APPENDIX C – 2011 SEDIMENT AND HABITAT ASSESSMENT

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ACRONYMS

Acronym	Definition
BEHI	Bank Erosion Hazard Index
BMP	Best Management Practices
DEQ	Department of Environmental Quality (Montana)
GIS	Geographic Information System
LWD	Large Woody Debris
MCA	Montana Code Annotated
NBS	Near Bank Stress
NHD	National Hydrography Dataset
RSI	Riffle Stability Index
TMDL	Total Maximum Daily Load
TPA	TMDL Planning Area

C1.0 Introduction

The Upper Clark Fork Total Maximum Daily Load (TMDL) Planning Area (TPA) is located within Granite, Silver Bow, and Deerlodge County and includes the Clark Fork watershed. The TPA encompasses the headwater tributaries from near Butte to Drummond at the confluence of Flint Creek. The Clark Fork River begins as Silver Bow Creek which originates from the confluence of Basin and Blacktail Creeks near Butte. Silver Bow Creek, flowing northwest and then north along the valley floor, becomes the Clark Fork River as it meets the confluence of Warm Springs Creek east of Anaconda. The watershed drains an area 1,495 square miles (956,800 acres).

The TPA does not coincide with the fourth-code Hydrologic Unit Code 17010201 as the Little Blackfoot River (413 square miles) was addressed as a separate TPA (Montana Department of Environmental Quality and U.S. Environmental Protection Agency, Region 8, 2011).

Under Montana law, an impaired waterbody is defined as a waterbody for which sufficient and credible data indicates non-compliance with applicable water quality standards (Montana Code Annotated (MCA) 75-5-103). Section 303 of the Federal Clean Water Act requires states to submit a list of impaired waterbodies or stream segments to the U.S. Environmental Protection Agency every 2 years in an "Integrated Report" (formerly referred to as the "303(d) list"). The Montana Water Quality Act further directs states to develop TMDLs for all waterbodies appearing on the 303(d) list as impaired or threatened by "pollutants" (MCA 75-5-703).

This document focuses on sediment and habitat impairments on the upper Clark Fork River (segments MT76G001_010, MT76G001_030and MT76G001_040) and Silver Bow Creek (segment MT76G003_020).

A detailed sediment and habitat assessment of streams in the Upper Clark Fork TPA was conducted to facilitate the development of sediment TMDLs. During this assessment, streams were first analyzed in Geographic Information System (GIS) using color aerial imagery and broken into similar reaches based on landscape characteristics. Following the aerial assessment reach stratification process, field data were collected at 11 different stream reaches during August and September 2011. Field data were then used to quantify stream condition variables at assessment reaches within the Upper Clark Fork TPA. A list of data collected for each selected reach is included in **Section C3.1**.

The following sections are descriptions of three main components of this project: aerial assessment reach stratification, and sediment and habitat assessment.

C2.0 Aerial Assessment Reach Stratification

An aerial assessment of streams in the Upper Clark Fork TPA from Little Blackfoot to Flint Creek was conducted using National Agricultural Imagery Program color imagery from 2009 in GIS along with other relevant data layers, including the National Hydrography Dataset (NHD) 1:100,000 stream layer and United States Geological Survey 1:24,000 Topographic Quadrangle Digital Raster Graphics. GIS data layers were used to stratify streams into distinct reaches based on landscape and land-use factors following techniques described in *Watershed Stratification Methodology for TMDL Sediment and Habitat Investigations* (Montana Department of Environmental Quality, 2008). Stream reaches in the TPA upstream of the Little Blackfoot River were completed as part of a different project following the same methodology (2006).

The reach stratification methodology involves breaking a waterbody stream segment into stream reaches and sub-reaches. The Montana Department of Environmental Quality (DEQ) tracks stream water quality status by stream segment, which may encompass the entire stream or just a portion of the stream. Each of the stream segments in the Upper Clark Fork TPA was initially divided into distinct reaches based on four landscape factors: ecoregion, valley gradient, Strahler stream order, and valley confinement. Stream reaches classified by these four criteria were then further divided into sub-reaches based on the surrounding vegetation and land-use characteristics, including predominant vegetation type, adjacent land use, riparian area condition, anthropogenic (human) influences on streambank erosion, level of development, and the presence of anthropogenic activity within 100 feet of the stream channel. This stratification resulted in a series of stream reaches and sub-reaches delineated based on landscape and land-use factors which were compiled into an Aerial Assessment Database for the Upper Clark Fork TPA.

C2.1 Reach Types

As described above, the aerial assessment reach stratification process involved dividing each stream segment into distinct reaches based on ecoregion, valley gradient, Strahler stream order, and valley confinement. Each individual combination of the four landscape factors is referred to as a "**reach type**" in this report. Reach types were labeled using the following naming convention based on landscape features in the order listed below:

Level III Ecoregion – Valley Gradient – Strahler Stream Order – Confinement

Landscape feature values and associated reach type identifiers are presented in **Table C2-1**.

Table C2-1. Reach Type Identifiers

Landscape Factor	Stratification Category	Reach Type Identifier
Level III Ecoregion	Middle Rockies	MR
Valley Gradient	0-<2%	0
	2-<4%	2
	4-<10%	4
	>10%	10
Strahler Stream Order	1st order	1
	2nd order	2
	3rd order	3
	4th order	4
	5th order	5
	6th order	6
	7th order	7
Confinement	unconfined	U
	confined	C

Thus, a stream reach identified as MR-2-2-U is a mid-gradient (2-<4%), 2rd order, unconfined stream in the Middle Rockies Level III Ecoregion.

C2.2 Reach Stratification Results

A total of 46 reaches were delineated during the aerial assessment reach stratification process covering 101.5 miles of streams in the Upper Clark Fork TPA (**Table C2-2**). Based on the Level III Ecoregion, a total of two distinct reach types was delineated in the Upper Clark Fork TPA for this project and field data was collected in both reach types.

Table C2-2. Aerial Assessment Stream Segments

Stream Segment	Number of Reaches	Length (miles)
Clark Fork River	27	74.4
Silver Bow Creek	19	27.1

C3.0 Sediment and Habitat Assessment

C3.1 Methods

Sediment and habitat data were collected following the methodology described in *Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments* (Montana Department of Environmental Quality, 2010). Field monitoring sites were selected in relatively low-gradient segments of the study streams where sediment deposition is likely to occur. Other considerations in selecting field monitoring sites included representativeness of the reach to other reaches of the same slope, order, confinement and ecoregion, the extent of anthropogenic impacts relative to other reaches, and ease of access.

Sediment and habitat assessments were performed at 12 field monitoring sites, which were selected based on the aerial assessment in GIS and on-the-ground reconnaissance conducted in August, 2010.

Sediment and habitat data were collected within three reach types (**Table C3-1**, **Figure C3-1)**.

Table C3-1. Reach Types and Monitoring Sites

Reach Type	Number of Reaches	Sites Monitored
MR-0-6-U	9	CFR-2-3
		CFR-8-1
		CFR-12-1
		CFR-13-1
		CFR-16-2
		CFR-17-2
		CFR-22-2
		CFR-24-1
		CFR-26-1
MR-0-5-U	2	SVB-4-2
		SVB-9-2

The length of the monitoring site was based on the bankfull channel width. An assessment reach length of 1,000 feet was used at two sites in which the bankfull width was between 10 feet and 50 feet. A monitoring site length of 1,500 feet was used at two sites in which the bankfull width was between 50 and 75 feet. A monitoring site length of 2,000 feet was used at seven sites in which the bankfull width was greater than 75 feet. Each monitoring site was divided into five equally sized study cells numbered 1 through 5 progressing in an upstream direction. Sites were assessed from downstream to upstream.

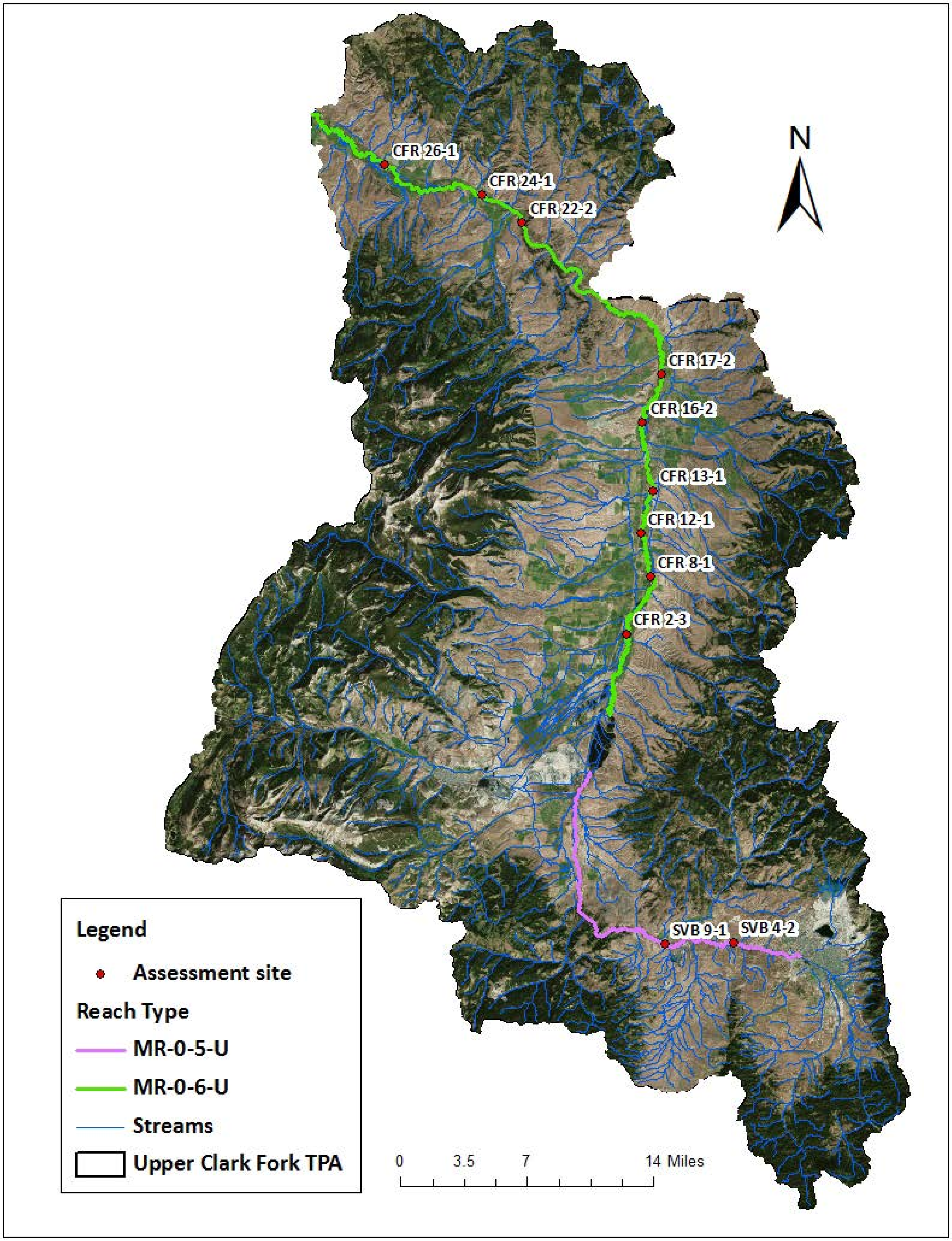

Figure C3-1. Aerial Assessment Reach Type Stratification and Sampled Sites

The following sections provide brief descriptions of the field methodologies employed during this assessment. A more in-depth description is available in *Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments* (Montana Department of Environmental Quality, 2010).

C3.1.1 Channel Form and Stability Measurements

Channel form and stability measurements include the field determination of bankfull, channel cross-sections, floodprone width, and surface water slope.

C3.1.1.1 Field Determination of Bankfull

The bankfull elevation was determined for each monitoring site. Bankfull is a concept used by hydrologists to define a regularly occurring channel-forming high flow. One of the first generally accepted definitions of bankfull was provided by Dunne and Leopold (1977):

> The bankfull stage corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels.

Indicators that were used to estimate the bankfull elevation included scour lines, changes in vegetation types, tops of point bars, changes in slope, changes in particle size and distribution, staining of rocks, and inundation features. Multiple locations and bankfull indicators were examined at each site to determine the bankfull elevation, which was then applied during channel cross-section measurements.

C3.1.1.2 Channel Cross-Sections

Channel cross-section measurements were performed at the first riffle in each cell using a line level and a measuring rod. At each cross-section, depth measurements at bankfull were performed across the channel at regular intervals, which varied depending on channel width. The thalweg depth was recorded at the deepest point of the channel independent of the regularly spaced intervals.

C3.1.1.3 Floodprone Width Measurements

The floodprone elevation was determined by multiplying the maximum depth value by two (Rosgen, 1996). The floodprone width was then measured by stringing a tape from the bankfull channel margin on both the right and left banks until the tape (pulled tight and "flat") touched the ground at the floodprone elevation. When dense vegetation or other features prevented a direct line of tape from being strung, the floodprone width was estimated by pacing or making a visual estimate.

C3.1.1.4 Water Surface Slope

Water surface slope was measured by a two-person team using a transit and stadia rod. This measurement was compared with the slope assigned in the GIS-based aerial assessment to verify reach type. The field measured slope was also used in determining the Rosgen stream type at each monitoring site.

C3.1.2 Fine Sediment Measurements

Channel cross-section measurements were performed at the first riffle in each cell using a leveled tape and a measuring rod. At each cross-section, depth measurements at bankfull were performed across the channel at regular intervals, which varied depending on channel width. The thalweg depth was recorded at the deepest point of the channel independent of the regularly spaced intervals.

C3.1.2.1 Riffle Pebble Count
One Wolman pebble count (Wolman, 1954) was performed at the first riffle encountered in four cells, generally including cells 1, 3 and 5, providing a minimum of 400 particles measured within each assessment reach. Particle sizes were measured along their intermediate length axis (b-axis) using a gravelometer and results were grouped into size categories. The pebble count was performed from bankfull to bankfull using the "heel to toe" method. Location of the counted pebbles within the wet vs. dry part of the channel was also noted.

C3.1.2.2 Riffle Grid Toss
The riffle grid toss was performed at the same location as the pebble count measurement. The riffle grid toss measures accumulation of fine sediment (particles less than 6mm diameter) on the surface of the streambed. Grid tosses were performed prior to the pebble count to avoid disturbances to surface fine sediment.

C3.1.2.3 Pool Tail-Out Grid Toss
A measurement of the percent of fine sediment in pool tail-outs was taken using the grid toss method at each pool in which potential spawning gravels were identified. Three measurements were taken in each pool with appropriately sized spawning gravels using a 49-point grid. The suitability for spawning was recorded as "Yes" (Y), or "No" (N) in cases where gravels of appropriate size were scarce or not available. No grid toss measurements were made when the substrate was determined to be too large to support spawning. Grid toss measurements were still performed when the substrate was observed to be too fine to support spawning since the goal of this assessment is to quantify fine sediment accumulation in spawning areas.

C3.1.2.4 Riffle Stability Index
A Riffle Stability Index (RSI) evaluation was performed in streams that had well-developed point bars. For assessment sites in which enough well-developed point bars were present, a total of three RSI measurements was taken, which entailed measurement of the intermediate axis (b-axis) of 15 particles determined to be among the largest size group of recently deposited particles that occur on over 10% of the point bar. During post-field data processing, the RSI was determined by calculating the geometric mean of the dominant bar particle size measurements and comparing the result to the cumulative particle distribution from the riffle pebble count in an adjacent or nearby riffle.

C3.1.3 Instream Habitat Measurements
Instream habitat measurements include channel bed morphology, residual pool depth and width, and pool habitat quality (cover type and woody debris quantification).

C3.1.3.1 Channel Bed Morphology
The length of pools and riffles within monitoring sites was recorded progressing in an upstream direction. The upstream and downstream stations of "dominant" riffle features were recorded. A riffle is considered "dominant" when occupying over 50% of the bankfull channel width (Heitke et al., 2006). Pools were documented if they were concave in profile, bounded by a "head crest" at the upstream end and a "tail crest" at the downstream end, and had a maximum depth at least 1.5 times the pool-tail depth (Kershner et al., 2004). Dammed pools were also assessed; backwater pools were not assessed.

C3.1.3.2 Residual Pool Depth
Maximum pool depth and the depth of the pool tail crest at its deepest point were measured at each pool encountered. The difference between the maximum depth and the tail crest depth is considered the residual pool depth. No pool tail crest depth was recorded for dammed pools.

C3.1.3.3 Pool Habitat Quality
Qualitative assessments of each pool feature were undertaken, including pool type, size, formative feature, and cover type, along with the depth of any undercut banks associated with the pool. The total number of pools was also quantified.

C3.1.3.4 Woody Debris Quantification
The amount of Large Woody Debris (LWD) within each monitoring site was recorded. Large pieces of woody debris located within the bankfull channel that were stable enough to influence the channel form were counted as either single, aggregate or "willow bunch." The term "willow bunch" refers to dead, decadent or living riparian shrubs (not just willows) that are influencing the channel bed morphology. A single piece of LWD was counted when it was greater than 9 feet long or spanned two-thirds of the wetted stream width, and 4 inches in diameter at the small end (Overton et al., 1997).

C3.1.4 Riparian Health Measurements
Riparian conditions were documented using the riparian greenline assessment.

C3.1.4.1 Riparian Greenline Assessment
Along each monitoring site, an assessment of riparian vegetation cover was performed. Vegetation types were recorded at 10-foot intervals, with the number of sampled points depending on the bankfull channel width. The riparian greenline assessment described the general vegetation community type of the groundcover, understory and overstory on both banks. At 50-foot intervals, the riparian buffer width was estimated on either side of the channel. The riparian buffer width corresponds to the belt of vegetation buffering the stream from adjacent land uses. Hummocking from livestock hoof action was also recorded where encountered during the greenline assessment.

C3.2 RESULTS

In the Upper Clark Fork TPA, sediment and habitat variables were assessed in late August and early September 2011 at 11 assessment reaches. Sediment and habitat assessments were performed in the dominant reach types on the Clark Fork River upstream of Flint Creek and on Silver Bow Creek. In the Upper Clark Fork TPA, both streams are comprised of a single reach type according to the DEQ stratification methodology. A statistical analysis of the sediment and habitat data is presented by reach type and for individual assessment reaches in the following sections.

C3.2.1 Reach Type Analysis
This section presents a statistical analysis of sediment and habitat base parameters for each of the reach types assessed in the Upper Clark Fork TPA. Reach type discussions are based on mean values, while summary statistics for the minimum, 25th percentile, median, 75th percentile and maximum values are also provided since these may be more applicable for developing sediment TMDL targets. Sediment and habitat analysis is provided by reach type for the following metrics:

- width/depth ratio
- entrenchment ratio

- riffle pebble count <2mm
- riffle pebble count <6mm
- riffle grid-toss <6mm
- pool tail-out grid toss <6mm
- residual pool depth
- pool frequency
- LWD frequency
- greenline understory shrub cover
- greenline percent bare ground
- RSI

C3.2.1.1 Width/Depth Ratio

The channel width/depth ratio is defined as the channel width at bankfull height divided by the mean bankfull depth (Rosgen, 1996). The channel width/depth ratio is one of several standard measurements used to classify stream channels, making it a useful variable for comparing conditions between reaches with the same stream type (Rosgen, 1996). A comparison of observed and expected width/depth ratios is also a useful indicator of channel over-widening and aggradation, which are often linked to excess streambank erosion and/or sediment inputs from sources upstream of the study reach. Channels that are over-widened are often associated with excess sediment deposition and streambank erosion, contain shallower and warmer water, and provide fewer deepwater habitat refugia for fish.

Figure C3-2 illustrates trends in width/depth ratio among reach types. Mean width/depth ratios for assessed reach types ranged from 17.0 in MR-0-5-U to 44.1 in MR-0-6-U (**Table C3-2**). A higher stream order indicates a larger, thus generally wider, stream.

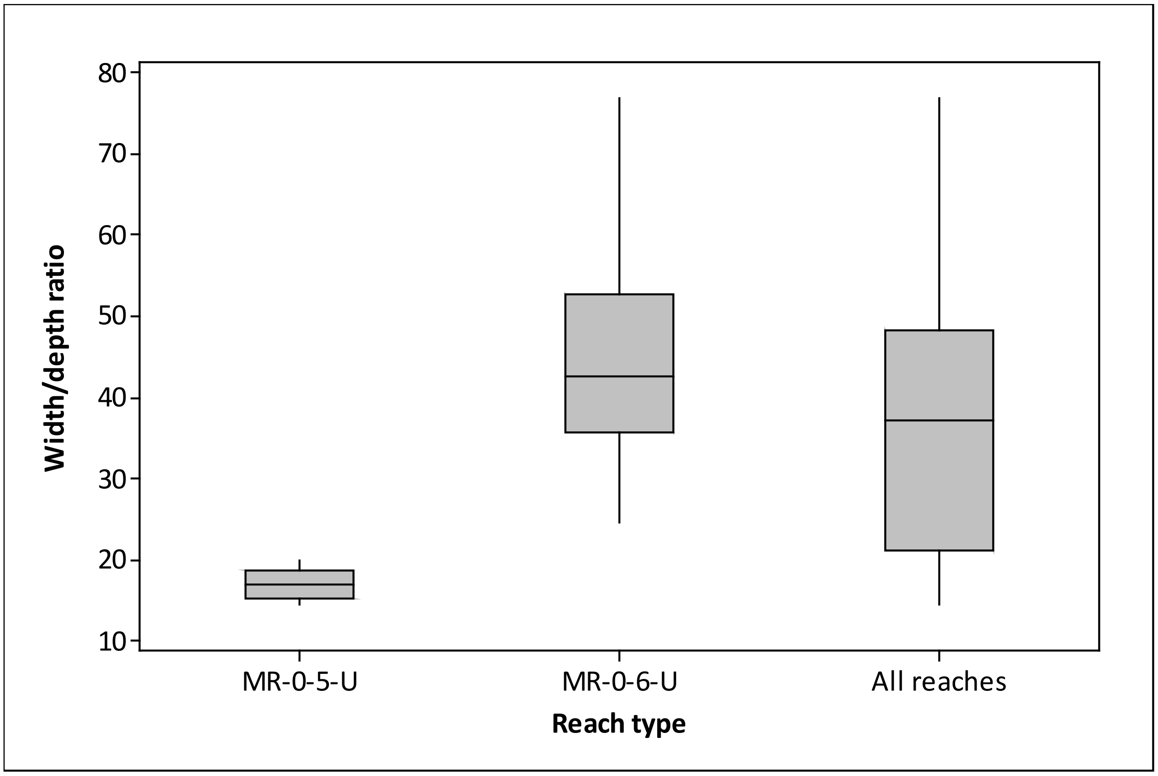

Figure C3-2. Width/Depth Ratio

Table C3-2. Width/Depth Ratio

Statistic	Reach Types		
	MR-0-5-U	**MR-0-6-U**	**All Reaches**
Number of Reaches	2	9	11
Sample Size	10	30	40
Minimum	14.5	24.6	14.5
25th Percentile	15.2	35.7	21.0
Median	17.0	42.7	37.1
Mean	17.0	44.1	37.3
75th Percentile	18.5	52.5	48.3
Maximum	19.8	76.9	76.9

C3.2.1.2 Entrenchment Ratio

A stream's entrenchment ratio is equal to the floodprone width divided by the bankfull width (Rosgen, 1996). The entrenchment ratio is used to help determine if a stream shows departure from its natural stream type and is an indicator of stream incision that describes how easily a stream can access its floodplain. Streams can become incised due to detrimental land management activities or may be naturally incised due to landscape characteristics. A stream that is overly entrenched generally is more prone to streambank erosion due to greater energy exerted on the banks during flood events. Greater scouring energy along incised channels results in higher sediment loads derived from eroding banks. If the stream is not actively degrading (downcutting), the sources of human caused incision may be historical in nature, though sediment loading may continue to occur. The entrenchment ratio is an important measure of channel conditions since it relates to sediment loading and habitat condition.

Figure C3-3 illustrates the distribution of values for entrenchment ratio among reach types. The mean entrenchment ratio for assessed reach types ranged from 2.2 in MR-0-6-U to 9.2 in MR-0-5-U (**Table C3-3**). The entrenchment ratio for reach type MR-0-6-U, which applies to reaches on the Clark Fork River, may be biased low because the floodprone width on these reaches with wide shrub-covered floodplain was often recorded as ">200," which was treated as 200 in the data analysis.

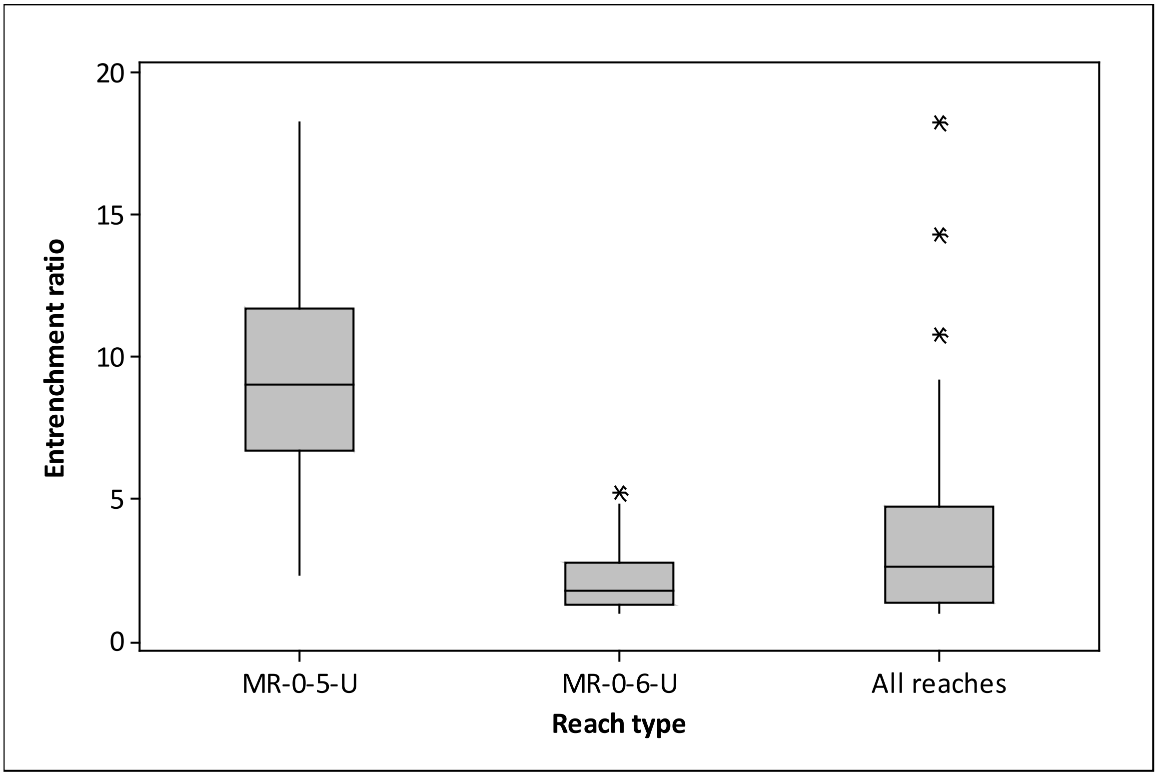

Figure C3-3. Entrenchment Ratio

Table C3-3. Entrenchment Ratio

Statistic	Reach Types		
	MR-0-5-U	**MR-0-6-U**	**All Reaches**
Number of Reaches	2	9	11
Sample Size	10	30	40
Minimum	2.3	1.0	1.0
25^{th} Percentile	6.7	1.3	1.3
Median	9.0	1.7	2.6
Mean	9.2	2.2	4.0
75^{th} Percentile	11.7	2.8	4.7
Maximum	18.2	5.2	18.2

C3.2.1.3 Riffle Pebble Count %<2mm

Percent surface fine sediment provides a good measure of the siltation occurring in a river system. Surface fine sediment measured using the Wolman (1954) pebble count method is one indicator of aquatic habitat condition and can signify excessive sediment loading. The Wolman pebble count provides a survey of the particle distribution of the entire channel width, allowing investigators to calculate a percentage of the surface substrate (as frequency of occurrence) composed of fine sediment.

Figure C3-4 illustrates the distribution of values for percent substrate size < 2mm from riffle pebble count among reach types. Mean values for the percent of fine sediment <2mm based on riffle pebble counts ranged from 13% in MR-0-6-U to 28% in MR-0-5-U (**Table C3-4**). Reaches documented as an E Rosgen channel type are generally removed from analyses for fine sediment because E channels inherently have a higher percentage of fine sediment than other types. None of the assessed reaches in the Upper Clark Fork TPA was considered an E type at present; therefore all reaches are included in the analysis.

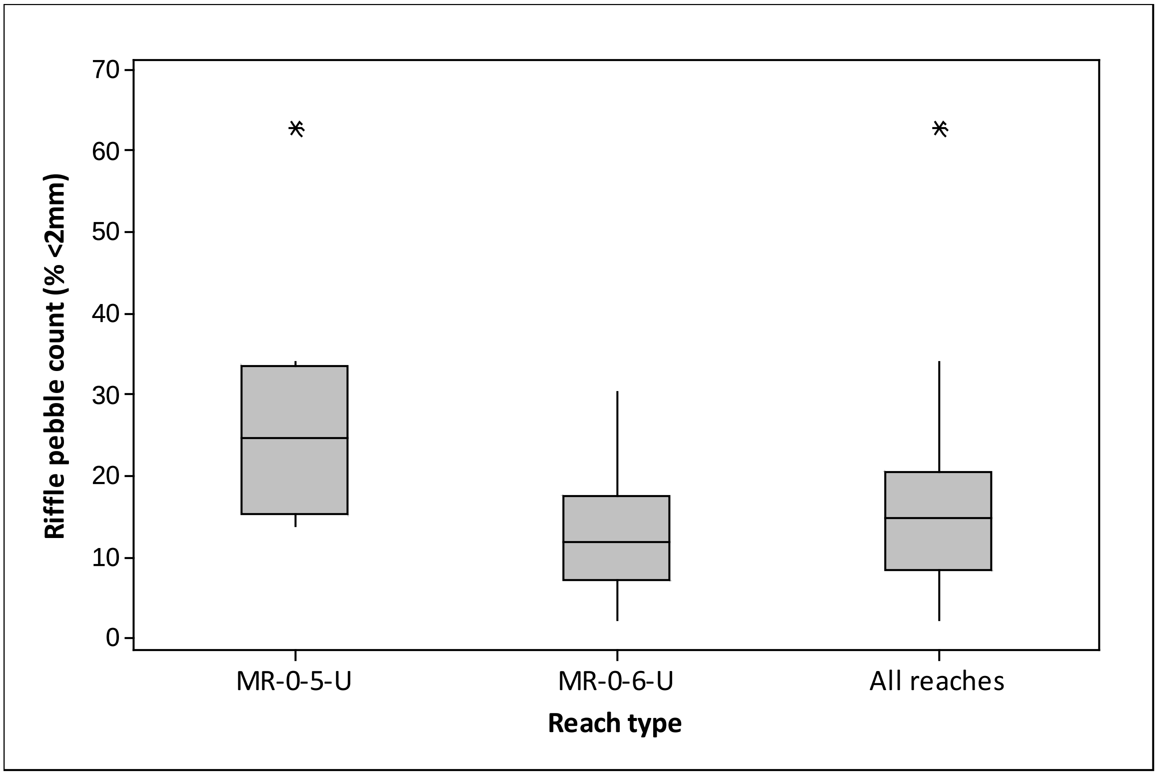

Figure C3-4. Riffle Pebble Count, % <2mm

Table C3-4. Riffle Pebble Count (% <2mm)

Statistic	Reach Types		
	MR-0-5-U	**MR-0-6-U**	**All Reaches**
Number of Reaches	2	9	11
Sample Size	8	28	36
Minimum	13.8	2.2	2.2
25th Percentile	15.3	7.1	8.5
Median	24.7	11.9	14.8
Mean	27.8	12.8	16.2
75th Percentile	33.4	17.5	20.4
Maximum	62.8	30.4	62.8

C3.2.1.4 Riffle Pebble Count %<6mm

As with surface fine sediment <2mm, an accumulation of surface fine sediment <6mm may indicate excess sedimentation and be detrimental to coldwater fish spawning. **Figure C3-5** illustrates the distribution of values for surface fine sediment < 6mm from riffle pebble counts. Mean values for the percent of fine sediment <6mm based on pebble counts conducted in riffles ranged from 17% in MR-0-

6-U to 35% in MR-0-5-U (**Table C3-5**). The two reaches on Silver Bow Creek, both in MR-0-5-U, had the highest percent fine sediment. These two reaches have undergone restoration from a highly disturbed state and are likely still in adjustment. These reaches also flow over the Boulder Batholith, a geologic formation that is composed primarily of undifferentiated granitic rocks which weather readily, supplying sand-sized sediment to Silver Bow Creek and lower-gradient streams in the region; therefore, the underlying geology is considered the primary long-term source of sediment to reaches on Silver Bow Creek (Montana Department of Environmental Quality, 1997).

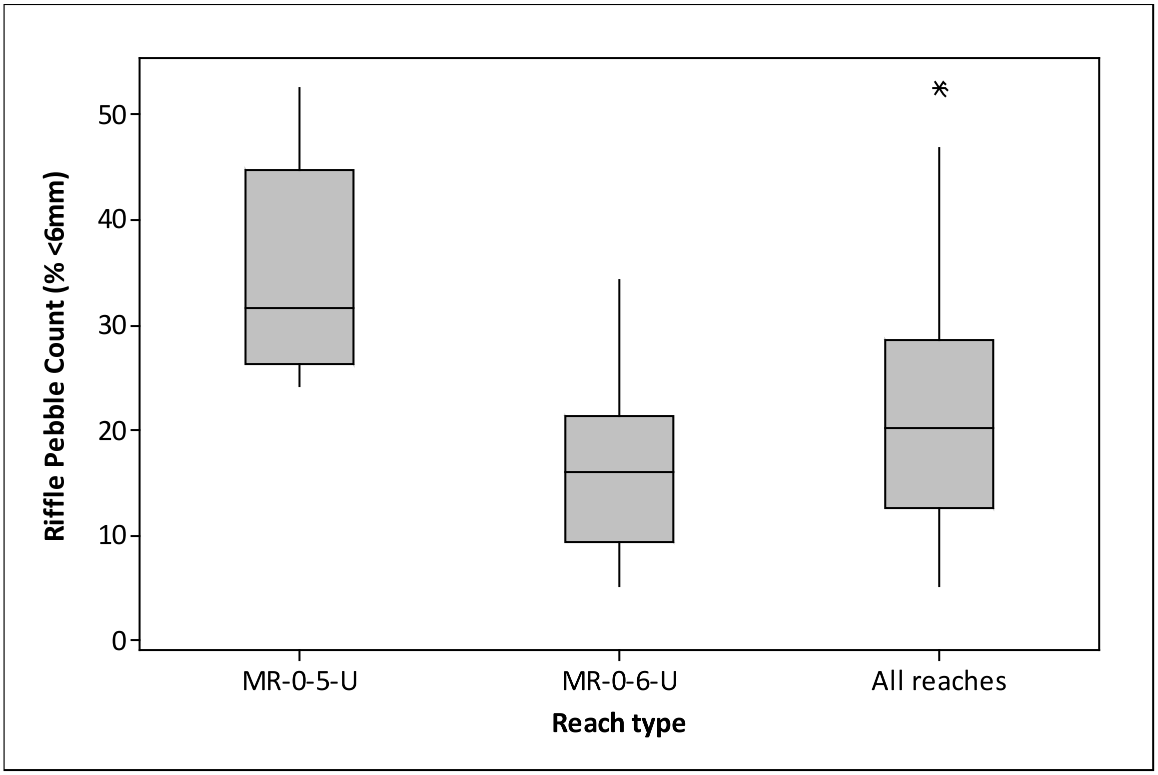

Figure C3-5. Riffle Pebble Count, % <6mm

Table C3-5. Riffle Pebble Count (% <6mm)

Statistic	Reach Types		
	MR-0-5-U	**MR-0-6-U**	**All Reaches**
Number of Reaches	2	9	11
Sample Size	8	28	36
Minimum	24.1	5.1	5.1
25th Percentile	26.4	9.3	12.7
Median	31.6	16.0	20.1
Mean	35.0	16.6	20.7
75th Percentile	44.8	21.2	28.5
Maximum	52.6	34.3	52.6

C3.2.1.5 Riffle Grid Toss %<6mm

The riffle grid toss is a standard procedure frequently used in aquatic habitat assessment that provides complimentary information to the Wolman pebble count. **Figure C3-6** illustrates the distribution of values for substrate < 6mm from riffle grid toss. Mean values for riffle grid toss fine sediment <6mm range 4.0% in MR-0-5-U to 4.7% in MR-0-6-U (**Table C3-6**).

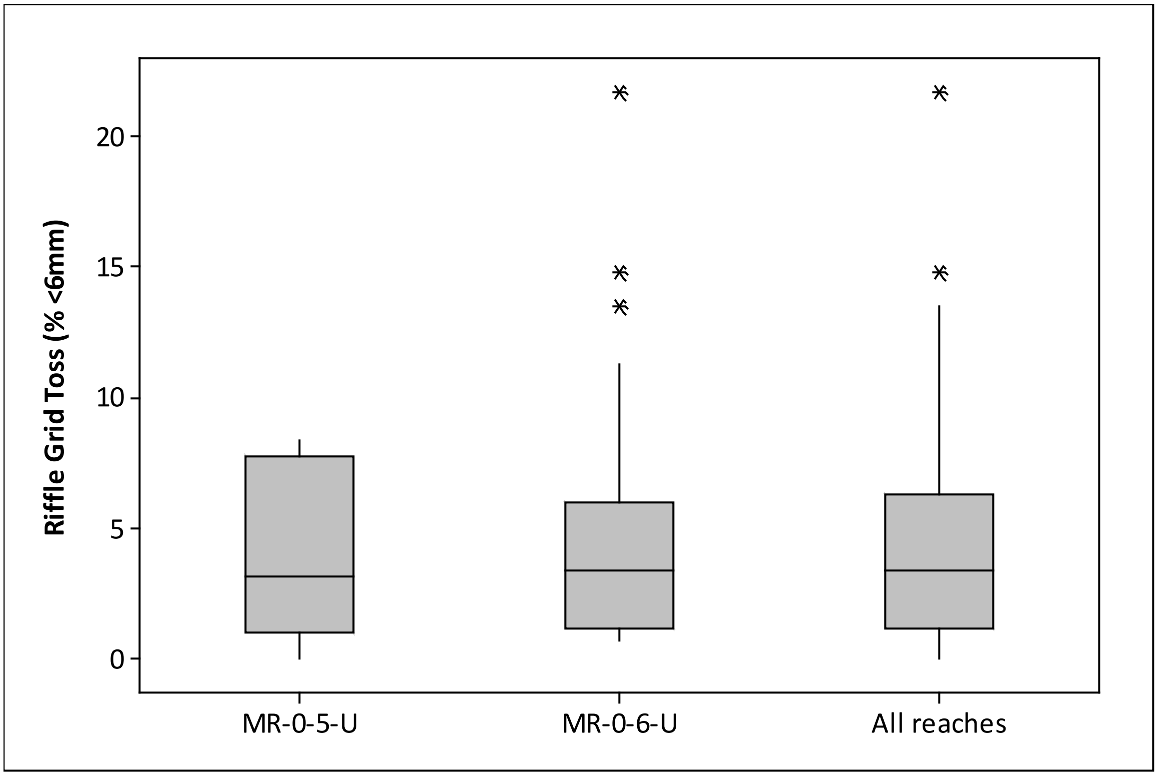

Figure C3-6. Riffle Grid Toss, % <6mm

Table C3-6. Riffle Grid Toss (% <6mm)

Statistic	Reach Types		
	MR-0-5-U	**MR-0-6-U**	**All Reaches**
Number of Reaches	2	9	11
Sample Size	8	29	37
Minimum	0.0	0.7	0.0
25th Percentile	1.0	1.2	1.2
Median	3.2	3.4	3.4
Mean	4.0	4.7	4.5
75th Percentile	7.7	6.0	6.3
Maximum	8.3	21.7	21.7

C3.2.1.6 Pool Tail-Out Grid Toss % <6mm

Grid toss measurements in pool tail-outs provide a measure of fine sediment accumulation in potential spawning sites, which may have detrimental impacts on aquatic habitat by cementing spawning gravels, preventing flushing of toxins in egg beds, reducing oxygen and nutrient delivery to eggs and embryos, and impairing emergence of fry (Meehan, 1991). Weaver and Fraley (Weaver and Fraley, 1991) observed a significant inverse relationship between the percentage of material less than 6.35mm and the emergence success of westslope cutthroat trout and bull trout.

Figure C3-7 illustrates the distribution of values for substrate < 6mm from pool tail-out grid toss among reach types. Mean values for pool tail-out grid toss fine sediment <6mm range from 4.3% in MR-0-6-U to 5.2% in MR-0-5-U (**Table C3-7**).

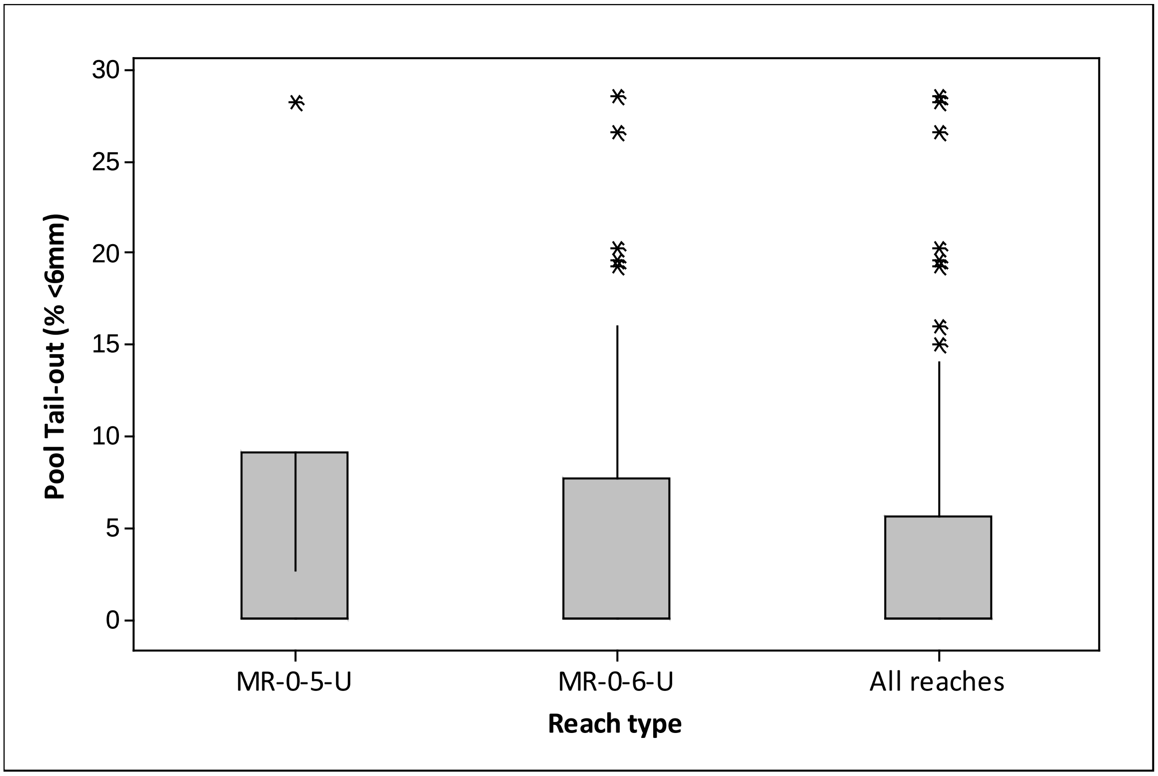

Figure C3-7. Poll Tail-Out Grid Toss, % <6mm

Table C3-7. Pool Tail-Out Grid Toss (% <6mm)

Statistic	Reach Types		
	MR-0-5-U	**MR-0-6-U**	**All Reaches**
Number of Reaches	2	9	11
Sample Size	6	51	57
Minimum	0.0	0.0	0.0
25th Percentile	0.0	0.0	0.0
Median	0.0	0.0	0.0
Mean	5.2	4.3	4.4
75th Percentile	9.1	7.7	5.7
Maximum	28.3	28.6	28.6

C3.2.1.7 Residual Pool Depth

Residual pool depth, defined as the difference between the maximum depth and the tail crest depth, is a discharge-independent measure of pool depth and an indicator of the quality of pool habitat. Deep pools are important resting and hiding habitat for fish, and provide refugia during temperature extremes and high flow periods. Residual pool depth is also an indirect measurement of sediment inputs to streams because an increase in sediment loading can cause pools to fill, thus decreasing residual pool depth over time.

Figure C3-8 illustrates the distribution of values for residual pool depth among reach types. Mean residual pool depths ranged from 1.8 feet in MR-0-5-U to 2.4 feet in MR-0-6-U (**Table C3-8**). In general, residual pool depths were greater for reaches on lower-gradient, larger streams.

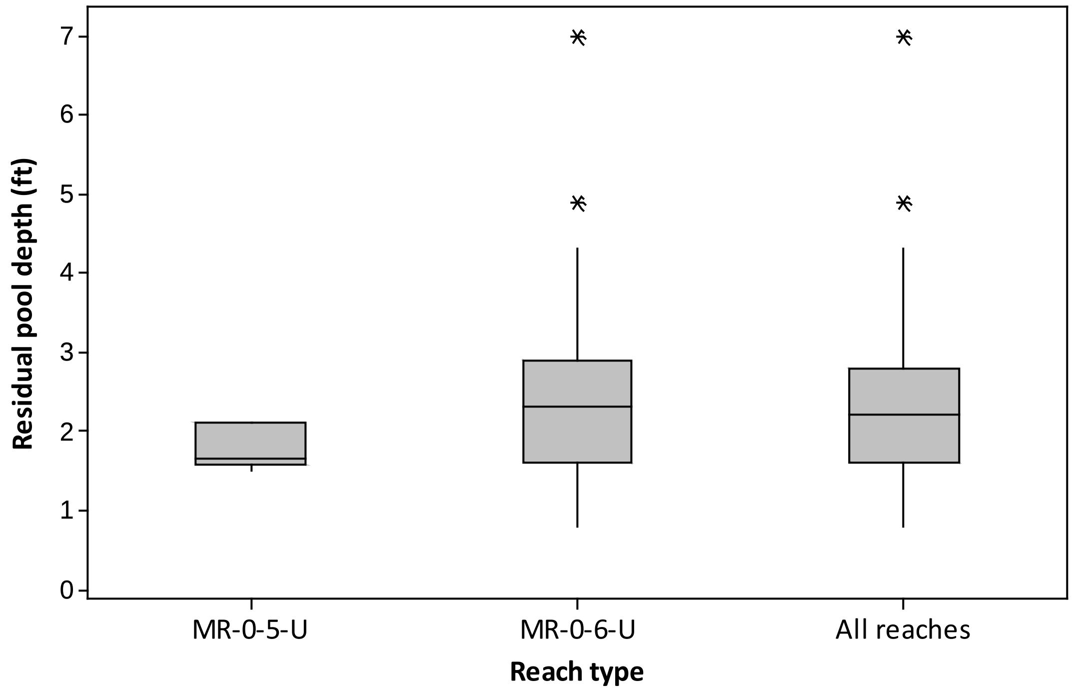

Figure C3-8. Residual Pool Depth (ft)

Table C3-8. Residual Pool Depth (ft)

Statistic	Reach Types		
	MR-0-5-U	**MR-0-6-U**	**All Reaches**
Number of Reaches	2	9	11
Sample Size	6	51	57
Minimum	1.5	0.8	0.8
25^{th} Percentile	1.6	1.6	1.6
Median	1.7	2.3	2.2
Mean	1.8	2.4	2.4
75^{th} Percentile	2.1	2.9	2.8
Maximum	2.1	7.0	7.0

C3.2.1.8 Pool Frequency

Pool frequency is a measure of the availability of pools to provide rearing habitat, cover, and refugia for salmonids. Pool frequency is related to channel complexity, availability of stable obstacles, and sediment supply. Excessive erosion and sediment deposition can reduce pool frequency by filling in smaller pools. Pool frequency can also be adversely affected by riparian habitat degradation resulting in a reduced supply of LWD or less scouring from stable root masses in streambanks.

Figure C3-9 illustrates the distribution of values for pool frequency among reach types. The mean value for the number of pools per mile was 16 for both MR-0-5-U and MR-0-6-U (**Table C3-9**).

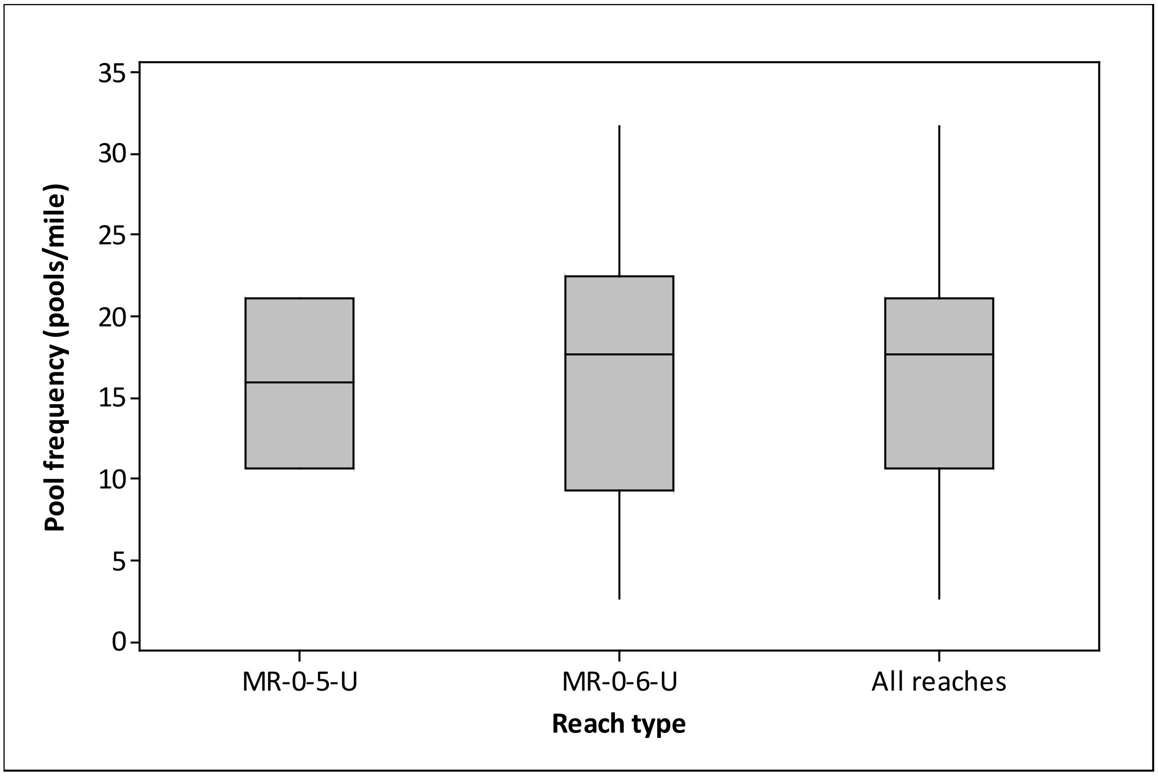

Figure C3-9. Pool Frequency (pools/mile)

Table C3-9. Pool Frequency (pools/mile)

Statistic	Reach Types		
	MR-0-5-U	**MR-0-6-U**	**All Reaches**
Number of Reaches	2	9	11
Sample Size	2	9	11
Minimum	10.6	2.6	2.6
25th Percentile	13.2	9.2	10.6
Median	15.8	17.6	17.6
Mean	15.8	16.3	16.2
75th Percentile	18.5	22.4	21.2
Maximum	21.1	31.7	31.7

C3.2.1.9 Large Woody Debris Frequency

LWD is a critical component of high-quality salmonid habitat, providing habitat complexity, quality pool habitat, cover, and long-term nutrient inputs. LWD also constitutes a primary influence on stream function, including sediment and organic material transport, channel form, bar formation and stabilization, and flow dynamics (Bilby and Ward, 1989). LWD frequency can be measured and compared to reference reaches or literature values to determine if more or less LWD is present than would be expected under optimal conditions. In the case of Silver Bow Creek and the upper Clark Fork River, many reaches do not support forested riparian ecosystems and are instead willow-dominated; thus, LWD generally occurs as willow bunches for those reaches, which includes all Silver Bow Creek reaches.

LWD was not recorded in reach type MR-0-5-U (Silver Bow Creek) as none was observed in the 2 restored reaches where sampling was conducted. LWD per mile for MR-0-6-U (Clark Fork River) is provided in **Table C3-10**. "Willow bunches" recorded in the field were not tallied with LWD; thus, these results do not include reaches in which the only LWD recorded were willow bunches.

Table C3-10. Large Woody Debris (per mile)

Statistic	Reach Types
	MR-0-6-U
Number of Reaches	3
Sample Size	7
Minimum	0.379
25th Percentile	0.38
Median	0.38
Mean	0.38
75th Percentile	0.38
Maximum	0.379

C3.2.1.10 Greenline Understory Shrub Cover

Riparian shrub cover is one of the most important influences on streambank stability. Removal of riparian shrub cover can dramatically increase streambank erosion and increase channel width/depth ratios. Shrubs stabilize streambanks by holding soil and armoring lower banks with their roots, and reduce scouring energy of water by slowing flows with their branches.

Good riparian shrub cover is also important for fish habitat. Riparian shrubs provide shade, reducing solar inputs and increases in water temperature. The dense network of fibrous roots of riparian shrubs allows streambanks to remain intact while water scours the lowest portion of streambanks, creating important fish habitat in the form of overhanging banks and lateral scour pools. Overhanging branches of riparian shrubs provide important cover for aquatic species. In addition, riparian shrubs provide critical inputs of food for fish and their feed species. Terrestrial insects falling from riparian shrubs provide one of the main food sources for fish. Organic inputs from shrubs, such as leaves and small twigs, provide food for aquatic macroinvertebrates, which are also an important food source for fish.

Figure C3-10 illustrates the distribution of values greenline understory shrub cover among reach types. The mean value for greenline understory shrub cover ranged from 26% in MR-0-6-U to 60% in MR-0-5-U, the reach type containing the restored reaches on Silver Bow Creek that were heavily planted with willows (**Table C3-11**).

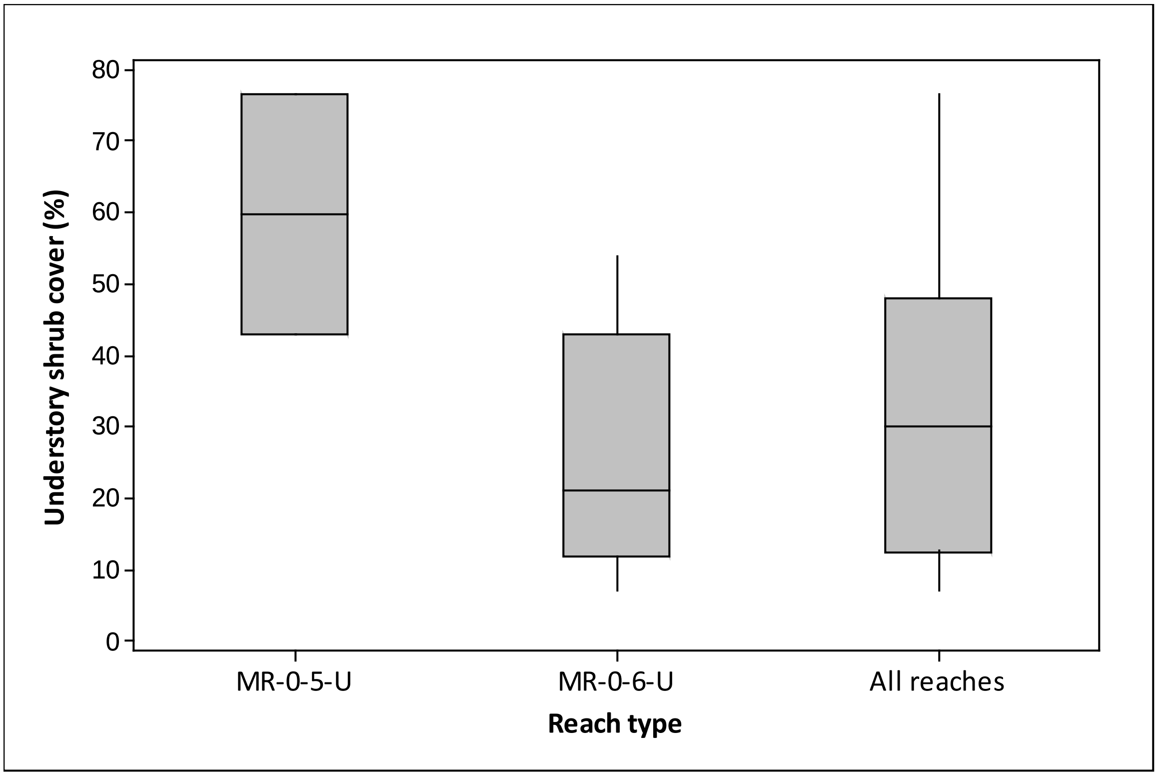

Figure C3-10. Understory Shrub Cover (%)

Table C3-11. Understory Shrub Cover (%)

Statistic	Reach Types		
	MR-0-5-U	**MR-0-6-U**	**All Reaches**
Number of Reaches	2	9	11
Sample Size	2	9	11
Minimum	43.0	7.0	7.0
25th Percentile	-	11.8	12.5
Median	59.8	21.0	30.0
Mean	59.8	26.1	32.23
75th Percentile	-	43.0	48.0
Maximum	76.5	54.0	76.5

C3.2.1.11 Greenline Bare Ground

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

Figure C3-11 illustrates the distribution of values for bare ground among reach types. The mean value for greenline percent bare ground ranged from 0% in MR-0-5-U to 16.3% in MR-0-6-U (**Table C3-12**). Reach type MR-0-5-U represents the restored reaches on Silver Bow Creek where extensive remediation efforts now support a dense cover of riparian graminoid (grass-like) species or shrubs.

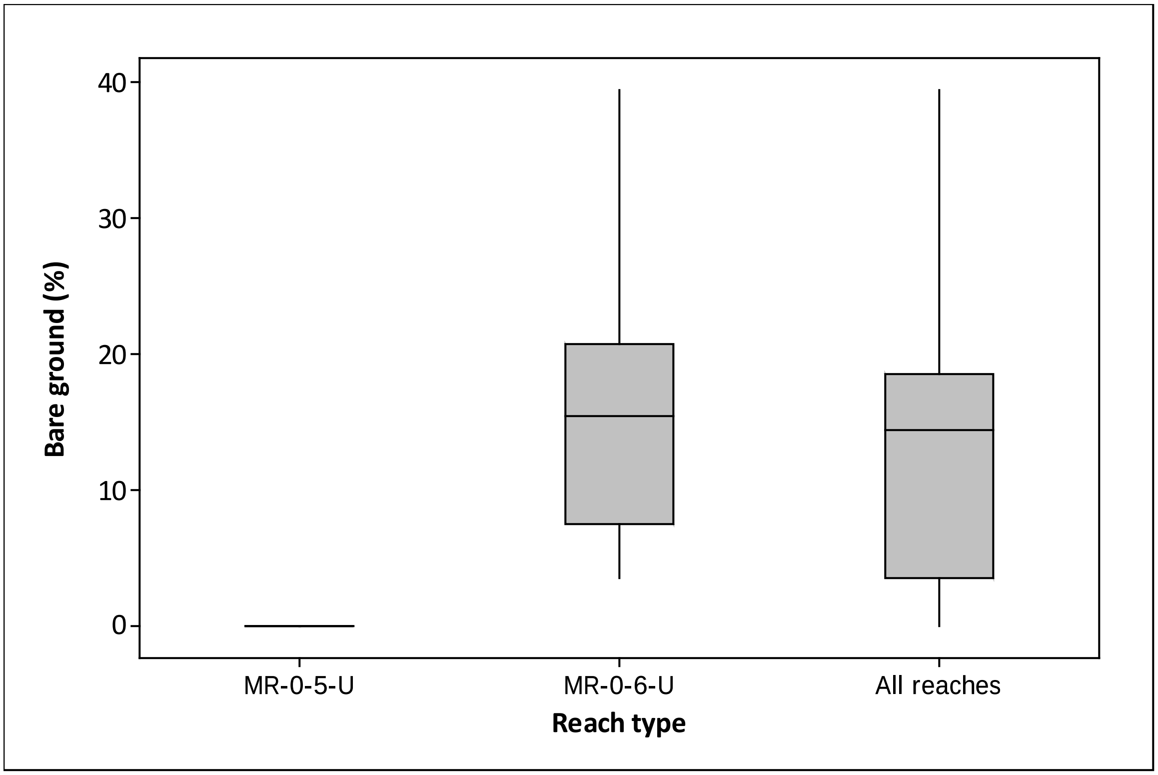

Figure C3-11. Bare Ground (%)

Table C3-12. Bare Ground (%)

Statistic	Reach Types		
	MR-0-5-U	**MR-0-6-U**	**All Reaches**
Number of Reaches	2	9	11
Sample Size	2	9	11
Minimum	0.0	3.5	0.0
25th Percentile	-	7.5	3.5
Median	0.0	15.5	14.5
Mean	0.0	16.3	13.3
75th Percentile	-	20.8	18.5
Maximum	0.0	39.5	39.5

C3.2.2 Monitoring Site Analysis

Sediment and habitat data collected at each monitoring site were reviewed individually in the following sections. Monitoring site discussions are based on median values, referencing the box plot statistics shown. Summary statistics for the minimum, 25th percentile, 75th percentile and maximum values are presented graphically, since these may be more applicable for developing sediment TMDL criteria. Statistics from these channels are included in the following analysis. **Table C3-13** outlines reaches by current channel type.

Table C3-13. Reaches by Rosgen Stream Type

Existing Rosgen Stream Type	REACH ID
C	CFR-02-3
	CFR-08-1
	CFR-12-1
	CFR-17-2
	CFR-24-1
	CFR-26-1
	SVB-4-2
	SVB-9-1
F	CFR-13-1
	CFR-16-2
	CFR-22-2

C3.2.2.1 Width/Depth Ratio

The highest median width/depth ratio was observed in CFR-24-1, a reach in the Clark Fork River (**Figure C3-12**). Width/depth ratio appears to follow a trend increasing from highest to lowest elevation reaches in the Upper Clark Fork TPA.

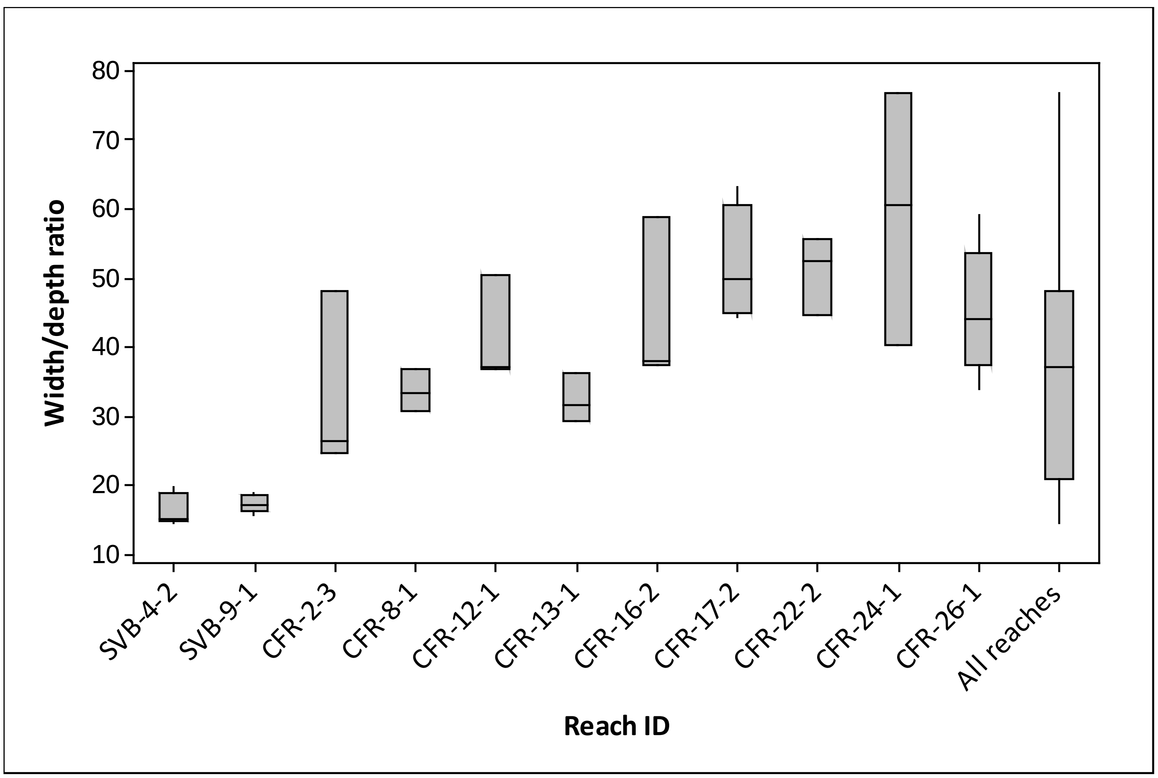

Figure C3-12. Width/Depth Ratio by Sample Location

C3.2.2.2 Entrenchment Ratio

Entrenchment ratio data collected within the Upper Clark Fork TPA indicates the following (**Figure C3-13**):

1. Of the sites assessed, reach SVB-9-1 has a significantly higher entrenchment ratio than the other sites (**Figure C3-13**). This trend could be in part because the floodplain on the mainstem CFR was generally recorded as "greater than 200 feet" on at least one side, which was treated as 200 feet

in the reach averages. Entrenchment ratio also could be higher on SVB reaches because these sites have undergone stream restoration and were designed to have more floodplain.

2. Variation in entrenchment ratio was generally low within reaches on the mainstem CFR.

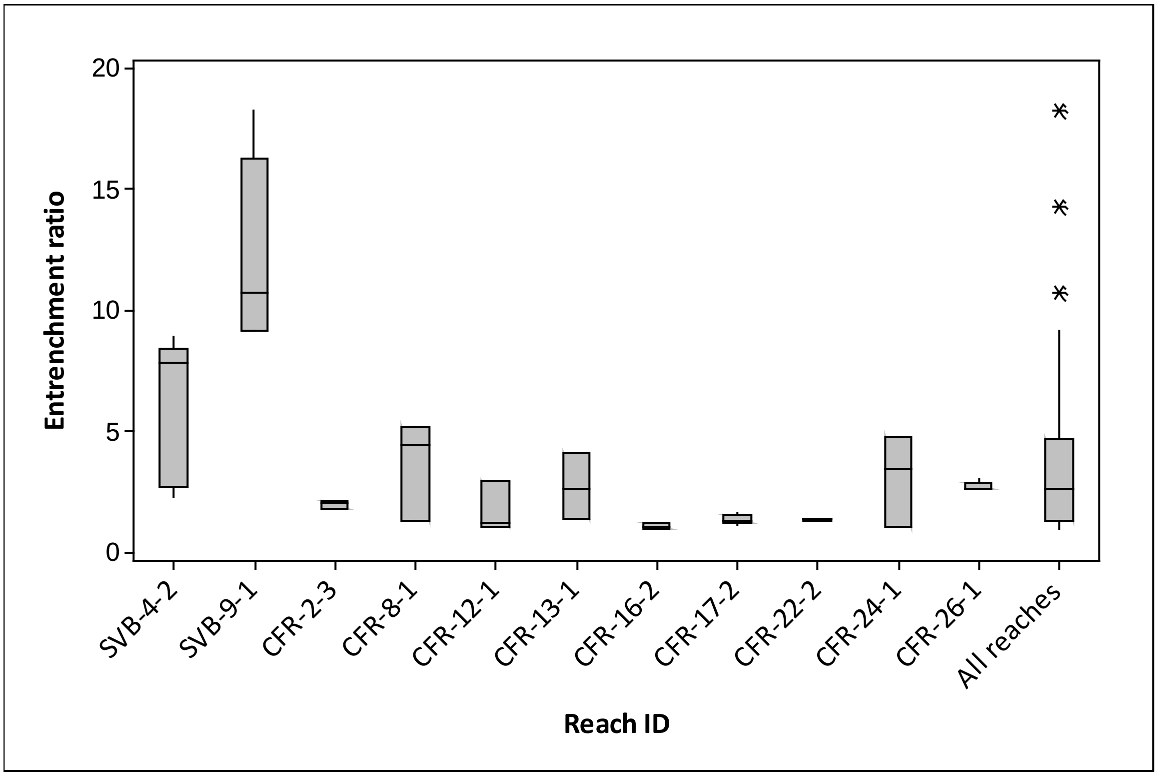

Figure C3-13. Entrenchment Ratio by Sample Location

C3.2.2.3 Riffle Pebble Count, % <2mm

The median percent of fine sediment in riffles <2mm as measured by a pebble count was highest in SVB-4-2 and generally decreased moving downstream through the Clark Fork River. A lot of aquatic vegetation in this SVB-4-2 contributed to higher fine sediment cover in addition to high natural fines in streams draining the Boulder Batholith (**Figure C3-14**).

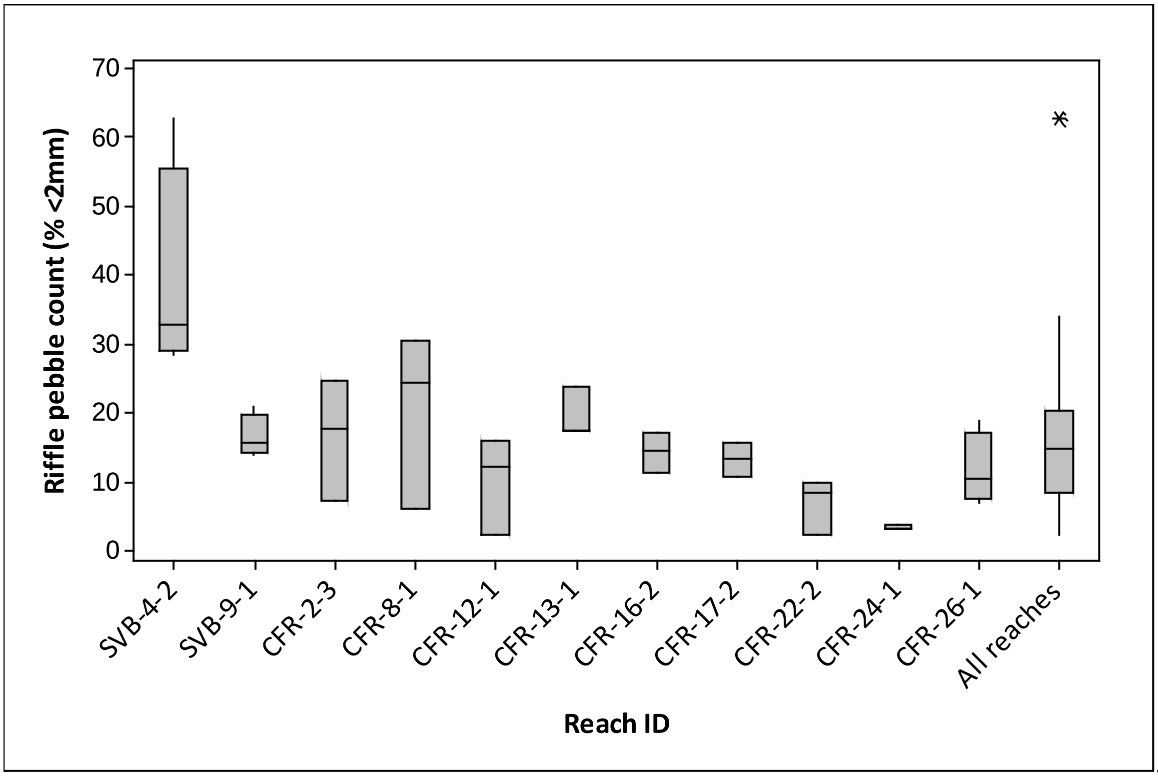

Figure C3-14. Riffle Pebble Count, % <2mm, by Sample Location

C3.2.2.4 Riffle Pebble Count, %<6mm

The percent of fine sediment in riffles <6mm as measured by a pebble count followed a similar trend as the percent of fine sediment <2mm, with the highest median value in SVB-9-1 (**Figure C3-15**). The same downward trend with distance downstream is observable in this dataset.

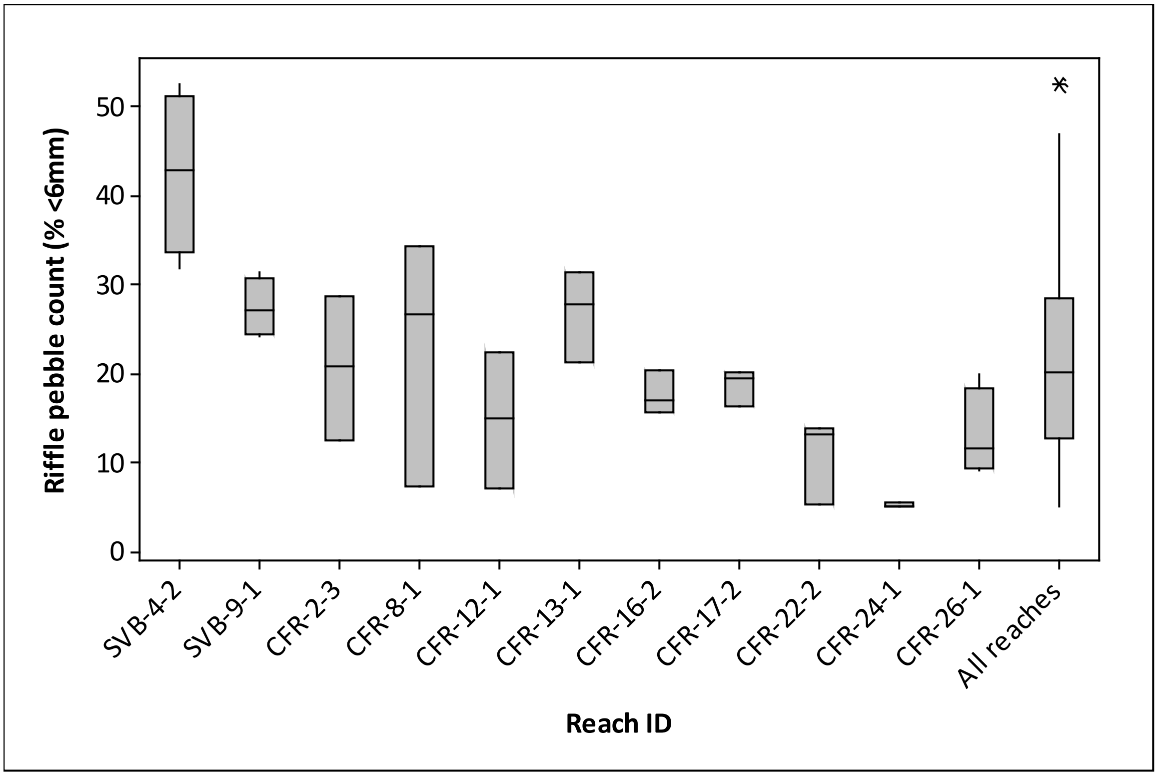

Figure C3-15. Riffle Pebble Count, % <6mm, by Sample Location

C3.2.2.5 Riffle Grid Toss, %<6mm

The median percent of fine sediment in riffles <6mm as measured by a grid toss was highest in CFR-17-2 (**Figure C3-16**). CFR-8-1 had the greatest range of observations among all sites.

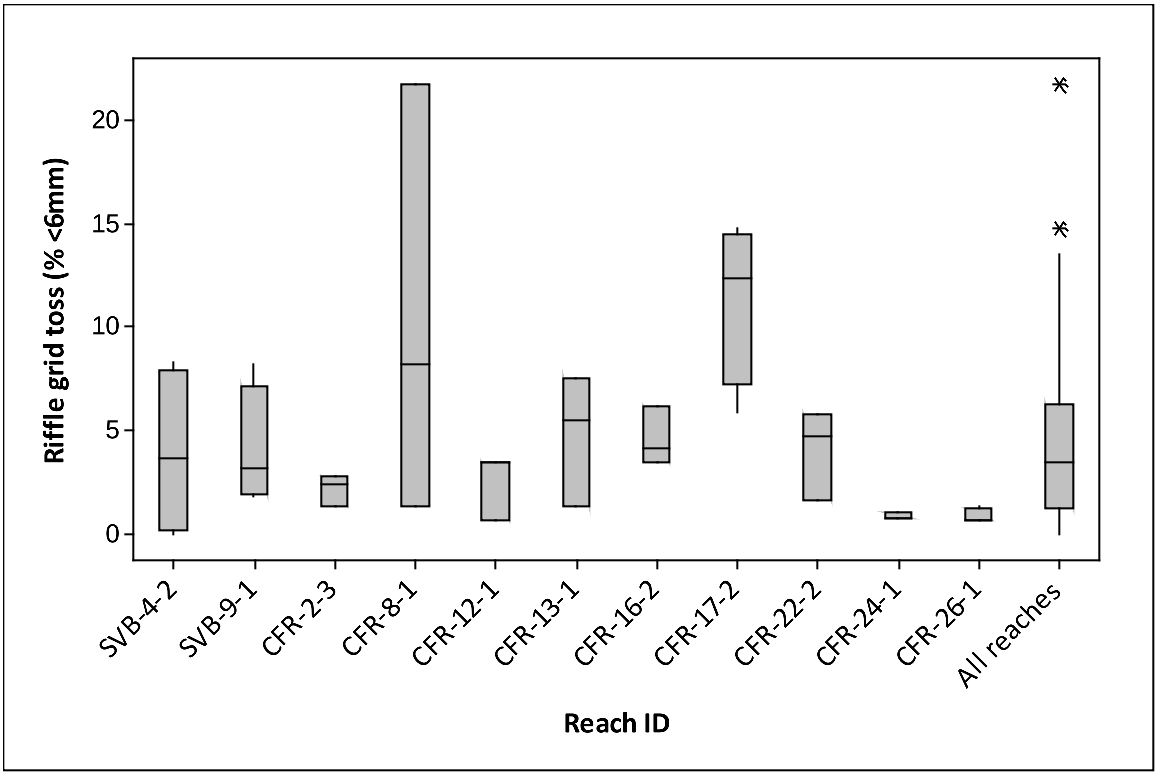

Figure C3-16. Riffle Grid Toss, % <6mm, by Sample Location

C3.2.2.6 Riffle Stability Index

The mobile percentile of particles on the riffle is termed "Riffle Stability Index" (RSI) and provides a useful estimate of the degree of increased sediment supply to riffles. The RSI addresses situations in which increases in gravel bedload from headwater activities is depositing material on riffles and filling pools, and it reflects qualitative differences between reference and managed watersheds. In the Upper Clark Fork TPA, very few gravel bars were encountered. RSI evaluations were, therefore, only performed in the assessment sites listed in **Table C3-14**. The D50 is the median pebble size encountered in the pebble count taken in closest proximity to the gravel bar used for RSI, and is used in calculating the RSI value.

Table C3-14. Riffle Stability Index Summary

Reach ID	Pebble Count Analysis		RSI
	Cell	D50	
CFR-02-3	1	45	31.25
CFR-02-3	3	56	65.75
CFR-02-3	4	58	64.84
CFR-08-1	1	45	42.68
CFR-08-1	3	106	97.78
CFR-08-1	4	61	86.27
CFR-12-1	1	55	46.73
CFR-12-1	4	51	52.13
CFR-16-2	3	69	89.77
CFR-22-2	4	85	54.46
CFR-24-1	1	89	62.38
CFR-24-1	2	118	52.78

Table C3-14. Riffle Stability Index Summary

Reach ID	Pebble Count Analysis		RSI
	Cell	D50	
CFR-24-1	3	116	96.94
CFR-26-1	1	89	71.72
CFR-26-1	3	144	100
CFR-26-1	4	76	76.67
CFR-26-1	5	35	13.51

C3.2.2.7 Pool Tail-Out Grid Toss %<6mm

The median percent of fine sediment in pool tail-outs as measured with the grid toss was highest in CFR-17-2 (**Figure C3-17**). This measure may be biased by the methodology which identifies 'spawning gravels' in pool tails where a grid toss measurement is performed. Some reaches had numerous pools where spawning gravels were determined to be present. CFR-17-2 only had a single pool where the measurement was done.

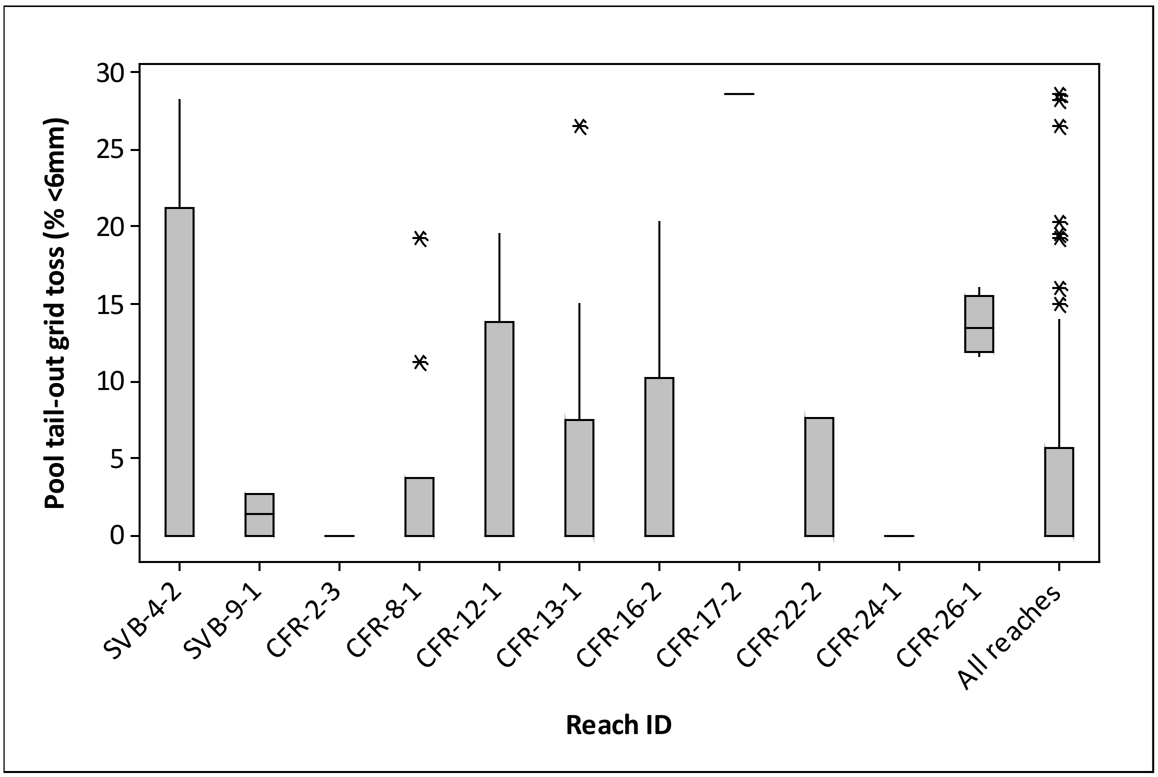

Figure C3-17. Pool Tail-Out Grid Toss, % <6mm, by Sample Location

C3.2.2.8 Residual Pool Depth

The greatest median residual pool depth was measured in CFR-8-1 (**Figure C3-18**). The lowest residual pool depth was observed in SVB-4-2, the most upstream reach in the dataset. Residual pool depths do not increase in the downstream direction within the assessed streams, as they do for greater stream orders among reach types (5th order (Silver Bow Creek) versus 6th order (Clark Fork River)).

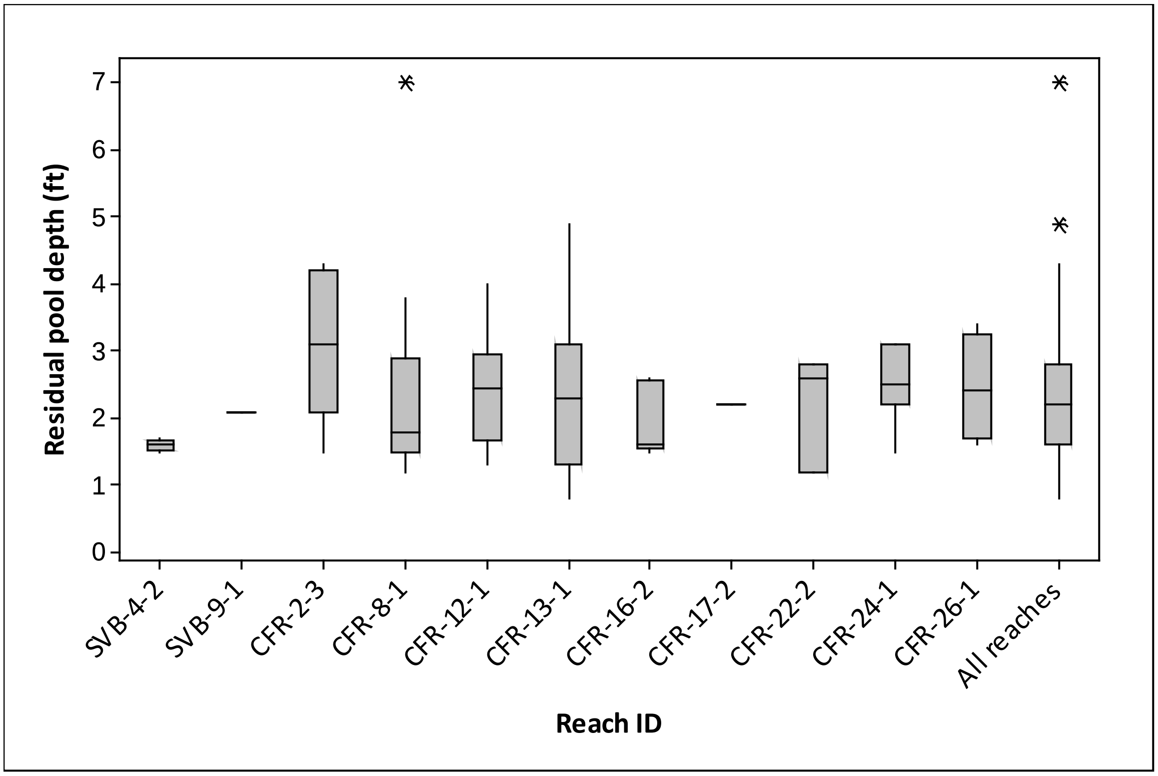

Figure C3-18. Residual Pool Depth (ft) by Sample Location

C3.2.2.9 Pool Frequency

The greatest number of pools per mile was found in CFR-8-1, a highly sinuous reach (**Figure C3-19**). It would be expected that pool frequency would decrease in the downstream direction although this is not well reflected in the data.

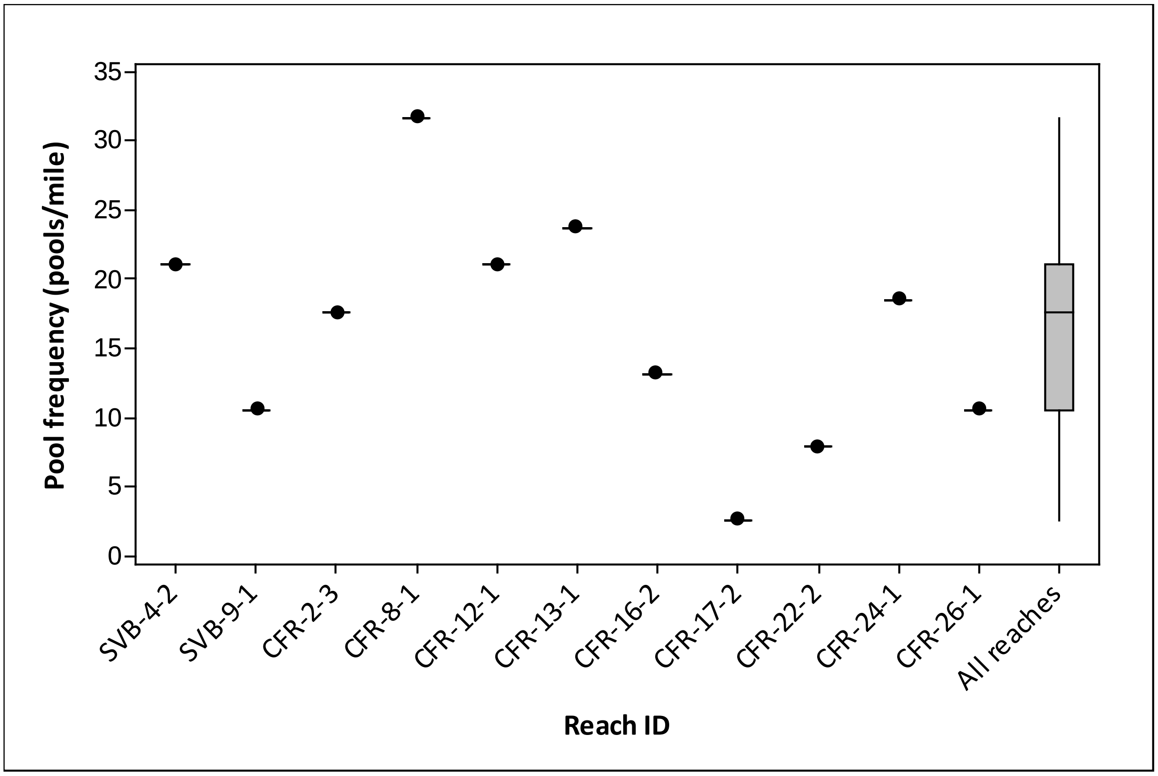

Figure C3-19. Pool Frequency (pools/mile) by Sample Location

C3.2.2.10 Large Woody Debris Frequency

The greatest concentration of LWD was found in CFR-26-1 the most downstream sampled reach on the Clark Fork mainstem (**Figure C3-20**). In general, LWD was rare among the assessed sites in the Upper Clark Fork TPA, which is predominantly willow-dominated. Upper reaches of the main CFR also are willow-dominated. Historic clearing of floodplain vegetation and reduced vegetation growth on tailings deposits may also contribute to low LWD counts.

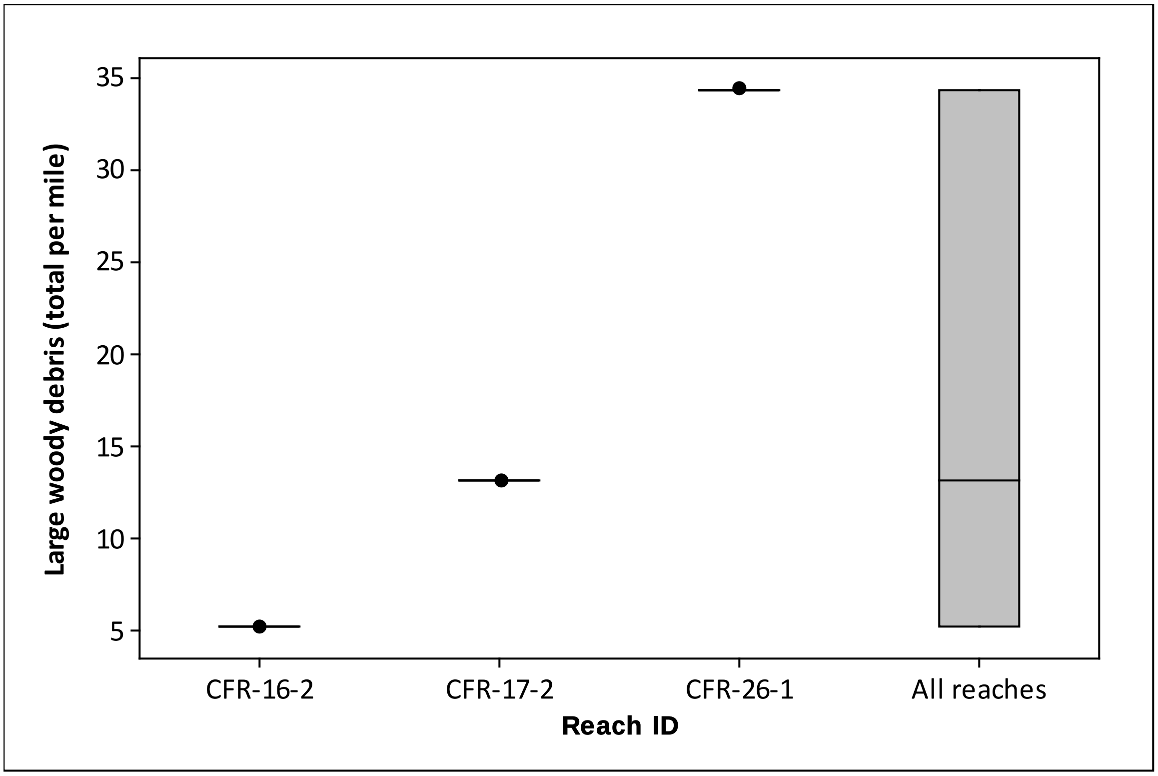

Figure C3-20. Large Woody Debris (total per mile) for Reaches in the Clark Fork River where Large Woody Debris Was Recorded

C3.2.2.11 Greenline Understory Shrub Cover

Reach SVB-4-2 had the highest percentage of understory shrub cover, at 76.5%. Nine of the 11 reaches sampled had less than 50% shrub cover. Four of the 11 reaches sampled had less than 20% shrub cover. (**Figure C3-21**). CFR-12-1, CFR-13-1 and CFR-16-2 are located immediately upstream and downstream of the city of Deer Lodge, Montana.

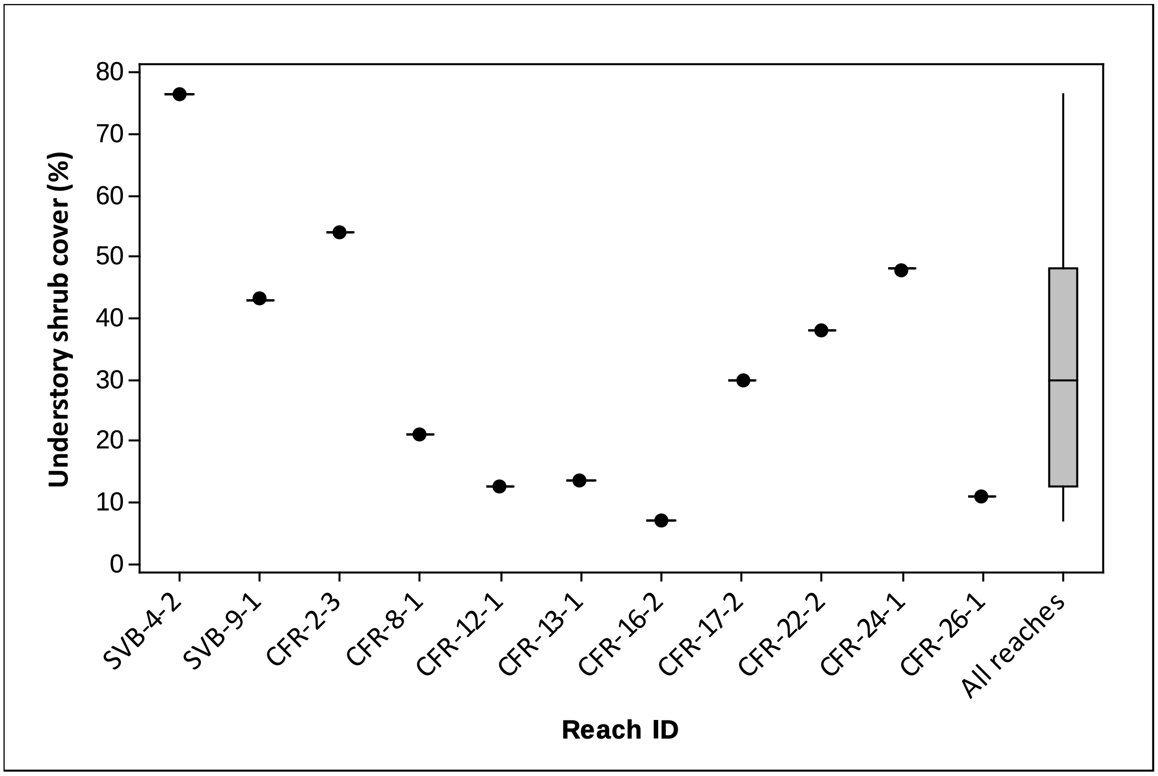

Figure C3-21. Understory Shrub Cover (%) by Sample Location

C3.2.2.12 Greenline Bare Ground

The highest percentage of bare ground was found at CFR-12-1. Two of the eleven sites surveyed had 20% or more bare ground, while approximately 5 of 11 reaches had less than 10% bare ground (**Figure C3-22**).

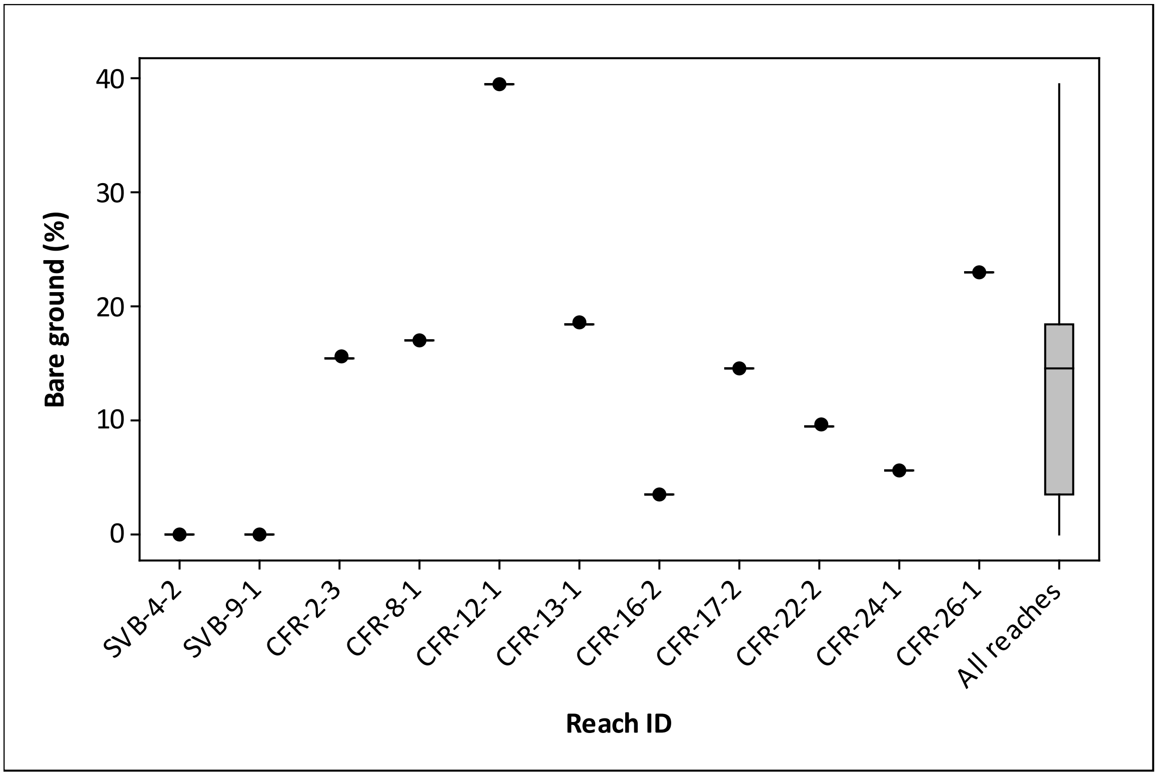

Figure C3-22. Bare Ground (%) by Sample Location

C4.0 Streambank Erosion Assessment

C4.1 Methods

Streambank erosion data were collected at 11 monitoring sites in the Upper Clark Fork TPA. At each of the sites, eroding streambanks were assessed for erosion severity and categorized as either "actively/visually eroding" or "slowly eroding/vegetated/undercut." **Bank Erosion Hazard Index (BEHI)** measurements were performed and **Near Bank Stress (NBS)** was evaluated at each eroding bank (Rosgen, 1996; Rosgen, 2006). Bank erosion severity was rated from "very low" to "extreme" based on the BEHI score, which was determined based on the following six variables: bank height, bankfull height, root depth, root density, bank angle, and surface protection. NBS was also rated from "very low" to "extreme" depending on the shape of the channel at the toe of the bank and the force of the water (i.e., "stream power") along the bank. In addition, the source, or underlying cause, of streambank erosion was evaluated based on observed anthropogenic disturbances within the riparian corridor, as well as current and historic land-use practices observed within the surrounding landscape. Source of streambank instability was identified based on the following near-stream source categories: natural, historic, residential/urban, irrigation, timber, mining, cropland and "other," for sources not included in the other categories. Sources of erosion in the "historic" or "other" categories included historic mining activities, historic beaver removal, and channel straightening in the Upper Clark Fork TPA. Natural sources of streambank erosion included natural channel scour or wildlife trails. If multiple sources were observed, then a percent of the total influence was estimated for each source.

Streambank erosion data collected at **monitoring sites** were extrapolated to the **stream reach**, **stream segment**, and **sub-watershed** scales based on similar reach type characteristics as identified in the Aerial

Assessment Database. Sediment load calculations were performed for monitoring sites, stream reaches, stream segments, and sub-watersheds which are distinguished as follows:

Assessment Reach	*- A 500-, 1,000-, 1,500-, or 2,000-foot section of a stream reach where field monitoring was conducted*
Stream Reach	*- Subdivision of the stream segment based on ecoregion, stream order, gradient and confinement as evaluated in GIS*
Stream Segment	*- Assessed segment*
Sub-Watershed	*- Assessed segment and tributary streams based on 1:100,000 NHD data layer*

The annual sediment load was estimated for each assessed bank based on the streambank length, mean height, and the annual retreat rate for each eroding streambank. The length and mean height were measured in the field, while the annual retreat rate was determined based on the relationship between the BEHI and NBS ratings. Annual retreat rates for the Upper Clark Fork TPA were estimated based on retreat rates from Rosgen BEHI studies in Colorado (Rosgen, 1996) (**Table C4-1**). While the predominant geologies between the Colorado research sites and the upper Clark Fork are different, they are similar enough in character to warrant their application. The annual sediment load in cubic feet was then calculated from the field data (annual retreat rate x mean bank height x bank length), converted into cubic yards, and finally converted into tons per year based on the bulk density of streambank material, which was assumed to average 1.3 tons/yard^3 as identified in *Watershed Assessment of River Stability and Sediment Supply* (WARSSS) (Rosgen, 2006; United States Environmental Protection Agency, 2006). This process resulted in a sediment load for each eroding bank expressed in tons per year.

Table C4-1. Annual Streambank Retreat Rates (ft/yr), Colorado, U.S. Department of Agriculture Forest Service (adapted from Rosgen (2006))

BEHI	NBS					
	Very Low	Low	Moderate	High	Very High	Extreme
Very Low	NA	NA	NA	NA	NA	NA
Low	0.02	0.05	0.07	0.16	0.32	0.67
Moderate	0.09	0.15	0.25	0.42	0.70	1.16
High - Very High	0.17	0.25	0.38	0.58	0.87	1.32
Extreme	0.16	0.42	1.07	2.75	7.03	17.97

C4.1.1 Streambank Erosion Sediment Load Extrapolation Method

Monitoring site sediment loads were extrapolated to the stream reach, stream segment and sub-watershed scales based on the aerial assessment reach type analysis and field-verified reach types for assessment sites. Streambank erosion data were extrapolated using the following procedure:

1. Monitoring site sediment loads were extrapolated directly to the stream reach in which the monitoring site was located, based on total loading per 1,000 ft.
2. Existing streambank erosion sediment loads were extrapolated to un-assessed reaches based on average sediment loading/1,000 ft from assessed sites for each reach type. Field data were collected within 2 individual reach types that were delineated by confinement, stream order and gradient. There were no un-assessed reach types for Silver Bow Creek and the Clark Fork River upstream of Flint Creek (**Table C4-2**).

Table C4-2. Measured Reach Types and Average Sediment Loads per Reach Types

Measured Reach Type	Number of Monitoring Sites	Measured Reach Type Avg. Sediment Load/1,000 ft (tons/yr)	Un-assessed Reach Types Grouped with Measured Reach Type
MR-0-5-U	2	4.3	All reaches in MR-0-5-U
MR-0-6-U	9	38.6	All reaches in MR-0-6-U

C4.1.2 Streambank Erosion Sediment Load Reduction Analysis Methods

The narrative water quality standards that apply to sediment relate to the naturally occurring condition, which is defined as conditions that occur if all reasonable land, soil, and water conservation practices are applied. To assist with TMDL development, the streambank erosion assessment includes an estimation of sediment loading reductions that could be achieved if implementation of Best Management Practices (BMPs) were applied to achieve naturally occurring condition. Streambank erosion sediment load reductions were evaluated based on field collected data and anticipated reductions through BMP implementation along the Clark Fork River mainstem and Silver Bow Creek. Given the extensive historic channel alteration and sediment deposition in in these systems, all reaches in the Clark Fork River mainstem are considered to be anthropogenically influenced. Anthropogenic alteration includes the sediment deposition from early 20th Century flooding up to existing land management practices leading to bank instability. Reductions from bank erosion were calculated from the following:

1. BEHI and NBS scores were calculated for 123 banks in Silver Bow Creek and in the Clark Fork River upstream of Flint Creek. While NBS will decrease with increased access to the floodplain. Improvements to bank cover, shaping and stability will decrease BEHI scores. The range of scores is in **Table C4-1**.
2. Sediment volume from bank erosion was normalized and the average value calculated for each BEHI/NBS score combination from the 123 assessed banks (**Table C4-3**).

Table C4-3. 2011 DEQ Average Sediment Volume per BEHI/NBS Score for Assessed Banks in Silver Bow Creek and the Clark Fork River Upstream of Flint Creek

	NBS Rating		
BEHI Rating	**Moderate**	**Low**	**Very Low**
Extreme	*No data*	1.93	*No data*
Very High	*No data*	1.03	1.27
High	*No data*	0.86	0.51
Moderate	1.04	0.54	0.22
Low	*No data*	0.09	0.03

All units are normalized to cu. ft./1 foot of bank length

3. The BMP reduction scenario assumed that banks with BEHI scores greater than Moderate (Extreme, Very High, High) can be reduced to Moderate. No assumptions were made regarding changes to NBS as this will likely require a long-term reduction in width/depth ratio and increase in entrenchment ratio. As an example, a bank with a BEHI/NBS of High/Low was assigned the average sediment load from Moderate/Low (0.54 cu. ft./1 foot of bank length).
4. For banks with BEHI scores less than Moderate (Low, Very Low), no changes were made from the assessed sediment load. As an example, for a bank with a BEHI/NBS of Low/Low the normalized sediment load from that bank was not changed even if it was greater than the average volume from **Table C4-3** (Low/Low = 0.09 cu. ft./1 foot of bank length).
5. Reductions from this BMP scenario were determined based on the composite reduction between the existing bank erosion sediment load and the BMP scenario for banks specific to each sub-watershed.

6. Sub-watershed composites included all upstream segments. For example, the Clark Fork River upstream of the Little Blackfoot River included the Clark Fork River segment from Warm Springs Ponds to Cottonwood Creek and the segment from Cottonwood Creek to the Little Blackfoot River as well as Silver Bow Creek.

C4.2 Streambank Erosion Results

C4.2.1 Streambank Erosion Sediment Load Reduction

A total annual sediment load of 656.7 tons/year was attributed to the 123 assessed eroding streambanks within the 11 sites monitored for streambank erosion in the Upper Clark Fork TPA by DEQ in 2011. Average annual sediment loads for each monitoring site were normalized to a length of 1,000 feet for the purpose of comparison. Sediment loads per 1,000 feet for each monitoring site are presented in **Figure C4-1**. Sediment loads per 1,000 feet ranged from 1.1 tons/yr at site SVB-4-2 to 57.3 tons/yr at site CFR-13-1. **Table C4-3** also lists monitoring sites for each reach type, with load totals by reach and reach type.

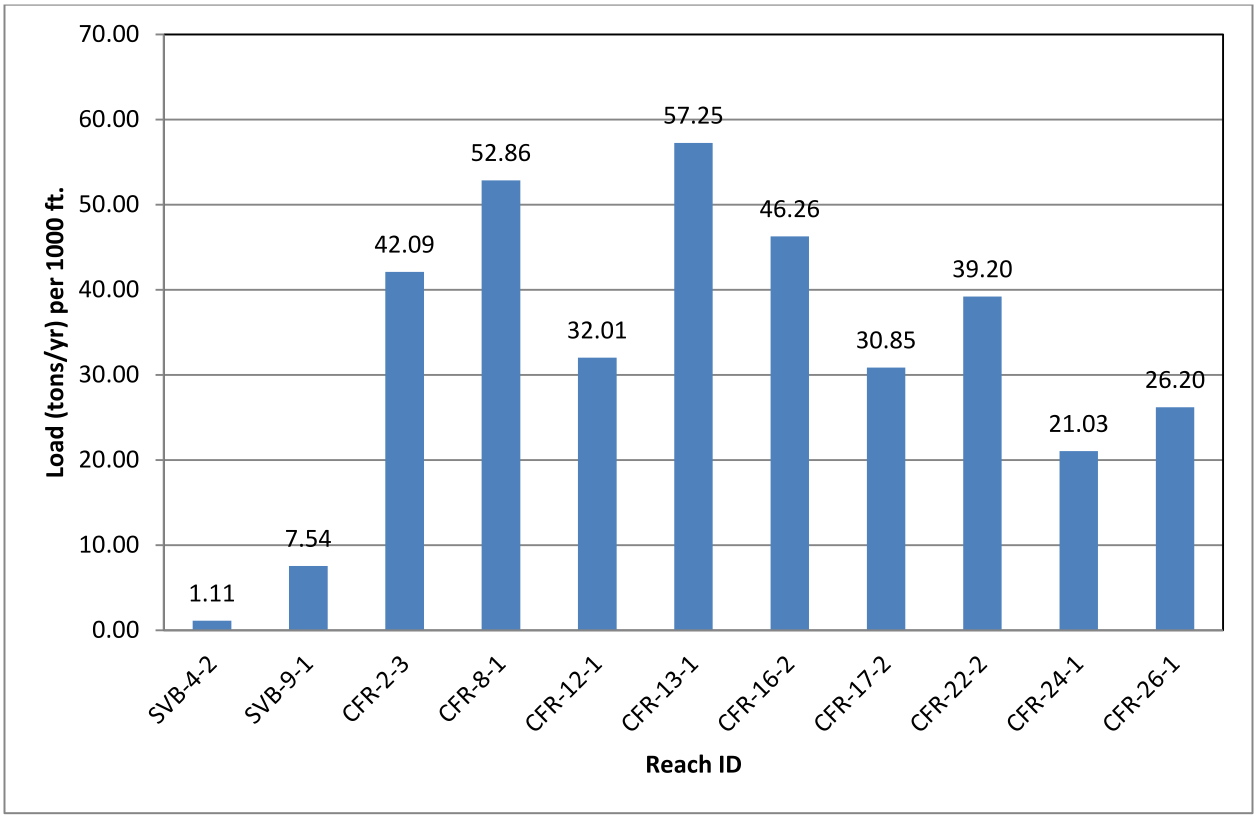

Figure C4-1. Assessment Site BEHI Sediment Load per 1,000 ft

Table C4-4. Streambank Erosion Summary for 2011 DEQ Field Work in Silver Bow Creek and the Clark Fork River Upstream of Flint Creek

Reach Type	Reach ID	Reach Length	Load per 1,000 ft (tons/yr)	Number of Assessed Banks	Sub-Watershed
MR-0-5-U	SVB-4-2	1000	1.11	5	Silver Bow Creek
MR-0-5-U	SVB-9-1	1000	7.54	3	
MR-0-6-U	CFR-2-3	1500	42.09	11	Clark Fork River, Warm Springs Ponds to Cottonwood Creek
MR-0-6-U	CFR-8-1	1500	52.86	9	
MR-0-6-U	CFR-12-1	2000	32.01	20	
MR-0-6-U	CFR-13-1	2000	57.25	16	Clark Fork River, Cottonwood Creek to Little Blackfoot River
MR-0-6-U	CFR-16-2	2000	46.26	16	
MR-0-6-U	CFR-17-2	2000	30.85	16	
MR-0-6-U	CFR-22-2	2000	39.20	8	Clark Fork River, Flint Creek to Little Blackfoot River
MR-0-6-U	CFR-24-1	2000	21.03	8	
MR-0-6-U	CFR-26-1	2000	26.20	11	

As described in **Section C4.1.2,** bank erosion reduction estimates were based on a decrease in the BEHI/NBS ratings to a Moderate BEHI rating by replacing calculated sediment erosion volume with the average sediment erosion volume for a given BEHI/NBS rating. Summarized sediment loads for the existing condition and the improved BMP scenario with the overall % reduction are provided per sub-watershed in **Table C4-5**.

Table C4-5. Calculated Bank Erosion Percent Reductions for Silver Bow Creek and the Clark Fork River Upstream of Flint Creek

Sub-Watershed	Existing Bank Erosion Load (cu. ft./yr)	BMP Scenario Bank Erosion Load (cu. ft./yr)	Percent Reduction
Silver Bow Creek	191.32	191.32	0%
Clark Fork, upstream of Cottonwood Creek	2699.34	2109.67	22%
Clark Fork, upstream of Little Blackfoot River	5749.60	3890.48	32%
Clark Fork, upstream of Flint Creek	7232.59	4935.37	32%

C5.0 Assumptions and Uncertainty

This assessment assumes that different streams with similar reach type characteristics will have similar physical attributes and sediment loads due to streambank erosion.

The analysis contains several potential sources of uncertainty:

- Calculating segment and reach lengths from GIS layers also may a create uncertainty, since layers are digitized based on topographic maps and generally underestimate stream lengths.
- Some degree of uncertainty is inherent in the BEHI methods and categorization of sediment loading by erosion source, as the index values for the BEHI ratings are based on studies conducted in a similar region but different geographic location, and percent loading due to different erosion sources must be estimated using best professional judgment.

- The identification of sediment as a pollutant in many streams in the Upper Clark Fork TPA relate to the fine sediment fraction found on the stream bottom, while streambank erosion sediment modeling examined all sediment sizes.
- Since sediment source modeling may underestimate or overestimate sediment inputs due to selection of sediment monitoring sites and the extrapolation methods used, model results should not be taken as an absolutely accurate calculation of sediment production within each assessment unit. Instead, the streambank erosion assessment model results should be considered an instrument for estimating sediment loads and making general comparisons of sediment loads from various sources.
- Per the BMP reduction scenario, implementation of all reasonable land, soil and water conservation practices can reduce BEHI ratings to Moderate.

C6.0 Summary

The 2011 sediment and habitat assessment in the Upper Clark Fork TPA provides a broad-scale analysis of existing sediment conditions within impaired stream segments and estimated streambank erosion sediment loads for use in TMDL development. A total of 46 reaches were delineated during the aerial assessment reach stratification process covering approximately 101.5 miles of stream. Only 2 distinct reach types were assigned within the one Level III Ecoregion (Middle Rockies) in the Upper Clark Fork TPA based on stream and landscape characteristics. Sediment and habitat variables and streambank erosion were assessed at 11 monitoring sites. Statistical analysis of the sediment and habitat data from the monitoring sites will aid in developing sediment TMDL targets that are specific for the Upper Clark Fork TPA, while streambank erosion data and calculated load reductions will be used in the sediment TMDL. A total annual sediment load of 666.9 tons/year was attributed to the 123 assessed eroding streambanks within the 11 sites monitored for streambank erosion in the Upper Clark Fork TPA. Based on a BMP reduction scenario using BEHI/NBS ratings, it is estimated that this sediment load can be reduced by 22–32% from streambanks in the Clark Fork River upstream of Flint Creek. A 0% reduction in streambank erosion from restored reaches in Silver Bow Creek was also determined based on the slowly eroding banks which all had BEHI ratings equal or less than moderate.

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