion associated with agriculture and the transportation network continue to be sources of excess sediment to Rocky Creek. This information supports the 303(d) listing; a sediment TMDL will be developed for Rocky Creek.

5.5.9 Smith Creek (MT41H003_060)

Smith Creek (MT41H003_060) is listed for sedimentation/siltation on the 2012 303(d) List. In addition, this segment is also listed for alteration in streamside or littoral vegetative covers and physical substrate

habitat alterations, which are non-pollutant listings commonly linked to sediment impairment. Smith Creek was originally listed in 1992 based reports from the late 1970s documenting eroding streambanks, overgrazing along the channel, and erosion from cropland. Smith Creek extends 6.8 miles from the confluence of Ross and Reese Creeks to its mouth at the East Gallatin River. As described in **Section 5.5.7** for Reese Creek, Ross Creek is contained within and intermixed with water in the Dry Creek Irrigation Canal when it flows into Reese Creek to form Smith Creek (**Figure 6-9**).

Physical Condition and Sediment Sources

In 2009 DEQ assessed sediment and habitat at one monitoring site on Smith Creek (**Figure 5-1**). The site (SMIT01-05) was located downstream of the Dry Creek Road crossing in a meandering section of stream with deep runs and glides. Spring and groundwater inputs were apparent. Although the landowner indicated flows were down, there was still a substantial amount of water in the channel in late August. The site was surrounded by a pasture that appeared to be used lightly for grazing. Riparian vegetation at the site most mostly wetland plants and grasses, with little shrub cover. Eroding streambanks were common and observed on the outside of most meander bends, which typically lacked woody vegetation.

Upstream of the site, riparian shrub density was greater, likely limiting streambank erosion. Downstream of the site, a large eroding streambank was observed at a livestock crossing. Substrate at the site was relatively fine, and riffles were dominated by medium and coarse gravels and contained a large amount of aquatic plants. Although the stream may provide spawning habitat for larger fish and grid toss measurements were performed, because of its spring-like nature, it was difficult to discern the break between the pool tail and riffle crest.

The nutrient source assessment report (**Attachment B**) noted that riparian vegetation was typically dense along Smith Creek but dominated by weeds. Some riparian fencing was observed as well as occasional clumps of willow and buffaloberry. Encroachment by pasture and residential yards was common and tended to correspond with actively eroding streambanks. Since much of the Smith Creek watershed is composed of the Reese and Ross Creek watersheds, the source assessment summary for Ross Creek is also presented here. See **Section 5.5.7** for a description of sources in the Reese Creek watershed. Conditions along Ross Creek were much more variable than along Smith Creek; some areas had dense healthy riparian vegetation and other areas were either overgrazed or had almost no riparian buffer from encroachment by pasture, cropland, or residential lawns. In areas with limited riparian vegetation, particularly downstream of Penwell Bridge Road, eroding streambanks were common. Because of loose gravel observed on culverts and bridge decking, unpaved roads were noted as a potential sediment source.

Comparison with Water Quality Targets

The existing data in comparison with the targets for Smith Creek are summarized in **Table 5-24**. No macroinvertebrate bioassessment data are available for Smith Creek. All bolded cells are beyond the target threshold; depending on the target parameter, this may equate to being below or above the target value.

Table 5-24. Existing sediment-related data for Smith Creek relative to targets.
Values that do not meet the target are in bold.

Reach ID	Assessment Year	Mean BFW (ft)	Existing Stream Type	Potential Stream Type	Riffle Pebble Count (mean)		Grid Toss (mean)	Channel Form (mean)		Instream Habitat		
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / Mile	LWD / Mile
SMITH01-05	2009	50.8	C4	E4	19	19	**29**	**27.0**	2.5	1.7	**26**	**5**

Summary and TMDL Development Determination
Riffle fine sediment <2mm exceeded the target, and fine sediment in pool tails exceeded the grid toss target. The width/depth ratio target was exceeded but is likely a factor of the large bankfull width of the channel; the stream did not appear overwidened. The site failed to meet the targets for pool and LWD frequency. Although the current grazing intensity is light, streambank erosion associated with past overgrazing and removal of riparian vegetation continues to be a substantial source of excess sediment. Additionally, the nutrient source assessment indicated Ross Creek may be a significant source of excess sediment to Smith Creek. This information supports the 303(d) listing; a sediment TMDL will be developed for Smith Creek.

5.5.10 Stone Creek (MT41H003_120)

Stone Creek (MT41H003_120) is listed for sedimentation/siltation on the 2012 303(d) List. In addition, this segment is also listed for alteration in streamside or littoral vegetative covers, which is a non-pollutant listing commonly linked to sediment impairment. Stone Creek was initially listed in 1994 for sediment impairment based on sedimentation associated with grazing and logging. Stone Creek flows 6.1 miles from its headwaters to the mouth at Bridger Creek.

Physical Condition and Sediment Sources
In 2004 DEQ assessed two sites. The upper site (M05STONC01) was approximately 4 miles upstream of the mouth within USFS-administered land. The road was typically more than 90 feet from the channel, and the riparian understory was primarily grass. Signs of past logging were noted, and the channel was slightly overwidened in certain areas as a result of historic grazing. The site was mostly riffles and runs with small pools that were formed by LWD, root wads, and boulders. The substrate was predominantly coarse gravels that were not embedded. The channel was well shaded, and streambanks were stable. Residential development had recently started downstream of the site.

The lower site (M05STONC02) was just upstream of Bridger Canyon Road. Pasture occasionally encroached on the channel, but the riparian vegetation was healthy and contained sedges, willows, alders, and multiple age classes of cottonwoods. Helicopter logging was occurring upstream of the site but appeared well managed. Silt accumulations were abundant in the channel, embedding riffles and spawning gravels, and partially filing pools. Some streambank erosion was observed, but there were no indications of mass wasting. Most sediment appeared to originate from channel sources. Potential sources were noted as past logging on steep terrain, which appeared to have a low rock content, as well as roads and residential development.

In 2009 DEQ assessed sediment and habitat at two monitoring sites on Stone Creek (**Figure 5-1**). The upper site (STON08-01) was a meandering section of channel that flowed through a narrow valley on USFS-administered land. The valley floor contained old homesteads/outbuildings, and the hills above the valley contained more recent rural residential development. There was a large eroding hillslope along the channel near the upper part of the site, and most of the streambank erosion appeared natural. However, the upper portion of the watershed has been extensively logged, and some streambank erosion at the site may be associated with increased peak streamflows that occurred after logging. Additionally, the past land use at the site and associated vegetation removal appeared to be minor a source of streambank erosion. Pool tails had large substrate that likely limits spawning potential. Riparian vegetation was predominantly willows and alders.

The lower site (STON13-02) was located approximately 0.3 mile upstream of M05STONC02 in a valley section of the stream lined with a dense overstory of cottonwoods and an understory of rose, snowberry, and red-osier dogwood. The site was in an area used for grazing, and streambank erosion primarily occurred at cattle access points along meander bends where the stream abutted a field.

In 2009 DEQ evaluated one additional site for streambank erosion (STON11-02). The site was located where the stream exits the canyon and enters the valley. The entire channel was lined with trees and shrubs, and all streambank erosion was observed where the stream cut into the base of hillslopes. Streambank erosion at the site was attributed entirely to natural sources.

There is a grazing allotment near the Stone Creek headwaters on land administered by the USFS (**Figure 5-1**). According to the Bangtail Allotment Management Plan Update Environmental Assessment (U.S. Forest Service, 2009), the area has long been grazed and was converted from a sheep to a cattle allotment in the 1950s. The permitted grazing density peaked at 251 yearlings in the 1980s, and certain areas received high levels of use. Since that time, and particularly after a land exchange in 2000 converted much of the allotment to privately owned lands primarily managed for timber, the stocking density has declined dramatically. The allotment allows for 104 cow/calf pairs, and cattle move freely between the allotment and private land to the west of the allotment, whose landowner has relinquished grazing management rights to the USFS. The allotment is used for part of the season (July–September), and use is typically light, but improper livestock distribution was noted as needing to be addressed. The USFS did not conduct a riparian assessment within this allotment, but the Environmental Assessment noted that no grazing or logging is occurring within the allotment along Stone Creek (U.S. Forest Service, 2009).

Comparison with Water Quality Targets

The existing data in comparison with the targets for Stone Creek are summarized in **Table 5-25**. The macroinvertebrate bioassessment data for Stone Creek is in **Table 5-26**. All bolded cells are beyond the target threshold; depending on the target parameter, this may equate to being below or above the target value.

Table 5-25. Existing sediment-related data for Stone Creek relative to targets.
Values that do not meet the target threshold (0.80) are in bold.

Reach ID	Assessment Year	Mean BFW (ft)	Existing Stream Type	Potential Stream Type	Riffle Pebble Count (mean)		Grid Toss (mean)	Channel Form (mean)		Instream Habitat		
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / Mile	LWD / Mile
M05STONC01	2004	11	B3/B4	--	10	8	--	17.7	2.1	--	--	--
M05STONC02	2004	9.5	C4	--	**50**	**49**	--	10.7	2.3	--	--	--
STONE08-01	2009	13.0	C4b/E4b	C4b	3	3	11	10.8	7.5	0.9	84	259
STONE13-02	2009	16.0	C4/E4	C4	4	4	14	14.8	8.0	0.9	84	290

Table 5-26. Macroinvertebrate bioassessment data for Stone Creek.
Values that do not meet the target threshold are in bold.

Station ID	Location	Collection Date	Collection Method	O/E
M05STONC01	4 miles upstream of the mouth near road crossing	7/26/2004	KICK	1.13
M05STONC02	Just upstream from Bridger Canyon Road	7/26/2004	KICK	0.93

Summary and TMDL Development Determination

The fine sediment targets for riffles were exceeded at the lower site in 2004, and the pool tail grid toss target was exceeded at both sites in 2009. All channel form targets and instream habitat targets were met. Both macroinvertebrate samples from 2004 met the target. Although some streambank erosion was attributed to grazing and pasture encroachment, fine sediment in riffles has decreased since 2004 and has likely decreased in pools as well. The healthy riparian vegetation, stable channel form, and adequate instream habitat, combined with the decline in fine sediment, reflect improved management practices and most excess sediment in Stone Creek is likely a result of excess loading associated with past management of logging, roads, and grazing. Because Stone Creek is still recovering, this information supports the 303(d) listing; a sediment TMDL will be developed for Stone Creek.

5.5.11 Thompson Creek (Thompson Spring) (MT41H003_090)

Thompson Creek (MT41H003_090) is listed for sedimentation/siltation on the 2012 303(d) List. In addition, this segment is also listed for alteration in streamside or littoral vegetative covers, which is a non-pollutant listing commonly linked to sediment impairment. Thompson Creek was initially listed for sediment impairment in 1990 based on data from the 1980s indicating sedimentation and degraded conditions that were attributed to land-use practices. Thompson Creek is a spring creek that extends 7.4 miles from it headwaters to its mouth at the East Gallatin River.

Physical Condition and Sediment Sources

In 2004 DEQ assessed two sites. Grazing was identified as the primary source of impairment. The upper site (M05TMPSC02) was heavily grazed and had cows in the stream. The channel was overwidened and contained shallow runs and pools. The substrate was overlain with silt, which ranged in depth from 2 inches to 1 foot, and mostly accumulated in pools and at channel margins. As a result of the excess sediment, mid-channel bars were observed and/or developing. Unstable streambanks and slumping

vegetated streambanks from livestock access were common, and eroding streambanks were noted as a significant sediment source. The riparian vegetation was evaluated as not functioning, with a downward trend, and was composed of sedges, grasses, and Canadian thistle. A small section of the site was fenced off and had willows.

The lower site (M05TMPSC01) was in an area that was being restored. Silt was abundant but attributed to upstream sources. As part of the restoration, silt from upstream sources was being retained in a silt trap and dredged approximately every 2 years. The stream channel was narrowing in response to the restoration. Evidence of beavers was observed at the site, and macrophyte growth was abundant in the channel. The riparian vegetation was predominantly sedges, with an occasional willow, and was noted as functioning, with an improving trend. Pools and runs were deep, and vertical streambanks were stable and vegetated with sedges. Grazing management was good at the site, although riparian fencing allowed for pasture/hayfield encroachment onto the channel in places.

In 2009 DEQ assessed sediment and habitat at one monitoring site on Thompson Creek (**Figure 5-1**). The site (THOM02-03) was located upstream of the Hamilton Road crossing in an area used for livestock grazing that was less than 0.2 mile upstream of M05TMPSC02. The substrate was fairly sandy, with larger substrate in some of the riffles. The channel contained extensive aquatic vegetation, and most pools were formed by water deflecting off clumps of vegetation. Spawning-size gravels were observed in portions of the channel. Streambank erosion was a result of cattle access, but loads are likely limited because of the low stream velocity. Current grazing pressure appeared light, and the overwidened channel and pugging and hummocking along the channel margin were attributed to past grazing. Even if grazing practices have recently improved, however, the fine-grained soils, high water table at the site, and consistent low-velocity flows in the spring creek make it sensitive to disturbance and slow to recover without active restoration.

In 2009 DEQ evaluated one additional site for streambank erosion (THOM01-04). The site was located upstream of the Penwell Bridge Road crossing near the upper extent of where surface flow is visible in aerial imagery from 2009. Small eroding streambanks were observed at the outside of meander bends associated with hoof shear but estimated to be a minor sediment source because of the relatively consistent low flow of the spring creek.

The nutrient source assessment report (**Attachment B**) noted healthy riparian buffers within pastures along most of the stream and a minimal amount of streambank erosion. Pasture encroachment and grazing along unobserved sections of stream, as well as unpaved roads, were cited as potential sediment sources.

Comparison with Water Quality Targets

The existing data in comparison with the targets for Thompson Creek are summarized in **Table 5-27**. The macroinvertebrate bioassessment data for Thompson Creek is in **Table 5-28**. All bolded cells are beyond the target threshold; depending on the target parameter, this may equate to being below or above the target value.

Table 5-27. Existing sediment-related data for Thompson Creek relative to targets.
Values that do not meet the target are in bold.

Reach ID	Assessment Year	Mean BFW (ft)	Existing Stream Type	Potential Stream Type	Riffle Pebble Count (mean)		Grid Toss (mean)	Channel Form (mean)		Instream Habitat		
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / Mile	LWD / Mile
M05TMPSC02	2004	21.9	E5	E4	**85**	**85**	--		3.2	--	--	--
M05TMPSC01	2004	30	E4	E4	17	**17**	--		4.3	--	--	--
THOM02-03	2009	30.8	B4c/C4	E4	21	**18**	11	**52.9**	2.5	0.7	**21**	**0**

Table 5-28. Macroinvertebrate bioassessment data for Thompson Creek.
Values that do not meet the target threshold (0.80) are in bold.

Station ID	Location	Collection Date	Collection Method	O/E
M05TMPSC01	0.3 mile upstream of the mouth	8/25/2004	KICK	1.15
M05TMPSC02	0.08 miles upstream of Hamilton Road	8/26/2004	KICK	**0.77**
THMPC02	0.4 miles upstream of Hamilton Road	7/26/2008	MAC-R-500	**0.54**
THMPC01	0.25 mile upstream of the mouth	7/26/2008	MAC-R-500	**0.63**

Summary and TMDL Development Determination

The upper site in 2004 failed to meet both riffle fine sediment targets. The other site in 2004, as well as the site assessed in 2009, failed to meet the riffle target for fine sediment <2mm. Riffle fine sediment values in 2009 were much lower than at the nearby location sampled in 2004. That, combined with recent observations of grazing practices, indicates that improvements in grazing management since 2004 have resulted in lower fine sediment values. However, the channel was overwidened in 2004 and remains overwidened, with the recent site being well over the width/depth ratio target.

As mentioned above, the nature of the system likely limits the extent of recovery that will occur without active restoration activities. Three of four macroinvertebrate samples failed to meet the target, indicating excess fine sediment is likely impairing aquatic life. The 2009 site failed to meet both the targets for pool and LWD frequency. As a spring creek, it may not have the same potential for LWD as other streams in the Lower Gallatin TPA, but willows in the fenced-off area at the site indicate it does have the potential for woody riparian vegetation. This information supports the 303(d) listing; a sediment TMDL will be developed for Thompson Creek.

5.6 Sediment TMDL Development Summary

Based on the comparison of existing conditions with water quality targets, 11 sediment TMDLs will be developed in the Lower Gallatin TPA. **Table 5-29** summarizes the sediment TMDL development determinations and corresponds to the waterbodies of concern identified in **Section 5.3**.

Table 5-29 Summary of Sediment TMDL Development Determinations

Stream Segment	Waterbody #	TMDL Development Determination (Y/N)
BEAR CREEK, headwaters to the mouth (Rocky Creek MT41H003_080)	MT41H003_081	Y
CAMP CREEK, headwaters to the mouth (Gallatin River)	MT41H002_010	Y
DRY CREEK, headwaters to the mouth (East Gallatin River)	MT41H003_100	Y
GODFREY CREEK, headwaters to White Ditch	MT41H002_020	Y
JACKSON CREEK, headwaters to the mouth (Rocky Creek)	MT41H003_050	Y
REESE CREEK, headwaters to the mouth (Smith Creek)	MT41H003_070	Y
ROCKY CREEK, confluence of Jackson and Timberline Creeks to mouth (East Gallatin River)	MT41H003_080	Y
SMITH CREEK, confluence of Ross and Reese Creeks to the mouth (East Gallatin River)	MT41H003_060	Y
SOURDOUGH (aka BOZEMAN) CREEK, Limestone Creek to the mouth (East Gallatin River)	MT41H003_040	Y
STONE CREEK, headwaters to the mouth (Bridger Creek)	MT41H003_120	Y
THOMPSON CREEK (or Thompson Spring), headwaters to mouth (East Gallatin River)	MT41H003_090	Y

5.7 Sediment Source Assessment and Quantification

We was inserted by tech editor

This section summarizes the assessment approach, current sediment load estimates, and the determination of the allowable load for each source category. ~~We~~ DEQ determine the allowable load by estimating the obtainable load reduction once all reasonable land, soil, and water conservation practices have been implemented. The reduction forms the basis of the allocations and TMDLs provided in **Section 5.8**. This section focuses on four potentially significant sediment source categories and associated controllable human loading for each of these sediment source categories:

- streambank erosion
- upland erosion and riparian health
- unpaved roads
- permitted point sources

EPA's guidance for developing sediment TMDLs states that the basic procedure for assessing sources includes compiling an inventory of all sediment sources to the waterbody. In addition, the guidance suggests using one or more methods to determine the relative magnitude of loading, focusing on the primary and controllable sources (U.S. Environmental Protection Agency, 1999b). Federal regulations allow that 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)).

Cite → what are these?

Using standard DEQ methods for source assessments, ~~we~~ DEQ evaluated loading from the primary sediment sources; however, the sediment loads presented here represent relative loading estimates within each source category and should not be considered as actual loading values. Instead, relative estimates provide the basis for percent reductions in loads that can be accomplished via improved land management practices for each source category. In turn, the percent reduction estimates are the basis for setting load or wasteload allocations. As better information becomes available and the linkages

Search & replace all "we" statements. unprofessional.

between loading and instream conditions improve, the loading estimates presented here can be further refined through adaptive management.

For each impaired waterbody segment, sediment loads from each source category were estimated based on field surveys, watershed modeling, and load extrapolation techniques (described below). The results include a mix of sediment sizes, particularly for bank erosion that involves both fine and coarse sediment loading to the receiving water. Conversely, loading from roads, upland erosion, and permitted point source discharges are predominately fine sediment. The complete methods and results for source assessments for streambank erosion, upland erosion, and roads are found in **Attachments A** and **C** and **Appendix C**, respectively.

5.7.1 Eroding Streambank Sediment Assessment

Data collected during DEQ's 2009 field work were used to estimate the total sediment load associated with bank erosion for each watershed. Streambank erosion was assessed in 2009 at the 30 assessment reaches discussed in **Section 5.3**. At each site, eroding streambanks were classified as either actively or slowly eroding. The susceptibility to erosion was assessed by performing Bank Erosion Hazard Index (BEHI) measurements, and the erosive force was determined by evaluating the Near Bank Stress (NBS) (Rosgen, 1996; 2004). BEHI scores were determined at each eroding streambank based on bank height, bankfull height, root depth, root density, bank angle, and surface protection.

In addition to collecting BEHI data, the source of streambank erosion was evaluated based on observed human-caused disturbances and the surrounding land-use practices based on the following near-stream source categories:

- transportation
- riparian grazing
- cropland
- mining
- (e.g., past sources)
- silviculture
- irrigation-shifts in stream energy
- natural sources
- other

Whether using field observations, aerial photography, or GIS methodology, it is difficult to discern between bank erosion influenced from current or past human practices and bank erosion as a result of natural processes. However, a simple break down of the apparent erosion sources provides a general indicator of the activities that may be affecting bank erosion, which in turn could help land managers prioritize areas for improvement. The erosion sources identified for each reach, and summarized at the watershed scale, are provided in **Attachment A**.

Streambank erosion data from each 2009 monitoring site was extrapolated to its respective reach (which was based on ecoregion, valley gradient, stream order, and valley confinement as described in **Section 5.3**). Then, the field-based estimates of annual streambank erosion were compiled into reach category groupings based on stream order and gradient similarities (e.g., MR-0-2-U, MR-2-2-U, and MR-2-2-C). Then, the average value for each unique reach category grouping was applied to unmonitored reaches within the corresponding category to estimate loading associated with bank erosion at the listed stream segment scales. To estimate existing loading for the remainder of the watershed for each impaired stream, the erosion rate for 1st order reaches (i.e., the lowest rate) was applied to non-303(d) listed tributaries, which were primarily 1st and 2nd order streams.

Explain - are streambank erosion estimates extrapolated just to the impaired reach or to all of the tributaries in the entire watershed. If just to the impaired reach, then explain how loads from tribs are calculated.

5.7.1.1 Establishing the Total Allowable Load

Streambank erosion is a natural process typically dominated by slowly eroding streambanks. Human disturbances to riparian vegetation and health and/or stream hydrology can accelerate the natural erosion rate. Human disturbances shift streambanks from being well vegetated and/or armored (and commonly undercut) to being largely, or entirely, unvegetated with vertical banks. The latter become chronic sources of sediment. Therefore, the potential for sediment load reduction was estimated based on the ratio of actively-to-slowly eroding banks at the reference site on South Cottonwood Creek (SCOT25-02). That ratio (i.e., 15% active/85% slowly) was applied to the average active and slow erosion rates for each reach category and extrapolated to all similar reach types for reaches with predominantly human sources (i.e., >75% based on the aerial assessment described in **Section 5.3**).

Tributaries to the 303(d) listed streams were included in the existing load estimate; however, because little is known about them, and the lowest erosion rate was applied to them, no reductions were applied to those waterbodies in determining the total allowable load at the watershed scale. 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. Applying riparian BMPs should lower the amount of actively eroding banks and result in the estimated reductions. DEQ acknowledges that some streams may have a higher or lower background rate of actively eroding streambanks; thus, although the reduction may not be achievable in all areas, greater reductions will likely be achievable in some areas.

Assessment Summary

Based on the source assessment, streambank erosion loads range from 149 tons per year in the Thompson Creek watershed to 3,187 tons per year in the Dry Creek watershed (**Table 5-30**). The wide range is largely a factor of the variation in stream miles per drainage; per mile, the largest annual streambank erosion load is in the Bear Creek watershed (43.7 tons/mile); the smallest loads are in the Dry and Reese Creek drainages (17.1 and 18.2 tons/mile, respectively). Significant human-caused sources of streambank erosion include grazing, encroachment of pasture/hayfields, logging, roads, and urban development. Depending on the watershed, we estimated that implementing riparian BMPs could decrease the human-caused level of streambank erosion by 31% to 61%. **Attachment A** contains additional information about the streambank erosion source assessment and associated load estimates for the 303(d) listed streams in the Lower Gallatin TPA, including a breakdown by particle size class (i.e., coarse gravel, fine gravel, and sand/silt).

Table 5-30. Existing and Reduced Sediment Load from Eroding Streambanks in the Lower Gallatin TPA.

Subbasin	Existing Sediment Load (tons/year)	Existing Sediment Load (tons/mile/year)	Allowable Sediment Load with Riparian BMPs (tons/year)	Percent Reduction
Bear Creek	758	43.7	374	51%
Bozeman Creek	1,212	22.5	842	31%
Camp Creek	3,119	36.5	1281	59%
Dry Creek	3,187	17.1	2203	31%
Godfrey Creek	526	32.3	270	49%
Jackson Creek	398	30.9	223	44%
Reese Creek	1,257	18.2	864	31%
Rocky Creek (excluding Jackson Creek sub-watershed)	1,149	36.2	583	49%
Smith Creek (including Ross but excluding Reese	966	23.3	597	38%

Table 5-30. Existing and Reduced Sediment Load from Eroding Streambanks in the Lower Gallatin TPA.

Subbasin	Existing Sediment Load (tons/year)	Existing Sediment Load (tons/mile/year)	Allowable Sediment Load with Riparian BMPs (tons/year)	Percent Reduction
Creek sub-watershed)				
Stone Creek	317	32.5	201	37%
Thompson Creek	149	20.7	58	61%

5.7.1.2 Streambank Assessment Assumptions

The following is a summary of the significant assumptions used during the assessment of eroding streambanks:

- The ratio of actively-to-slowly eroding streambanks at sites with predominantly natural sources is an appropriate and achievable rate in reaches where all reasonable land, soil, and water conservation practices are applied.
- The streambank erosion data collected during 2009 represents conditions within the watershed.
- The average annual load per reach type is applicable to other reaches within the same category.
- The assignment of influence to eroding streambanks and the distinction between natural and human-caused erosion is based on best professional judgment by qualified and experienced field personnel.
- Sources of bank erosion at the assessed stream segment scale are representative of sources for that watershed.
- The annual streambank erosion rates used to develop the sediment loading numbers were based on Rosgen BEHI studies along the Lamar River in Yellowstone National Park. While the predominant geologies differ between the Wyoming research sites and the Lower Gallatin watershed (which has primarily sedimentary rock formations and erosive alluvium with some volcanic geology), the rates are applicable to the Lower Gallatin watershed and suitable for helping estimate the percentage in streambank-associated loading reductions achievable by implementing riparian BMPs.

5.7.2 Upland Erosion and Riparian Buffering Capacity Assessment

Upland sediment is that which originates beyond the stream channel. The erosion rate of sediment from upland sources is influenced by land use and/or vegetative cover. Sediment from the landscape may be entirely natural, or it may be increased by human activities, such as timber harvesting, farming or grazing, or clearing land for development. Upland sediment loading from hillslope erosion was modeled using a GIS application of the Universal Soil Loss Equation (USLE).

USLE uses five main factors to estimate soil erosion: R * K * LS * C * P, where

R = rainfall/intensity
K = erodibility
LS = length/slope
C = vegetation cover
P = field practices

All factors except for vegetation cover (C-factor) and field practices (P-factor) are environmental variables unaffected by management practices. Because the P-Factor generally relates to practices occurring at a finer scale than is practical for establishing TMDLs in the Lower Gallatin TPA, we set it at 1 for all scenarios. To estimate the existing upland load associated with each land-use category,

adjustments were made to the C-Factor, which integrates a number of variables that influence erosion, including vegetative cover, plant litter, soil surface, and land management.

what about upland sediment loads to tributary streams, + riparian buffers on tributary streams?

The existing sediment load delivered to each 303(d) listed stream was estimated by combining the USLE model results with a sediment delivery ratio that accounts for downslope travel distance to surface water, along with a riparian buffer factor that reflects ability of buffers to filter sediment from runoff. The ability of existing riparian vegetation to reduce upland sediment loads was based on a riparian health classification performed for the left and right streambank of each 303(d) listed waterbody during the stratification process described in **Section 5.3**. Buffer health was classified as good, fair, or poor, which ranged from a dense riparian buffer to a mix of bare ground and no woody shrubs (in areas with potential for shrub cover). Based on studies that have found that a well-vegetated riparian buffer filters 75% to 90% of incoming sediment from reaching the stream channel (Wegner, 1999; Knutson and Naef, 1997), a 75% removal efficiency was applied to good buffers; this was scaled down to 50% and 25% for fair and poor buffers, respectively.

5.7.2.1 Establishing the Total Allowable Load

The allowable load from upland erosion, which is associated with implementing BMPs, was determined by a two-fold approach: (1) C-factors for human-influenced land-use categories were modified to reflect the improvement in ground cover that is expected by implementing upland BMPs and (2) riparian health was improved to a ratio of 75% good/25% fair for human-influenced land-use categories to represent the additional decrease in upland sediment loading that will occur by implementing riparian BMPs.

The land-use categories with modified C-factors were shrub/scrub, grasslands/herbaceous, pasture/hay, and cultivated crops. Although urban land may transport sediment (particularly during storms), because urban landscapes are generally impervious and do not generate sediment, no change in C-factor was applied to that land-use category.

For the categories with unmodified C-factors, the change equated to an approximate 10% improvement in ground cover per category. The C-factor values for both scenarios (i.e., existing and improved conditions) were based on literature values, stakeholder input, and field observations. DEQ acknowledges that C-factor values are variable within land-use categories throughout the watershed and over time; however, because of the model's scale, we assumed that values for ground cover were consistent throughout each land-use category and throughout the year.

It is important to note that under the improved-conditions scenario, a significant portion of the remaining sediment load, after BMPs are implemented in human-influenced land-use categories, is also a component of the natural background load. Additionally, the allocation to human 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. A more detailed description of the assessment can be found in **Attachment C**.

Assessment Summary

Sediment loads from upland erosion range from 4 tons/year in the Thompson Creek sub-watershed to 6,733 tons/year in the Dry Creek watershed (**Table 5-31**). Since this assessment was conducted at the watershed scale, we expect larger watersheds to have greater sediment loads. A significant portion of the sediment load from upland erosion is contributed by natural sources, but the estimated contribution by all land-use categories is provided in **Attachment C**.

Although many streams are affected by sediment loading associated with historical harvest and vegetation removal, the predominant existing human sources of upland erosion are grazing and cropland, particularly where those activities encroach on the stream channel. By implementing upland and riparian BMPs, annual loading reductions are expected to range from 41% to 72%. Improvement in riparian health comprises a substantial portion (36% to 49%) of the estimated reduction in annual loading from upland sources.

Table 5-31. Existing and Reduced Sediment Loads from Upland Erosion in the Lower Gallatin TPA.

Subbasin	Existing Delivered Sediment Load (tons/year)	Improved Upland and Riparian Conditions Sediment Load (tons/year)	Percent Reduction
Bear Creek	207	122	41%
Bozeman Creek	1,056	577	45%
Camp Creek	5,309	1,832	65%
Dry Creek	6,733	2,455	64%
Godfrey Creek	2,242	625	72%
Jackson Creek	1,175	467	60%
Reese Creek	1,727	662	62%
Rocky Creek (excluding Jackson Creek sub-watershed)	2,100	861	59%
Smith Creek (including Ross but excluding Reese Creek sub-watershed)	47	16	66%
Stone Creek	419	196	53%
Thompson Creek	4	1	63%

5.7.2.2 Upland Assessment Assumptions

As with any modeling effort, and especially when modeling at a watershed scale, a number of assumptions are made. The following is a summary of the significant assumptions used during the assessment of upland erosion:

- The data sources used are reasonable and appropriate to characterize the watershed and build the model.
- The input variables used in the USLE calculations represent their respective land-use conditions.
- The land management practices that define the vegetative cover throughout the year are relatively consistent and represent practices throughout the watershed.
- The riparian condition as estimated through the aerial assessment represents on-the-ground conditions. Riparian buffer health was included to emphasize its importance in reducing upland sediment loading; however, DEQ acknowledges the classification and improvement potential was conducted at a coarse scale.
- The improvement scenarios to riparian condition and land management are reasonable and achievable.
- The USLE model provides an appropriate level of detail and is sufficiently accurate for developing upland sediment loads for TMDL purposes.

5.7.3 Road Sediment Assessment

Roads located near stream channels can reduce stream function by degrading riparian vegetation, encroaching on the channel, and adding sediment. The degree of harm is determined by a number of factors, including road type, construction specifications, drainage, soil type, topography, and

precipitation, as well as whether BMPs were used. Unpaved road crossings and near-stream parallel road segments typically have the greatest potential to contribute excess sediment to streams. However, paved roads increase surface runoff and can result in loading from inadequately armored/vegetated ditches and fillslopes. Sediment loading from the road network in the Lower Gallatin watershed was assessed using GIS, field data, and sediment modeling.

5.7.3.1 Roads Crossings and Parallel Segments

Each road crossing and near-stream parallel road segment identified using GIS tools was assigned attributes for road name, surface type (i.e., native, gravel, paved), road ownership, stream name, and subwatershed. Additionally, each crossing/parallel segment was associated with one of three nearby climate stations that best matched the elevation and annual precipitation and corresponded to a low, medium, or high precipitation class. In 2010, 20 unpaved crossings, 7 paved crossings, and 6 unpaved near-stream parallel segments were field assessed. The following measurements were collected: road surface, design (insloped or outsloped), soil type, percent rock, traffic level, road and fillslope, contributing road length, fill length, and buffer slope and length. Any existing BMPs were noted.

The field effort aimed to sample roads that represented the range of conditions within the watershed; therefore, sampling sites were randomly selected. However, a site was added in the Bear Creek watershed because it was placed on the 303(d) list largely as a result of road-related sediment, and the random selection process did not identify a site there. The average sediment contribution from field assessed road crossings and near-stream road segments were estimated using the Water Erosion Prediction Project Methodology (WEPP:Road) and a 30- or 50-year simulation period (depending on the precipitation class). The average load per crossing and by road mile for parallel segments was then extrapolated to all roads in the watershed based on road surface type and precipitation class. Because the Bear Creek road crossing site was not randomly selected, and does not necessarily represent other road conditions in the Lower Gallatin TPA, it was used for the Bear Creek load estimate but was not included in the extrapolation process for that or other watersheds.

5.7.3.2 Establishing the Total Allowable Load

Because the existing load estimate for paved road crossings and unpaved parallel segments was such a minimal amount of the overall road load (<3% each), and buffers were well-vegetated, the allowable load for those road types is set at the current load. For unpaved road crossings, the allowable load was determined by re-entering the 2009 field data into the WEPP:Road model and changing inputs that simulated the implementation of reasonable BMPs for each ownership category. For county, city, and state-maintained roads, a regular maintenance scenario was used. This scenario was based on the most common BMP used by Gallatin County and that typically used by the city of Bozeman: gravel roads are bladed and re-graded on average biannually or bimonthly, depending on the condition; native roads are resurfaced at most biannually (Water & Environmental Technologies, 2010).

This scenario effectively reduces the formation of ruts, which can be major sources of and conduits for sediment. For roads under private or USFS ownership, a contributing length reduction scenario was used that set the contributing length to 200 feet (or 100 feet from each direction for crossings with two contributing segments). No adjustment was made to segments with a current contributing length of less than 200 feet.

These scenarios were intended to provide a reasonable estimate of loading reductions that can be achieved from roads; they are not prescriptive measures. The intent is to ensure that all road crossings

have the appropriate BMPs in place to protect water quality via reduced sediment loading. BMPs that may be used to either reduce the contributing length to less than 200 feet, or achieve the allowable load, include installing full structural BMPs at existing road crossings (drive through dips, culvert drains, settling basins, silt fence, etc.), improving the road surface, and reducing traffic levels (seasonal or permanent road closures). Although the estimated reductions may not be possible at all locations because of site-specific conditions or existing BMPs, additional loading reductions will likely be achievable at other locations. For instance, the contributing length exceeded 200 feet at 93% of the county/city/state road crossings, and improving road maintenance will likely also decrease the contributing length. A more detailed description of this assessment can be found in the Road Sediment Assessment report (**Appendix C**).

Assessment Summary

Based on the source assessment, the sediment load from the road network ranges from 0.7 ton/year in the Thompson Creek watershed to 32 tons/year in the Dry Creek watershed (**Table 5-32**). The magnitude of loading is largely related to watershed size because the size of the stream network and number of roads tends to increase with watershed size; however, precipitation class is also a large factor for certain watersheds, particularly Rocky Creek. Similarly, county roads were estimated to contribute the largest sediment load, which is predominantly a factor of the ownership distribution within the Lower Gallatin TPA (i.e., 65% of roads are maintained by the county).

The only in-road BMP observed was a cross drain, which was seen at two road crossing sites and three parallel segments. Numerous sites had heavily vegetated ditches and swales, which are important in reducing sediment loading to streams from the road network. With improved BMP implementation, loading reductions ranging from 15% to 38% (**Table 5-1**) are achievable.

Table 5-32. Annual Sediment Load (tons/year) from Roads in the Lower Gallatin TPA.

Watershed	Total Load (tons/year)*	Percent Load Reduction After BMP Application	Total Sediment Load After BMP Application*
Bear Creek	2.1	27%	1.5
Bozeman Creek	10	27%	7.4
Camp Creek	23	17%	19
Dry Creek	32	19%	26
Godfrey Creek	5.9	17%	4.9
Jackson Creek	16	37%	9.9
Reese Creek	6.1	25%	4.6
Rocky Creek (excluding Jackson Creek sub-watershed)	21	35%	14
Smith Creek (including Ross but excluding Reese Creek sub-watershed)	3.9	19%	3.1
Stone Creek	2.3	39%	1.4
Thompson Creek	0.7	18%	0.6

*Because of rounding, differences in loads presented in this table may not correspond to the percent reduction.

5.7.3.3 Traction Sand

Traction sand applied to paved roads in the winter can be a significant source of sediment loading to streams. A study by the Montana Department of Transportation (MDT) (Staples et al., 2004) found that traction sand predominantly contains particles <6mm and <2mm, sizes that can harm fish and other

aquatic life as instream concentrations increase (Irving and Bjorn, 1984; Mebane, 2001; Weaver and Fraley, 1991; Shepard et al., 1984; Suttle et al., 2004; Zweig and Rabeni, 2001).

The significance of loading from traction sand was evaluated for the city of Bozeman and I-90. Within the city, approximately 218 miles of streets and alleys are maintained, and between 3,500 and 5,000 tons of traction sand are applied annually (16–23 tons/mile/year) (Water & Environmental Technologies, 2010). Application mostly occurs at intersections and problem areas. As part of its storm water program, the city sweeps main arterial roads weekly and residential areas twice a year (spring and fall) (HDR Engineering and Morrison-Maierle,Inc., 2008). In recent years, salt and magnesium chloride have been added to the traction sand mix to improve safety and decrease the application rate of sand (HDR Engineering and Morrison-Maierle,Inc., 2008).

(App C)

Was a Study done? if so, Cite it. Sounds like "take my word for it"

Traction sand was evaluated at all 2009 paved road crossing field sites within the city, and as many additional crossings as possible were also evaluated. A few sites were observed to directly deliver traction sand from the road surface; however, most crossings had curbs and/or storm water infrastructure to limit delivery to surface water (**Figure 5-4**). Additionally, a negligible amount of traction sand was present on the road surface, indicating street sweeping was effective at removing traction sand. Although traction sand has the potential to be a significant source of road-related sediment, particularly during spring runoff, the field observations indicate sediment loading to streams from traction sand has been minimized via street sweeping and bridge design as well as storm water infrastructure.

No traction sand load from within Bozeman will be incorporated into the existing road-sediment estimate or the allocation to roads, but it is inherently addressed under the city's storm water permit as part of its Storm Water Management Program (SWMP) (see **Section 5.7.4.5** for more details). The city is expected to continue minimizing loading from traction sand as part of its SWMP as well as when designing and maintaining roads. Particularly because spring runoff on the streets has the potential to deliver large quantities of traction sand to streams, the timing of spring street sweeping is important.

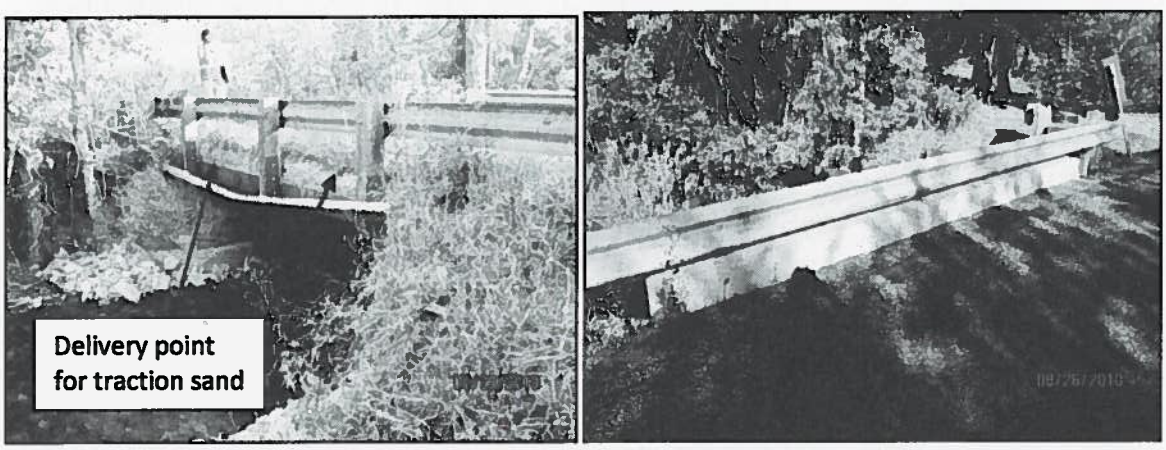


Figure 5-4. Crossing with observed areas of traction sand delivery (left); curbed crossing (right).

Several streams in the Lower Gallatin TPA flow under I-90; however, because of the Interstate's grade, only Bear Creek and Rocky Creek are the primary streams of concern for traction sand. The streams cross under the highway between mile markers 288 and 323, where the application rate averaged 348 tons/mile/year between 2008 and 2010. According to MDT (Water & Environmental Technologies,

2010), BMPs are used to reduce the application rate, and deicer usage decreased the amount of traction sand by 14% between 2008 and 2010.

During the road field assessment in 2009, traction sand depth was measured at distances ranging from 9 feet to 45 feet from the shoulder of the highway. The traction sand depth was 1–2 inches near a culvert 25 feet from the road along Rocky Creek, but traction sand depth was typically minimal beyond 35 feet. Additionally, most fillslope and buffer lengths were greater than the extent of traction sand migration. This indicates traction sand may occasionally be a sediment source to Bear and Rocky Creeks but that it is an insignificant quantity. Therefore, no traction sand load estimate or allocation will be provided for I-90; however, we recommend that MDT continue to implement BMPs, which include seeking to optimize conditions for public safety while minimizing the use of traction sand and properly maintaining roadside buffers.

5.7.3.4 Culvert Failure and Fish Passage

Undersized or improperly installed culverts may be a chronic source of sediment to streams, or a large acute source during failure. They may also be passage barriers to fish. Therefore, during the roads assessment, the flow capacity and potential to be a fish passage barrier was evaluated for each culvert. After we excluded crossings with bridges, those with no culvert, or those lacking perennial flow, the culvert analysis was performed at 19 of the 24 road crossings. The assessment incorporated bankfull width measurements taken upstream of each culvert to determine the stream discharge associated with different flood frequencies (e.g. 2, 5, 10, 25, 50, and 100 year), as well as measurements to estimate the capacity and amount of fill material of each culvert. We 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% probability for the loading analysis.

A common BMP for culverts is designing them to accommodate 25-year storm events; this capacity is specified as a minimum in Water Quality BMPs for Montana Forests (Montana State University, Extension Service, 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 considered during culvert installation and replacement. When these are factored in, larger culverts may be necessary. For instance, USFS typically designs culverts to pass the 100-year event, while also accommodating fish and aquatic organism passage on fish bearing streams (U.S. Department of Agriculture, Forest Service, 1995). Therefore, the BMP scenario 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. For fish-bearing streams, or those with a high level of road development upstream, meeting the 100-year event is recommended.

Fish passage assessments were performed on 15 culverts. Bridges and sites where all measurements could not be collected, as well as sites lacking perennial flow, were excluded. The assessment was based on the methodology defined in **Appendix C**, which is geared toward assessing passage for juvenile salmonids. Considerations for the assessment include streamflow, 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 barriers and those that need a more in-depth analysis. The culvert assessment in **Appendix C** contains information that may help land managers focus restoration efforts on those culverts that were deemed fish barriers and/or undersized per this analysis.

5 out of

why 25% Shouldn't it be 4%?

Assessment Summary

Out of the 19 culverts assessed for failure risk, 6 (32%) were estimated to pass a 25-year event, and none were estimated to pass the 100-year event. All culverts estimated to pass a 25-year event were on county or state roads. We note, however, the sampling of federal and privately owned culverts was quite small (5/19) as a result of their small percentage of all crossings within the watershed. Assuming a 25% probability of failure annually (for culverts meeting less than Q25), DEQ estimated that 4,609 tons of sediment are at-risk; this load is presented to give an estimate of the potential loading associated with undersized culverts in sediment-impaired watersheds within the Lower Gallatin TPA. However, because of the sporadic natural and uncertainty regarding timing of culvert failures, the estimated load at-risk is not included in the existing loads estimates for each impaired stream. For the fish passage assessment, 2 culverts require additional assessment and the other 13 (87%) assessed culverts were determined to pose a significant passage risk to juvenile fish at all flows. The predominant reason cited as a barrier to fish was a steep culvert gradient, but five culverts were perched above the stream channel and five had an insufficient constriction ratio (i.e., culvert width/bankfull width).

5.7.3.5 Road Assessment Assumptions

The following is a summary of the significant assumptions used during the roads assessment:

- The road crossings and parallel segments assessed in the field represent conditions throughout the watershed.
- Although ownership may affect the level of BMP implementation, precipitation class and road surface type were assumed to be the largest determinants of loading per crossing. Field sites were selected to have a representative number per ownership type, but the loads were extrapolated based on precipitation class and road surface type.
- Using modeling scenarios that focus on improving maintenance for city/county/state maintained roads, and reducing the contributing length near road crossings for private and federally maintained roads, will effectively reduce the majority of the sediment load from roads. This is an effective way to represent loading reductions associated with implementing all reasonable, land, soil, and water conservation practices.
- BMPs may have already have been implemented on many roads, and therefore the reductions necessary in some locations may be less than described in this document.

5.7.4 Permitted Point Sources

As of March 19, 2012, the Lower Gallatin TPA had nine Montana Pollutant Discharge Elimination System (MPDES) permitted point sources within sediment-impaired watersheds (**Figure A-22**). All of the permits fall within three watersheds: Bozeman, Rocky, and Smith. There is one individual permit for the city of Bozeman's drinking water treatment plant, but all other permits are general. Five of the general permits are for construction storm water (MTR100000), one is for industrial storm water (MTR000000), one is for construction dewatering (MTG070000), and one is for a small Municipal Separate Storm Sewer System (MS4) (MTR040000). To provide the required wasteload allocation (WLA) for permitted point sources, a source assessment was performed for these point sources. Because of the conditions set within all of the applicable permits, and the nature of sediment loading associated with these permits, the WLAs are not intended to add load limits to the permits; DEQ assumed that the WLAs will be met by adhering to the permit requirements.

5.7.4.1 City of Bozeman Water Treatment Plant (MT0030155)

The city of Bozeman has a potable water treatment plant along upper Bozeman Creek near the USFS boundary (**Figure A-22**). The facility currently has a design flow of 0.86 million gallons per day (Mgd) and

an average flow over the year of 0.2 Mgd. An upgrade was started in 2011 (anticipated completion 2012) that will increase the design flow to 1.1 Mgd, with an estimated actual discharge of 0.5 Mgd. The permit has a maximum daily effluent concentration limit of 45 mg/L, a monthly average effluent limit of 30 mg/L, and a monthly average load limit of 215 lbs/day.

sediment? TSS?

The facility is required to monitor the TSS concentration of its effluent weekly. As part of its Discharge Monitoring Report (DMR), the plant submits a 30-day average TSS concentration and load; since 2002, that concentration has ranged from below the detection limit (1 mg/L) to 26 mg/L, with an average value of 5 mg/L. Therefore, the average monthly concentration is well below the permit limit. Also, since the plant usually discharges at a rate less than its design flow, the average monthly load over the past 10 years is 20 lbs/day. Based on this data, the typical annual TSS load is approximately 3.7 tons. Although the facility is upgrading its discharge capacity, because of nondegradation requirements, its permitted average monthly load limit will stay at 215 lbs/day. Therefore, its WLA is based on the monthly load limit in the permit and, abiding by the permit conditions, will meet the WLA. Based on the monthly average load limit, the allowable annual load is 39 tons of sediment (i.e., 215 lbs/day *365 days * conversion factor = 39 tons).

compare to existing load.

5.7.4.2 Construction Storm Water Permits (MTR100000)

Because construction activities at any given site are temporary and relatively short term, the number of construction sites covered by the general permit at any given time varies. Collectively, these areas of severe ground disturbance have the potential to be significant sediment sources if proper BMPs are not implemented and maintained. Each construction storm water permittee is required to develop a Storm Water Pollution Prevention Plan (SWPPP) that identifies the storm water BMPs that will be in place during construction. Before a permit is terminated, disturbed areas must have a vegetative density equal to or greater than 70% 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 (Heckenberger, Brian, personal communication 2009).

The permit files were reviewed to determine the amount of disturbed land associated with each permit. In the Bozeman Creek watershed, the estimated level of disturbance is 46 acres for three permits; in the Rocky Creek watershed, 15 acres for one permit; and in the Smith Creek watershed, 7 acres for one permit. All permits are for either road/highway construction or home construction. The SWPPPs contain BMPs, such as silt fencing, retention basins, fiber rolls, erosion control blankets, and vegetated buffers.

To estimate the potential sediment loading for the construction sites if adequate BMPs are not followed, an upland erosion rate for disturbed ground with less than 15% cover was multiplied by the amount of disturbed acreage associated with each permit (**Table 5-33**). Because the Lower Gallatin upland model did not have a disturbed ground category, the erosion rate (1.37 tons/acre/year) from a recently completed upland model for the Little Blackfoot watershed was used (Montana Department of Environmental Quality and U.S. Environmental Protection Agency, 2011).

The Little Blackfoot watershed is also in the Middle Rockies ecoregion, and 1.37 tons/acre/year was determined to be an appropriate estimate of the annual erosion potential for disturbed ground within the Lower Gallatin TPA. To estimate the reduction in loading associated with following proper BMPs and adhering to permit requirements, a 65% reduction was applied based on studies from EPA and the International Storm Water Best Management Practices Database (Geosyntec Consultants and Wright Water Engineers, Inc., 2008; EPA, 2009b). The reduced loads (**Table 5-33**) will be used to set the WLAs

for construction storm water permits. Because following permit conditions meet the intent of the WLA for construction storm water, any future permits within any watersheds with sediment TMDLs in the Lower Gallatin TPA will meet the TMDL by following all permit conditions, including the SWPPP.

Table 5-33. Sediment Loading and Reductions from Permitted Construction Sites

Watershed	Loading rate based on SWAT (T/Acre/ Year)	Annual Disturbed Acres	Estimated Load Without Adequate BMPs (T/Year)	BMP Sediment Load (T/Year)	Percent Reduction
Bozeman Creek	1.37	46	63	22	65%
Rocky Creek	1.37	15	21	7	65%
Smith Creek	1.37	7	9.6	3.4	65%

5.7.4.3 Industrial Storm Water Permit (MTR000095)

Storm water from the Kenyon Noble Ready Mix concrete batch plant is regulated under the General Permit for Storm Water Discharges Associated with Industrial Activity (MTR000000). This permit regulates the direct discharge of storm water draining the facility and its grounds. Under the stipulations of the permit, the facility maintains an approved SWPPP. The SWPPP sets forth the procedures, methods, and equipment used to prevent the pollution of storm water discharges. In addition, the SWPPP describes general practices used to reduce pollutants in storm water discharges. According to the SWPPP, the facility's primary BMP is to use conveyances that minimize contact between runoff and sediment and other pollutants.

The site, which is within the Bozeman Creek watershed, is approximately 2.2 acres and is primarily used for the loading and unloading of trucks with building materials. No monitoring data are available; however, DEQ conducted a site inspection in 2007 and found it in compliance with the permit. DEQ did, however, recommend additional vegetation and site contouring to prevent runoff from the site. According to Attachment B (Monitoring Parameter Benchmark Concentrations) within the general storm water permit, the benchmark value for TSS is 100 mg/L; this means that the TSS concentration of runoff from the site should not exceed 100 mg/L if permit conditions are followed. Based on the site size of 2.2 acres, an average annual precipitation rate of 18 inches (from the MSU climate station), and the benchmark value of 100 mg/L, the maximum allowable annual sediment load from this site is 0.4 ton/year. The WLA is provided because it is a requirement for permitted point sources but is not intended to add load limits to the permit. DEQ assumed that the WLA will be met by adhering to the permit requirements, including the SWPPP.

5.7.4.4 Construction Dewatering Permit (MTG070687)

There is a construction dewatering permit for a 0.5-acre pond in the Smith Creek watershed, which is covered under the General Permit for Construction Dewatering (MTG070000). The dewatering effluent is routed from the construction site into a vegetated swale and has the potential to eventually flow into Ross Creek, one of the tributaries that forms Smith Creek. The estimated maximum pumping capacity is 1 cfs, and dewatering is expected to occur during the summer season (May–September). Since the maximum pumping rate typically occurs during the initial phase of pumping then drops off drastically, a conservative estimate of the potential load was calculated assuming a constant pumping rate of 1 cfs from May through September.

The permit has a numeric turbidity limit for the effluent of 10 NTU. Because turbidity cannot be expressed as a load, a TSS conversion ratio of 2:1 TSS-to-turbidity was used based on a study used for the Swan TMDL (Bansak et al., 2000) and a study done for the Boulder River (Water Consulting, Inc.,

2002). The Boulder River is also in the Middle Rockies ecoregion, so this relationship was determined to be a reasonable approximation of the relationship between turbidity and TSS in the Lower Gallatin TPA. Assuming a 1 cfs discharge at 20 mg/L TSS (10 NTU *2) over 5 months, the estimated annual load is 8.3 tons. This value will also be used for the WLA. Although it is based on the permit, it is not intended to be incorporated into the permit. Adhering to the permit conditions will meet the intent of the WLA.

5.7.4.5 MS4 Permit (MTR040002)

Storm water within the city of Bozeman is regulated under the General Permit for Storm Water Discharge Associated with Small Municipal Separate Storm Water Sewer System (MS4) (MTR04000). The city shares the permit with Montana State University – Bozeman (MSU) and MDT. The permit primarily applies within the city limits (**Figure A-22**) but also includes some receiving waters outside the city. There are two sediment-impaired receiving waters identified in the permit: Bozeman Creek and Bear Creek. Because they are identified in the permit, TMDLs for both streams must include a WLA for the MS4.

The permit does not include effluent limits but requires the development and implementation of a SWMP to minimize sediment loading to surface waters. The SWMP must include six minimum control measures: (1) public education and outreach; (2) public involvement/participation; (3) detection and elimination of illicit discharge; (4) control of storm water runoff from construction sites; (5) management of post-construction storm water in new development and redevelopment; and (6) pollution prevention/good housekeeping. Additionally, the permit requires semiannual monitoring at two sites, one representing a residential area (the Langhor site) and the other representing a commercial/industrial area (the Tamarack site) (**Figure A-22**).

A Storm Water Management Model (SWMM) initially developed for the city of Bozeman (HDR Engineering and Morrison-Maierle,Inc., 2008) was adapted by DEQ for this project to help estimate existing storm water-related sediment and nutrient loads. The model includes only the city of Bozeman, and therefore does not include Bear Creek, which is east of the city. Model specifics pertaining to the nutrient source assessment are described in detail in **Section 6.5.2.2**. The model was based on 30 years of climate data from the weather station on MSU's campus (Coop ID 241044), and two scenarios were run to simulate existing loading conditions: one with an average TSS event mean concentration (EMC) from measurements across multiple city storm water systems in the Intermountain West (literature value scenario) (Caraco, 2000) and the other with benchmark TSS concentrations from the permit (benchmark value scenario) that are based on the median from the Nationwide Urban Runoff Program (NURP). For Bozeman Creek, the literature value scenario estimated an annual sediment load of 288 tons, and the benchmark value scenario estimated an annual sediment load of 177 tons.

To help evaluate the model output and quality of the city's storm water, the city's TSS monitoring data from 2007 through 2010 were compared with the upper and lower literature TSS EMCs as well as with the permit benchmark TSS concentration for residentially-dominated areas (**Figure 5-5**) relative to commercially-dominated areas of the city (**Figure 5-6**). TSS concentrations from the residential site (Langhor) were well below both the benchmark concentration and the minimum literature EMC. TSS concentrations from the commercial site (Tamarack) commonly exceeded the benchmark concentration and occasionally exceeded the maximum literature EMC. Although the data are limited, it indicates additional BMPs are needed, particularly in commercially-dominated areas.

As discussed in the data review for Bozeman Creek (**Section 5.5.2**), however, there is also room for improvement in residential areas. Based on the data comparison, the benchmark value scenario load is

more representative of storm water TSS loads from a residentially-dominated area of Bozeman and the literature value scenario load is more representative of storm water TSS loads from a commercially-dominated portion of Bozeman. Therefore, a weighted approach based on the land use breakdown within the MS4 boundary in the Bozeman Creek watershed was used to derive a load estimate that is a composite of both model runs. Using this approach, the estimated existing storm water sediment load to Bozeman Creek is 218 tons per year.

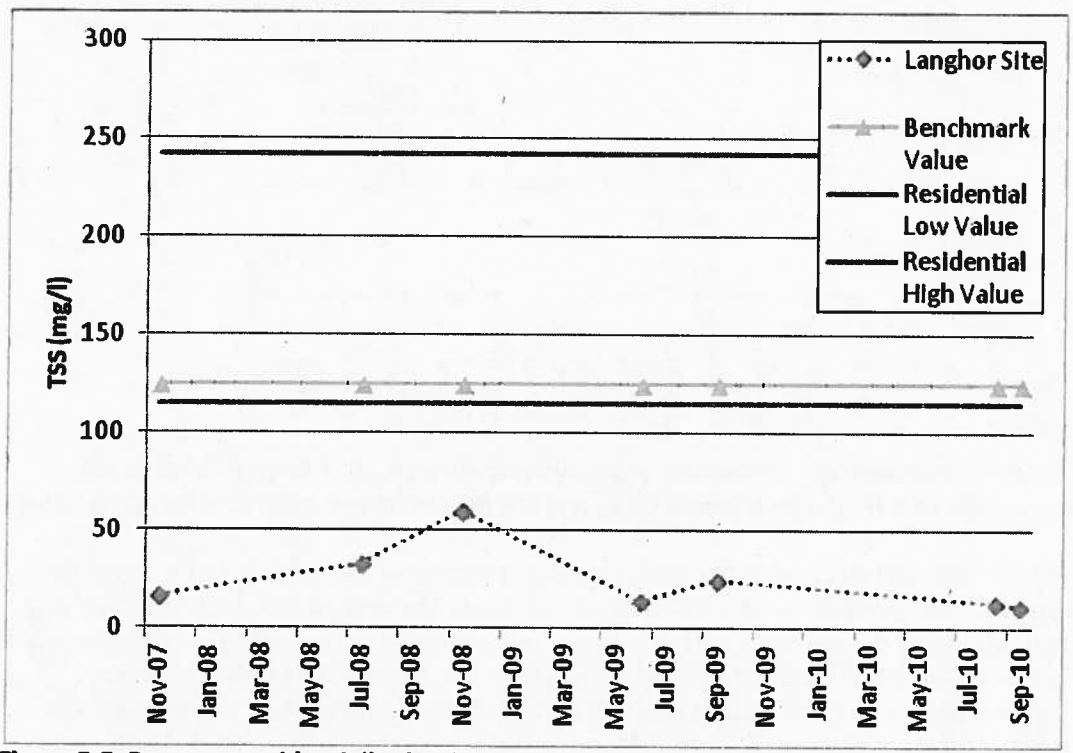


Figure 5-5. Bozeman residentially-dominated storm water data from 2007 through 2010 at the Langhor site compared with the benchmark value and the maximum and minimum literature value.

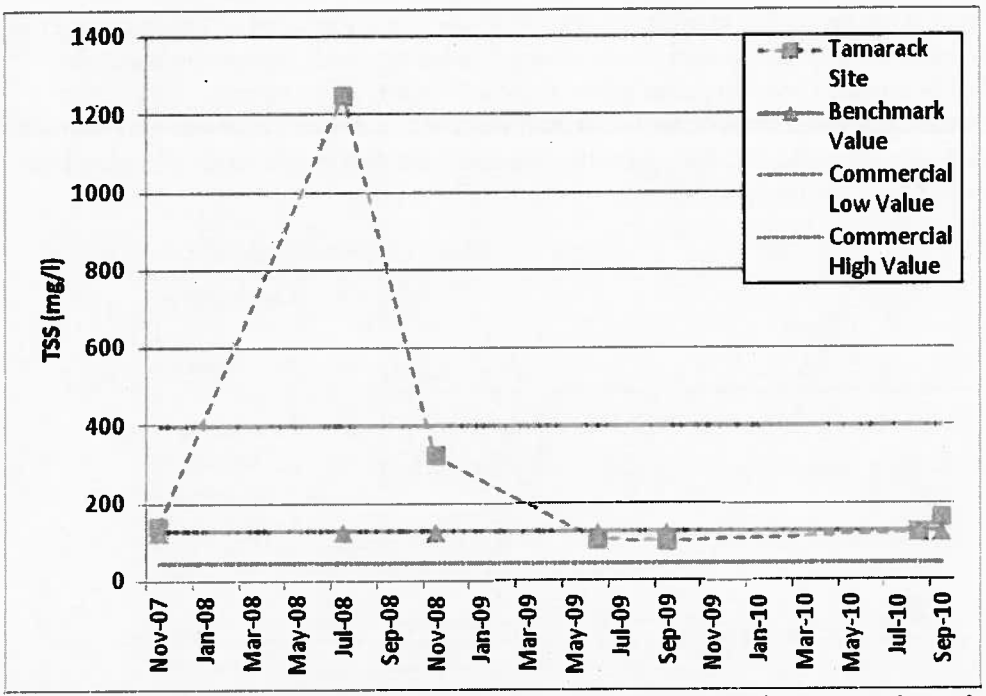


Figure 5-6. Bozeman commercially-dominated storm water data from 2007 through 2010 at the Tamarack site compared with the benchmark value and the maximum and minimum literature value.

Because Bear Creek was not included in the model, a rough estimate of the existing storm water TSS load was calculated using the estimated load for Bozeman Creek. The only portion of the Bear Creek watershed that falls under the permit is the I-90 corridor, which means some loading is associated with traction sand (discussed in **Section 5.7.3.3**). Overall, however, there is a limited area that could contribute sediment. Therefore, the loading rate is likely on the lower end of the modeled loads and closer to the benchmark value scenario. The load from the benchmark value scenario (177 tons) was divided by the MS4 acreage in the Bozeman Creek watershed (2,034 acres) to get a loading rate of 0.087 ton/acre. That value was multiplied by the MS4 acreage within the Bear Creek watershed (61.96 acres) to get an estimated existing sediment storm water load to Bear Creek of 5.4 tons per year.

Establishing the Total Allowable Load

Because of the limited amount of information regarding storm water BMPs currently in place within the MS4, no BMP scenario was run in the model. Instead, BMP effectiveness values reported from the International Storm Water BMP Database (Geosyntec Consultants and Wright Water Engineers, Inc., 2011) will be used as the basis for the WLA. The database includes statistics for loading reduction efficiencies from a compilation of studies for a variety of BMPs. The BMPs include bioretention, bioswales, detention basins, filter strips, manufactured devices, media filters, porous pavement, retention ponds, wetland basins, and wetland channels. The effectiveness range among different studies and practices are fairly tight. Studies were summarized by evaluating the 75th percentile, median, and 25th percentile concentration of influent and effluent. The quartiles for each percentile category ranged from a reduction efficiency of 53% to 76%. Using the median influent and effluent concentration, the average percent reduction among BMPs was 62%.

Because some BMPs are already in place within all land-use categories, but the monitoring data reflect more effective BMPs within residentially-dominated areas, a reduction less than 62% is necessary at the

watershed scale. Therefore, a weighted approach based on the land use distribution in the Bozeman Creek watershed was used to approximate the reduction in loading that additional BMP implementation across all land-use categories could achieve and to determine the WLA.

Approximately 40% of the land within the MS4 boundary in the Bozeman Creek watershed is residential, so no reduction was applied to 40% of the estimated existing load. Although the remainder of the watershed is not all commercial, to err on the conservative side, a 62% reduction was applied to the remaining 60% of the existing load (based on the 62% reduction efficiency from the database). Using this approach, the WLA is 137 tons of sediment per year for the Bozeman Creek watershed, which is a 37% reduction from the estimated existing load. Because of the limited amount of data for Bear Creek, the Bear Creek WLA is also a 37% reduction (3.4 tons/year).

As stated previously, the WLAs are not intended to add load limits to the permit. DEQ assumed that the WLAs will be met by adhering to the permit requirements. As identified in the permit, monitoring data should continue to be evaluated to assess BMP performance and help determine whether and where additional BMP implementation may be necessary.

5.7.5 Source Assessment Summary

Based on field observations and associated source assessment work, all assessed source categories represent significant controllable loads. Each source category has different seasonal loading rates, and the relative percentage of the total load from each source category does not necessarily indicate its importance as a loading source. Instead, because of the coarse nature of the source assessment work, and the unique uncertainties involved with each source assessment category, the intention is to separately evaluate source effects within each assessment category (e.g., bank erosion, upland erosion, roads). Results for each source assessment category provide an adequate tool to focus water quality restoration activities in the Lower Gallatin TPA; they indicate the relative contribution of different subwatersheds or landcover types for each source category and the percent loading reductions that can be achieved with the implementation of improved management practices (**Appendix C and Attachments A** and **C**).

5.8 TMDL AND ALLOCATIONS

The sediment TMDLs for the Lower Gallatin TPA will be based on a percent reduction approach, discussed in **Section 4.0.** This approach will apply to the loading allocated among sources as well as to the TMDL for each waterbody. An implicit margin of safety will be applied, further discussed in **Section 5.9.**

5.8.1 Application of Percent Reduction and Yearly Load Approaches

Cover et al. (2008) observed a correlation between sediment supply and instream measurements of fine sediment in riffles and pools. DEQ assumed that a decrease in sediment supply, particularly fine sediment, will correspond to a decrease in the percent fine sediment deposition within the streams of interest and result in attaining sediment-related water quality standards. A percent-reduction approach is preferable because there is no numeric standard for sediment to calculate the allowable load and because of the uncertainty associated with the loads derived from the source assessment (which are used to establish the TMDL), particularly when comparing different load categories, such as road crossings to bank erosion. Additionally, the percent-reduction TMDL approach is more applicable for

restoration planning and sediment TMDL implementation because this approach helps focus on implementing water quality improvement practices (BMPs) versus focusing on uncertain loading values.

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

5.8.2 Development of Sediment Allocations by Source Categories

The percent-reduction allocations are based on BMP scenarios for each major source type (e.g., streambank erosion, upland erosion, roads, and permitted point sources). These BMP scenarios are discussed in **Section 5.7** and associated appendices/attachments. They reflect reasonable reductions as determined from literature, agency and industry documentation of BMP effectiveness, and field assessments. Sediment loading reductions can be achieved through a combination of BMPs, and the most appropriate BMPs will vary by site. Sediment loading was evaluated at the watershed scale and associated sediment reductions are also applied at the watershed scale based on the fact that many sources deliver sediment to tributaries that then deliver the sediment load to the impaired waterbodies.

It is important to recognize that the first critical step toward meeting the sediment allocations involves applying and/or maintaining the land management practices, or BMPs, that will reduce sediment loading. Once these actions have been completed at a given location, the landowner or land manager will have taken action consistent with the intent of the sediment allocation for that location. For many nonpoint source activities, it can take several years to decades to achieve the full load reduction at the location of concern, even though full BMP implementation is in effect. For example, it may take several years for riparian areas to fully recover after implementing grazing BMPs or allowing re-growth in areas of past riparian harvest. It is also important to apply proper BMPs and other water quality protection practices for all new or changing land management activities to limit any potential increased sediment loading.

Progress toward TMDL and individual allocation achievement can be gaged by adhering to point source permits, implementing BMPs for nonpoint sources, and improving or attaining the water quality targets defined in **Section 5.4**. Any effort to calculate loads and percent reductions for comparison with TMDLs and allocations in this document should be accomplished via the same methodology and/or models used to develop the loads and percent reductions presented within this document.

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

5.8.2.1 Streambank Erosion

Streambank stability and erosion rates are closely linked to the health of the riparian zone. Reductions in sediment loading from bank erosion are expected to be achieved by applying BMPs within the riparian zone. Sediment loads associated with bank erosion are identified by separate source categories (e.g., transportation, grazing, natural) in **Attachment A**; however, because of the inherent uncertainty in extrapolating this level of detail to the watershed scale, and also because of uncertainty regarding the

effects of past land management activity, all sources of bank erosion were combined to express the TMDL and allocations.

DEQ acknowledges that the annual sediment loads, and the method by which to attribute human and historic influence, are estimates based on aerial photography, best professional judgment, and limited access to on-the-ground reaches. The assignment of bank erosion loads to the various land uses is not definitive but was done to direct efforts to reduce the loads toward those causes that are likely having the biggest effect on the investigated streams. Ultimately, local land owners and managers are responsible for identifying the causes of bank erosion and for adopting practices to reduce bank erosion wherever practical.

5.8.2.2 Upland Erosion

The allocation to upland sources includes application of BMPs to present land-use activities as well as recovery from past land-use influences, such as riparian harvest. No reductions were allocated to natural sources, which are a significant portion of all upland land-use categories. For all upland sources, the largest percent reduction will be achieved via riparian improvements. The anticipated loading reductions achievable by implementing upland and riparian BMPs for each land cover category are presented in **Attachment C**. For the TMDL, the allocation to upland erosion sources is presented as a single load and percent reduction.

5.8.2.3 Roads

The allocation to roads can be met by incorporating and documenting that all road crossings and parallel segments with potential sediment delivery to streams have the appropriate BMPs in place. Routine maintenance of the BMPs is also necessary to ensure that sediment loading remains consistent with the intent of the allocations. At some locations, road closure or abandonment alone may be appropriate. Further, because of the low erosion potential linked to native vegetation growth on the road surface, additional BMPs may not be necessary. The allocation to roads also includes no loading from undersized, improperly installed, or inadequately maintained culverts. At a minimum, culverts should meet the 25-year event; however, for fish-bearing streams and streams with a high level of road and impervious surface development upstream, or for culvert sites with a large amount of fill, meeting the 100-year event is recommended.

5.8.2.4 Permitted Point Sources

All WLAs are expected to be met by adhering to permit conditions.

5.8.3 Allocations and TMDL for Each Stream

The following subsections present the existing quantified sediment loads, allocations, and TMDL for each waterbody (**Tables 5-34 through 5-44**). Note, sediment loads and percent reductions were rounded and may not exactly match the loads presented in the appendices.

5.8.3.1 Bear Creek (MT41H003_081)

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

Sediment Sources		Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% reduction)
Roads		2.1	1.5	27%
Streambank Erosion		758	374	51%
Upland Sediment Sources		207	122	41%
Point Source	Bozeman MS4 (MTR040002)	5.4	3.4	37%
Total Sediment Load		973	501	48%

5.8.3.2 Bozeman Creek, lower segment (MT41H003_040)

Because TMDLs are presented on a watershed basis, the TMDL for lower Bozeman Creek also includes all loading to the stream upstream of the lower segment.

Table 5-35. Sediment Source Assessment, Allocations and TMDL for lower Bozeman Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% reduction)
Roads		10	7.4	27%
Streambank Erosion		1,212	842	31%
Upland Sediment Sources		1,056	577	45%
Point Source	Bozeman Water Treatment Plant (MT0030155)	3.7	39	0%
	Bozeman MS4 (MTR040002)	218	137	37%
	Kenyon Noble Ready Mix (MTR000095)	0.4	0.4	0%
	Construction Storm Water (MTR100000)	63	22	65%
Total Sediment Load		2,563	1,625	37%

5.8.3.3 Camp Creek (MT41H002_010)

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

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% reduction)
Roads	23	19	17%
Streambank Erosion	3,119	1,281	59%
Upland Sediment Sources	5,309	1,832	65%
Total Sediment Load	8,451	3,132	63%

5.8.3.4 Dry Creek (MT41H003_100)

Table 5-37. Sediment Source Assessment, Allocations and TMDL for Dry Creek

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% reduction)
Roads	32	26	19%
Streambank Erosion	3,187	2,203	31%
Upland Sediment Sources	6,733	2,455	64%
Total Sediment Load	9,952	4,684	53%

5.8.3.5 Godfrey Creek (MT41H002_020)

Table 5-38. Sediment Source Assessment, Allocations and TMDL for Godfrey Creek

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% reduction)
Roads	5.9	4.9	17%
Streambank Erosion	526	270	49%
Upland Sediment Sources	2,242	625	72%
Total Sediment Load	2,774	900	68%

5.8.3.6 Jackson Creek (MT41H003_050)

Table 5-39. Sediment Source Assessment, Allocations and TMDL for Jackson Creek

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% reduction)
Roads	16	9.9	37%
Streambank Erosion	398	223	44%
Upland Sediment Sources	1,175	467	60%
Total Sediment Load	1,589	700	56%

5.8.3.7 Reese Creek (MT41H003_070)

Table 5-40. Sediment Source Assessment, Allocations and TMDL for Reese Creek

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% reduction)
Roads	6.1	4.6	25%
Streambank Erosion	1,257	864	31%
Upland Sediment Sources	1,727	662	62%
Total Sediment Load	2,990	1,531	49%

5.8.3.8 Rocky Creek (MT41H003_080)

Because TMDLs are presented on a watershed basis, the TMDL for Rocky Creek also includes an allocation to Jackson Creek. See the Jackson Creek TMDL for allocations to sediment source categories.

Table 5-41. Sediment Source Assessment, Allocations and TMDL for Rocky Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% reduction)
Roads		21	14	35%
Streambank Erosion		1,149	583	49%
Upland Sediment Sources		2,100	861	59%
Jackson Creek watershed		1,589	700	56%
Point Source	Construction Storm Water (MTR100000)	21	7	65%
Total Sediment Load		4,880	2,165	56%

5.8.3.9 Smith Creek (MT41H003_060)

Because TMDLs are presented on a watershed basis, the TMDL for Smith Creek includes an allocation to Reese Creek. See the Reese Creek TMDL for allocations to sediment source categories.

Table 5-42. Sediment Source Assessment, Allocations and TMDL for Smith Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% reduction)
Roads		3.9	3.1	19%
Streambank Erosion		966	597	38%
Upland Sediment Sources		47	16	66%
Reese Creek watershed		2,990	1,531	49%
Point Source	Construction Storm Water (MTR100000)	9.6	3.4	65%
	Construction Dewatering (MTG070687)	8.3	8.3	0%
Total Sediment Load		4,025	2,159	46%

5.8.3.10 Stone Creek (MT41H003_120)

Table 5-43. Sediment Source Assessment, Allocations and TMDL for Stone Creek

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% reduction)
Roads	2.3	1.4	39%
Streambank Erosion	317	201	37%
Upland Sediment Sources	419	196	53%
Total Sediment Load	738	398	46%

5.8.3.11 Thompson Creek (MT41H003_090)

Table 5-44. Sediment Source Assessment, Allocations and TMDL for Thompson Creek

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% reduction)
Roads	0.7	0.6	18%
Streambank Erosion	149	58	61%
Upland Sediment Sources	4	1	63%
Total Sediment Load	154	60	61%

5.9 Seasonality and Margin of Safety

Seasonality and margin of safety are both required elements of TMDL development. This section describes how seasonality and margin of safety were applied during development of the Lower Gallatin TPA sediment TMDLs.

5.9.1 Seasonality

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

- The applicable narrative water quality standards (**Appendix B**) are not seasonally dependent, although low-flow conditions provide the best ability to measure harm-to-use based on the selected target parameters. The low-flow or base-flow condition represents the most practical time period for assessing substrate and habitat conditions, and also represents a time period when high fine sediment in riffles or pool tails will likely influence fish and aquatic life. Therefore, meeting targets during this time frame represents an adequate approach for determining standards attainment.

There is additional uncertainty regarding the amount of bank erosion linked to human activities and the specific human sources, as well as the ability to reduce the human-related bank erosion levels. This uncertainty is largely associated with past disturbances; it is extremely difficult to identify the level to which they still affect streambank erosion, how much is associated with human sources, and what the dominant human sources are. Even if difficult to quantify, the linkages between human activity, such as riparian clearing and bank erosion, are well established, and these linkages clearly exist at different locations throughout the Lower Gallatin watershed. Evaluating bank erosion levels, particularly where BMPs have been applied along streams, is an important part of adaptive management that can help define the level of human-caused bank erosion as well as the relative effect that bank erosion has on water quality throughout the Lower Gallatin watershed.

Upland Erosion

A professional modeler determined upland erosion loads by applying a landscape soil loss equation (USLE), defined in **Attachment C**. As with any model, there will be uncertainty in the model input parameters, including land use, land cover, and assumptions regarding existing levels of BMP application. For example, only one vegetative condition was assigned per land cover type. In other words, the model cannot reflect land management practices that change vegetative cover from one season to another, so an average condition is used for each scenario in the model. The potential to reduce sediment loading was based on modest land cover improvements, along with riparian improvements, to reduce the generation of eroded sediment particles. Thus, there is uncertainty regarding existing erosion prevention BMPs and the ability to reduce erosion with additional BMPs.

The upland erosion model integrates sediment delivery based on riparian health; riparian health evaluations linked to the stream stratification work are discussed in **Attachment A**. The riparian health classifications were performed using aerial imagery and a coarse classification system (i.e., poor, fair, good). This particularly introduced uncertainty in watersheds that had limited woody vegetation but that may have had a high buffering capacity from other vegetation, such as wetland grasses.

Additionally, because of the coarseness of the categories, the process resulted in a large quantity of riparian vegetation being classified as fair, which limits analysis of fine-scale differences. However, the analysis was not performed with the expectation that it would identify specific locations for implementation of additional BMPs. Instead it was performed to simulate the buffering capacity of riparian vegetation and emphasize the importance of a healthy riparian buffer. Even with these uncertainties, the ability to reduce upland sediment erosion and delivery to nearby waterbodies is well documented in literature, and the estimated reductions are consistent with literature values for riparian buffers.

Roads

As described in **Appendix C**, the road crossings sediment load was estimated via a standardized simple yearly model developed by USFS. This model relies on a few basic input parameters that are easily measured in the field, as well as inclusion of precipitation data from local weather stations. A total of 24 sites were randomly selected for evaluation, representing about 5% of the total population of roads. The results from these 24 sites were extrapolated to the whole population of roads stratified by road surface type and precipitation class.

The reduction potential for all roads was also based on road ownership, although DEQ acknowledges that actual reductions will vary by site, depending on the existing maintenance level and site-specific

Target Development

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

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

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

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

5.10.2 Source Assessments and Load Reduction Analyses

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

Bank Erosion

Bank erosion loads were initially quantified using the DEQ protocols (Montana Department of Environmental Quality, 2010) and the standard BEHI methodology, defined in **Attachment A**. Before any sampling, a SAP was developed to ensure that all activity was consistent with applicable quality control and quality assurance requirements. Site selection was a major component of the SAP and was based on a stratification process described in **Attachment A**. The results were then extrapolated across the Lower Gallatin watershed to provide an estimate of the relative bank erosion loading from various streams and associated stream reaches. Based on this process, the relative contribution from human versus natural sources, as well as the potential for reduction with the implementation of riparian BMPs, was estimated and used for TMDL allocations. Stratifying and assessing each unique reach type was not practical, therefore adding to uncertainty associated with the load extrapolation results.

5.10 TMDL Development Uncertainties and Adaptive Management

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

As noted in **Section 5.9.2**, adaptive management represents an important component of the implicit MOS. This document provides a framework to satisfy the MOS by including sections focused on TMDL implementation, monitoring, and adaptive management (**Sections 9.0** and **10.0**). Furthermore, state law (ARM 75-5-703) requires monitoring to gauge progress toward meeting water quality standards and satisfying TMDL requirements. These TMDL implementation monitoring reviews represent an important component of adaptive management in Montana.

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

5.10.1 Sediment and Habitat Data Collection and Target Development

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

<u>Data Collection</u>

The stream sampling approach used to characterize water quality is described in **Attachment A**. To control sampling variability and improve accuracy, the sampling was done by trained environmental professionals using a standard DEQ procedure developed for creating sediment TMDLs (Montana Department of Environmental Quality, 2010). This procedure defines specific methods for each parameter, including sampling location and frequency, to ensure proper representation and applicability of results. Before any sampling, a sampling and analysis plan (SAP) was developed to ensure that all activity was consistent with applicable quality control and quality assurance requirements. Site selection was a major component of the SAP and was based on a stratification process described in **Attachment A**. The stratification work ensured that each stream included one or more sample sites representing a location where excess sediment loading or altered stream habitat could affect fish or aquatic life.

Even with the applied quality controls, a level of uncertainty regarding overall accuracy of collected data will exist. There is uncertainty regarding whether the appropriate sites were assessed and whether an adequate number of sites were evaluated for each stream. Also, there is the uncertainty of the representativeness of collecting data from one sampling season. These uncertainties are difficult to quantify and even more difficult to eliminate given resource limitations and occasional stream access problems.

- The substrate and habitat target parameters within each stream are measured during summer or autumn low-flow conditions consistent with the time of year when reference stream measurements are conducted. This time period also represents an opportunity to assess effects of the annual snow runoff and early spring rains, which is the typical time frame for sediment loading to occur.
- The DEQ sampling protocol for macroinvertebrates identifies a specific time period for collecting samples based on macroinvertebrate life cycles. This time period coincides with the low-flow or base-flow condition.
- All assessment modeling approaches are standard approaches that specifically incorporate the yearly hydrologic cycle specific to the Lower Gallatin TPA. The resulting loads are expressed as average yearly loading rates to fully assess loading throughout the year.
- Allocations are based on average yearly loading, and the preferred TMDL expression is as an average yearly load reduction, consistent with the assessment methods.

5.9.2 Margin of Safety

Natural systems are inherently complex. Any approach used to quantify or define the relationship between pollutant loading rates and the resultant water quality effects, no matter how rigorous, will include some level of uncertainty or error. To compensate for this uncertainty and ensure water quality standards are attained, a margin of safety (MOS) is required as a component of each TMDL. The MOS may be applied implicitly by using conservative assumptions in the TMDL development process or explicitly by setting aside a portion of the allowable loading (U.S. Environmental Protection Agency, 1999b). This plan incorporates an implicit MOS in a variety of ways:

- By using multiple targets to assess a broad range of physical and biological parameters known to illustrate the effects of sediment in streams and rivers. These targets serve as indicators of potential impairment from sediment and also help signal recovery, and eventual standards attainment, after TMDL implementation. Conservative assumptions were used during development of these targets. → What are they? discuss the conservative assumptions in Section 5.4
- By developing TMDLs for all streams evaluated, even though some streams were close to meeting all target values. This approach addresses some of the uncertainty associated with sampling variability and site representativeness and recognizes that capabilities to reduce sediments exist throughout the watershed.
- By using standards, targets, and TMDLs that address both coarse and fine sediment delivery. → explain → how is that a MOS?
- By properly incorporating seasonality into target development, source assessments, and TMDL allocations. → explain.
- 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 in **Sections 5.10, 9.0**, and **10.0**).
- By using naturally occurring sediment loads as described in ARM 17.30.602(17) (see **Appendix B**) to establish the TMDLs and allocations based on reasonably achievable load reductions for each source category. Specifically, each major source category must meet percent reductions to satisfy the TMDL because of the relative loading uncertainties between assessment methodologies.
- By developing TMDLs at the watershed scale to address all potentially significant human-related sources beyond just the impaired waterbody segment scale. This approach should also reduce loading and improve water quality conditions within other tributary waterbodies throughout the watershed.

factors. Random selection of the stratified sites was intended to capture a representative subset of the road crossings for existing conditions and level of BMP implementation. However, some uncertainty is introduced because of the small sample size relative to the total number of road crossings.

Although the traction sand assessment indicated traction sand is a minor source of sediment, there is some uncertainty because the assessment was not performed during the spring, when its effects are most apparent. Also, although the culvert assessment is a coarse level assessment, there is uncertainty in the peak flow capacity that was calculated for each culvert because it is based on regional regression equations, which may substantially overestimate or underestimate peak flow.

* JASON'S WISH → THAT we/DEQ/you/us would collect TSS data and attempt to do some kind of analysis on in-stream measured sediment loads. How are we ever going to know if we are within several orders of magnitude on the TMDLs?