SEDIMENT BENEFICIAL USE SUPPORT ASSESSMENT FOR MIDDLE AND LOWER SEGMENTS OF BITTERROOT RIVER

Addresses Bitterroot River Assessment Units MT76H001_020 and MT76H001_030

Contributing authors:
Dave Feldman
Kyle Flynn
Elizabeth Hezel
Darrin Kron
Christian Schmidt

June 19, 2014

1.0 INTRODUCTION

In the spring of 2013, the Water Quality Planning Bureau of the Planning, Prevention and Assistance Division of Montana DEQ decided to re-assess the existing sediment impairment listings on the mainstem of the Bitterroot River. The Bitterroot River from the confluence of the East and West Forks to the mouth is divided into 3 segments which span 85.1 miles. The 3 segments were last formally assessed for sediment by DEQ in 2003.

The lower segment of the Bitterroot River flows 23.6 miles from the Eightmile Creek confluence to the mouth (Clark Fork River) (MT76H001_030) (**Figure 1**). First listed for sedimentation/siltation in 2000, the stream is identified on the 2012 303(d) list as not supporting aquatic life. The middle segment of the Bitterroot River includes 34.3 miles between the Skalkaho Creek and Eightmile Creek confluences (MT76H001_020). The middle segment was first listed for sedimentation/siltation in 1988 and is identified as not supporting primary contact recreation or aquatic life beneficial uses. Both segments are B-1 use class. The upper segment of the Bitterroot River is not listed for a sediment impairment on the 2012 303(d) list (27.2 mi from East and West Forks to Skalkaho Creek) (MT76H001_010).

Waterbody Name & Description	AU ID	2012 IR Sediment Related Pollutant/Pollution Listing
Upper Bitterroot River – East and West Forks to Skalkaho Creek	MT76H001_010	Alteration in stream-side or littoral vegetative covers
Middle Bitterroot River – Skalkaho Creek to Eightmile Creek	MT76H001_020	Low flow alterations
		Sedimentation/Siltation
		Temperature
Lower Bitterroot River – Eightmile Creek to mouth (Clark Fork River)	MT76H001_030	Alteration in stream-side or littoral vegetative covers
		Sedimentation/Siltation
		Temperature

It should be noted that the upper and lower segments of the Bitterroot River are also listed for habitat alterations (non-pollutant listings), the lower segment is listed for lead, and that the middle and lower segments are listed for temperature impairments. Additionally the middle segment is also listed for low flow alterations. Temperature TMDLs for these segments were completed in 2011 (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011). In addition, Montana Fish, Wildlife and Parks lists a portion of the middle segment as chronically dewatered (dewatering is a significant problem most years). This portion includes 17 miles of the Bitterroot River mainstem from ≈1 mile downstream of the Woodside Bridge west of Corvallis, MT to the Stevensville Bridge (**Figure 1**).

The objective of this assessment is to examine the effects of sediment to beneficial uses on the mainstem of the Bitterroot River. As a medium-sized river system, most metrics and approaches developed for smaller streams cannot be directly applied. A multi-tiered approach using multiple lines of evidence was used to re-assess the mainstem segments of the Bitterroot River. This approach encompassed sediment parameters including channel form and function, fine sediment data collected by DEQ personnel in September 2011, and suspended sediment loading dynamics using USGS flow and water quality data. In addition, aquatic health was reviewed using fish population data collected by

Montana FWP and aquatic macroinvertebrate samples collected by several different entities, including EPA and DEQ from mainstem sampling locations. Results are presented throughout the rest of the document.

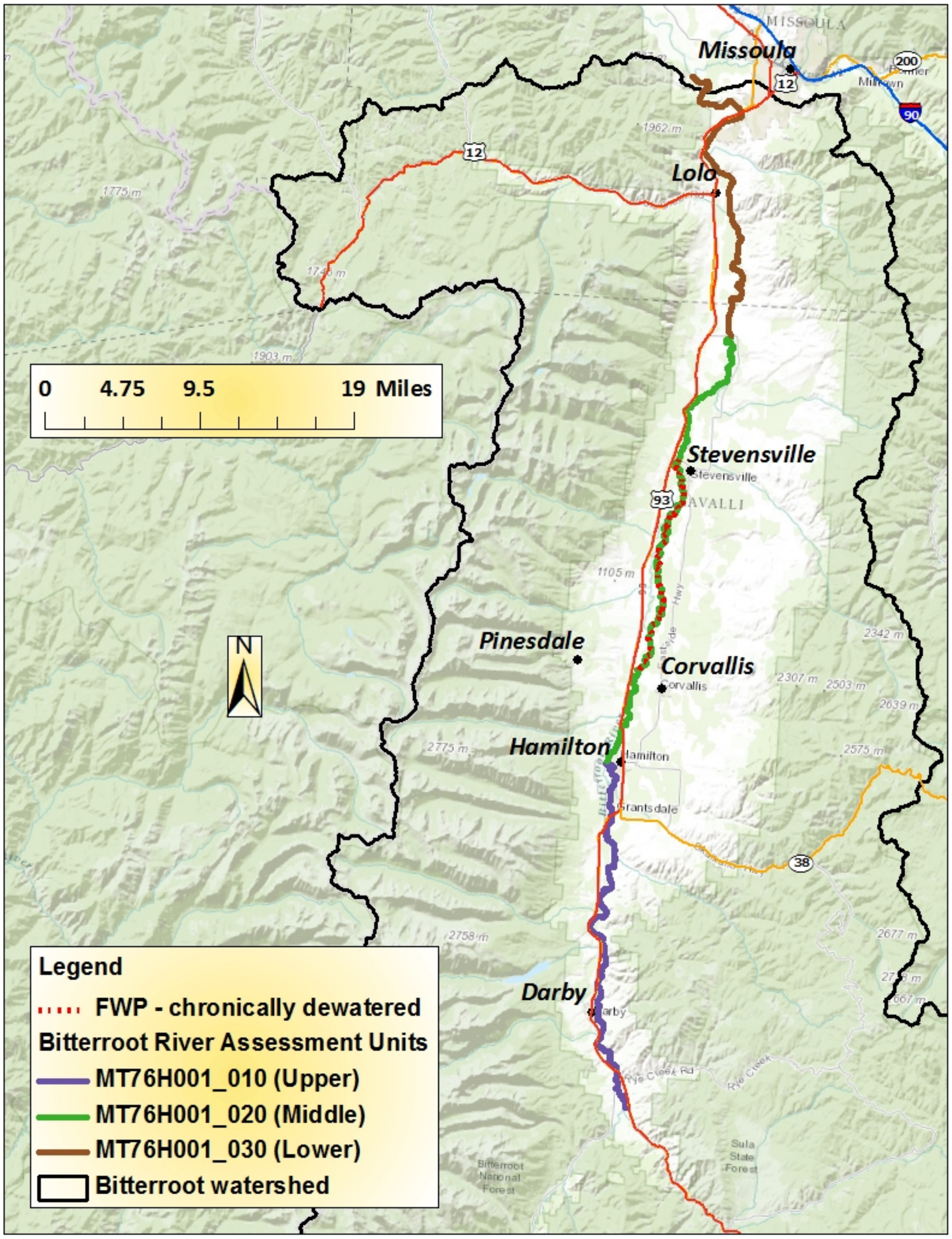

Figure 1. Bitterroot River assessment units downstream of Hamilton, MT.

1.1 Approach

Montana's sediment assessment method for western Montana Wadable Streams does not apply to the Bitterroot River because of its size. For a medium-sized river system such as the Bitterroot River, the sediment assessment follows a weight of evidence approach linking sediment conditions to the most sensitive beneficial use support, which is aquatic life. It includes

- Stream channel form and function analysis (**Section 2.1**),
- Fine benthic sediment analysis (pebble counts, grid toss, etc.; **Section 2.2**),
- Suspended sediment transport evaluation (**Section 2.3**),
- Biological data review (**Section 3.0**).

Each of the above sections are followed by a brief justification of why the data suggest that the river is fully supporting beneficial uses relative to potential sediment affects. We conclude with a discussion wrapping up our beneficial use support determination.

2.0 SEDIMENT ASSESSMENT

2.1 STREAM CHANNEL FUNCTION AND FORM

The Bitterroot River is historically known to have active, migrating banks, and braided sections. In fact, such morphology can occur naturally in high energy, snow-melt dominated systems. Alternatively, anthropogenic influences such as bank armoring, poor riparian condition, or other channel modifications can also alter the river and change its form or function. We qualitatively assess each of these conditions in the following sections.

2.1.1 Natural Factors Influencing Bank Erosion

The Bitterroot River is prone to accelerated rates of erosion, transport, and deposition during large flood events. In fact, this is the primary mechanism that drives a majority of the changes in the channel pattern and river course (Boyd and Thatcher, 2008). In this regard, the river can be classified into several geomorphic channel types: (1) straight- and entrenched-B4; (2) meandering-C4; (3) braided- D4; and (4) anastomosing-Da4 (using Rosgen, 1994). Spatially, the B4 channel types tend to be located upstream of Silver Bridge (upper watershed) and are associated with total flood plain belt widths of less than 500 feet. The relatively wide braided (D) and meandering/braided (C/D) channel types exist primarily between Woodside Bridge and Stevensville Bridge in the lower watershed (Boyd and Thatcher, 2008). These appear to be naturally prone to stream braiding and avulsion.

Other Bitterroot River reaches are more prone to single channels due to complex geologic factors. For example, between Stevensville and Lolo, there is an eastward migration of the river, and south of Stevensville to Hamilton there is a westward migration. These migrations are likely explained by two rotational faults, the Stevensville Fault and the Charlos Heights Fault (Cartier, 1984). These faults provide probable explanations for the following channel and landscape characteristics (Cartier, 1984):

- The straight reach of the Bitterroot River upstream of Hamilton, MT,
- The point at which the river changes from a single to a multi-channel pattern,
- The point at which the theoretical and topographic longitudinal profile diverge transport in the Bitterroot River,
- The Darby tertiary volcanic field,
- The Sleeping Child Hot Springs near Hamilton.

Hence some natural factors influence the channel behavior. In fact, Boyd and Thatcher (2008) suggest these greatly influence channel erosion and patters during flood flows. Potential anthropogenic effects are described in the next section.

2.1.2 Anthropogenic Factors Influencing Bank Erosion

Manmade structures such as bank armor and bridges also influence river sedimentation. A fairly comprehensive assessment of these features has already been completed on the Bitterroot River. Riprap and other bank armor are used to limit bank erosion and protect private property and transportation infrastructure, including highways and railroads (Boyd and Thatcher, 2008). Of 61 river miles (122 miles of bank) mapped between the Rye Creek confluence and the Ravalli/Missoula County line (Darby to Florence), 12% of the observed bank length is affected by armoring. Types of armor include cabled logs, car bodies, concrete, logs, toe riprap, full bank riprap, and root wads. The most common form of armor is riprap which extends the full face of the bank and was documented to be in place of 9.5% of the total bank length assessed by Boyd and Thatcher (2008).

A large percentage of banks are actively eroding in the watershed (36%). Although armoring may shift locations in aquatic species habitat, it is unlikely to reduce overall pool formation, cause fine sediment accumulation, or over-widen the channel in any given section of river. In most applications hardened bank treatments decrease channel width and increase pool depths near the riprap due to vertical scour. This is accompanied by a concomitant increase in pool crest height and width in the adjacent downstream area. Hence the overall effect of hardening may affect only localized sediment conditions, leading to aggrading or degrading due to an increase in vertical sheer stress from deflection of horizontal sheer stress. The exception is in the areas influenced by the natural fault zones described in **Section 2.1.1**. The most severe erosion was found between Darby and Hamilton where 15% of the bank was mapped as severely eroding. This increase in erosion is most likely caused by the valley becoming more confined (Boyd and Thatcher, 2008).

Roadways and bridges also influence local erosion. An inventory and mapping of bank erosion on banks indicate that there are no significant increases or decreases in bank stability near bridges (Boyd and Thatcher, 2008). Likewise, roadway encroachments do not appear to trigger reach-scale changes in channel pattern or alignment. Nonetheless, these are only qualitative observations which potentially suggest anthropogenic effects are greatly overshadowed by natural processes. Therefore, a more quantitative approaches are needed and these are described in the following sections.

2.1.3 Width to Depth

Width to depth (W/D) ratios measured in the Bitterroot River between the Rye Creek confluence south of Darby to the Ravalli/Missoula County line range from 30 to 65 and are expected for a river with the approximate roughness, discharge volume, and channel slope as those found in the Bitterroot River (Boyd and Thatcher, 2008). Boyd and Thatcher (2008) also compared historic W/D ratios (from the 1930s to the 1960s) to data that was collected during 1992/1993 to observe the changes near six bridges along the Bitterroot River mainstem. When compared, there was no evidence to suggest that the bridge structures significantly changed the width to depth ratios in the mainstem (Boyd and Thatcher, 2008). Assessed bridges included: (1) Silver Bridge, (2) Woodside Bridge, (3) Victor Bridge, (4) Bell Crossing, (5) Stevensville, and (6) Florence Bridge. Bridges (1) – (5) are entirely within the middle segment of the Bitterroot River. Florence Bridge (6) is located at the boundary between the middle and lower assessment units of the Bitterroot River. For each assessed bridge, impacts were local and confined to an area within a few thousand feet of bridge structures. While roadway encroachments, bank armoring, and bridge spans have local impacts to channel alignment and pattern, they do not appear to control or trigger reach-scale changes in channel pattern in the assessed portion of the Bitterroot River (Boyd and Thatcher, 2008).

2.1.4 Riparian Condition

Previous assessments of the Bitterroot River suggest that the riparian area is in good condition. In fact, Boyd and Thatcher (2008) indicate that it is relatively healthy and regeneration and recruitment of cottonwood, willow, and various confiner species in various age classes appear to be occurring. This is generally supported by previous interpretation and analysis by DEQ which indicate that a 100+ foot buffer exists on a large percentage of the river (PBS&J 2007). As a consequence, despite vigorous and diverse plant community types and even dense vegetative cover, it appears that the riparian area has little effect on the erosional behavior and stability of the river channel (Boyd and Thatcher, 2008).

2.2 Fine Benthic Sediment Analysis

Fish spawning can be affected by the fine sediment which accumulates in pool tails and riffles. Modified Woman pebble counts, and pool tail grid tosses were collected from 6 sites in the middle and lower segments of the Bitterroot River in September 2011 to determine the percentage of fines at each location. The 6 sites included locations near:

Lower segment
- Maclay Bridge (upstream)
- Lolo Park
- Chief Looking Glass Bridge

Middle segment
- Stevensville, MT
- Victor, MT
- Hamilton, MT

2.2.1 Pebble Counts in Riffles

At least 100 substrate measurements were collected along four evenly spaced transects within a riffle at each site for a total of more than 400 measurements per site. The percentage of fines in the pebble counts less than 2mm and less than 6mm are provided in **Table 1**, along with the D50 value for the riffle. In the field, the substrate was categorized as wet, dry fluvial, or dry non-fluvial. During data collection, it was observed that fine sediment was accumulating along the dry non-fluvial part of the channel. Because of this observation, the wet and dry fluvial parts of the channel were separated from the dry non-fluvial to quantify this fine sediment. The entire channel, including all fluvial and non-fluvial parts of the riffle, is expressed in **Table 1** as “All.”

As shown in **Table 1**, all sites contained values less than the riffle pebble count sediment targets identified in the Bitterroot Temperature and Tributary Sediment Total Maximum Daily Loads and Framework Water Quality Improvement Plan (2011). This TMDL document for Bitterroot River tributaries provides sediment targets in the Middle Rockies ecoregion for riffle pebble counts as the percentage of fines <2 mm to be ≤ 10%, and the percentage of fines < 6 mm fines to be ≤ 14%. Particle size distribution curves were created to see if there is a bimodal distribution which may indicate fine sediment sources within a watershed. The distribution curves for all sites (not shown) are not bimodal, with the maximum distribution similar to the respective D50 size. For the Hamilton site, the median particle size in the riffle was determined to be too large for spawning fish to move and a pool grid toss measurement was not made.

2.2.2 Pool Tail Grid Toss

Seven to 14 grid tosses were collected along a single pool crest at each site, excluding the Hamilton site where the stream substrate was too large for the methodology and where fish spawning was unlikely to occur. The D50s at the other sites were in the “coarse” to “very coarse” gravel range of 16 mm to 64 mm (**Table 1**). For pool tail grid tosses, the TMDL target value applied to Bitterroot River tributaries for less than 6 mm is ≤ 6%. All 2011 DEQ mainstem Bitterroot River sites were less than or equal to this target.

Table 1. Pebble Count and Pool Tail Grid Toss Results

Site Name	Riffle D50 (mm)	Pebble Count				Pool Grid Toss- % <6mm
		Fluvial - % <2mm	All- % <2mm	Fluvial - % <6mm	All - % <6mm	
Maclay Bridge (upstream)	35.9	2.2%	3.7%	6.8%	8.5%	6.0%
Lolo Park	24.6	2.6%	3.0%	5.4%	5.8%	4.3%
Chief Looking Glass	26.8	5.0%	6.2%	6.3%	7.4%	5.4%
Stevensville	35.7	3.4%	3.8%	4.0%	4.4%	1.1%
Victor	46.8	1.8%	1.8%	3.1%	3.1%	2.0%
Hamilton	79.2	3.7%	3.7%	4.0%	4.0%	*Not measured* [1]
[1] Spawning gravels not present as determined by D50; grid toss measurement not recorded.						

Based on these fine sediment indicators above, it appears that there is little evidence to suggest impairment in the middle or lower Bitterroot River assessment segments.

2.3 Suspended Sediment Transport Evaluation

Suspended sediment transport conditions were also considered as these are another quantitative line of evidence for assessing the river’s stability. Several different aspects of the sediment transport relationship were investigated: (1) a comparison with ecoregional load-response curves for stable rivers and (2) a comparison with a reference location within the watershed. Both of these are quasi-reference approaches, but nonetheless they address whether or not the Bitterroot River is comparable in stability to other locations that are unimpaired.

2.3.1 Comparison with Ecoregionally-derived Load Response Curves

A comparison between ecoregionally-based load-response curves of stable and unstable streams and the Bitterroot River watershed was initiated (*sensu* Klimetz et al. 2009). Since the Bitterroot River is located within three different Level III ecoregions (**Table 2**, **Figure 2**), this analysis is somewhat tenuous as the largest percentage of the watershed area (and flow) originate from the Idaho Batholith, which was not characterized. This is then followed by the Northern Rockies (i.e., Lolo Creek), and then by the dry eastern side which drains the Middle Rockies. Even so, a coarse assessment of load transport curves can be made.

Table 2. Level III ecoregions and overlapping percentage with the Bitterroot watershed. Note that watershed area does not necessarily reflect the relative streamflow contribution volume.

Level III Ecoregion	Area (sq. mi)	As % of total area
Northern Rockies	243.01	8.57%
Middle Rockies	936.32	33.02%
Idaho Batholith[a]	1656.32	58.41%

This region was not characterized by Klimetz et al. (2009)

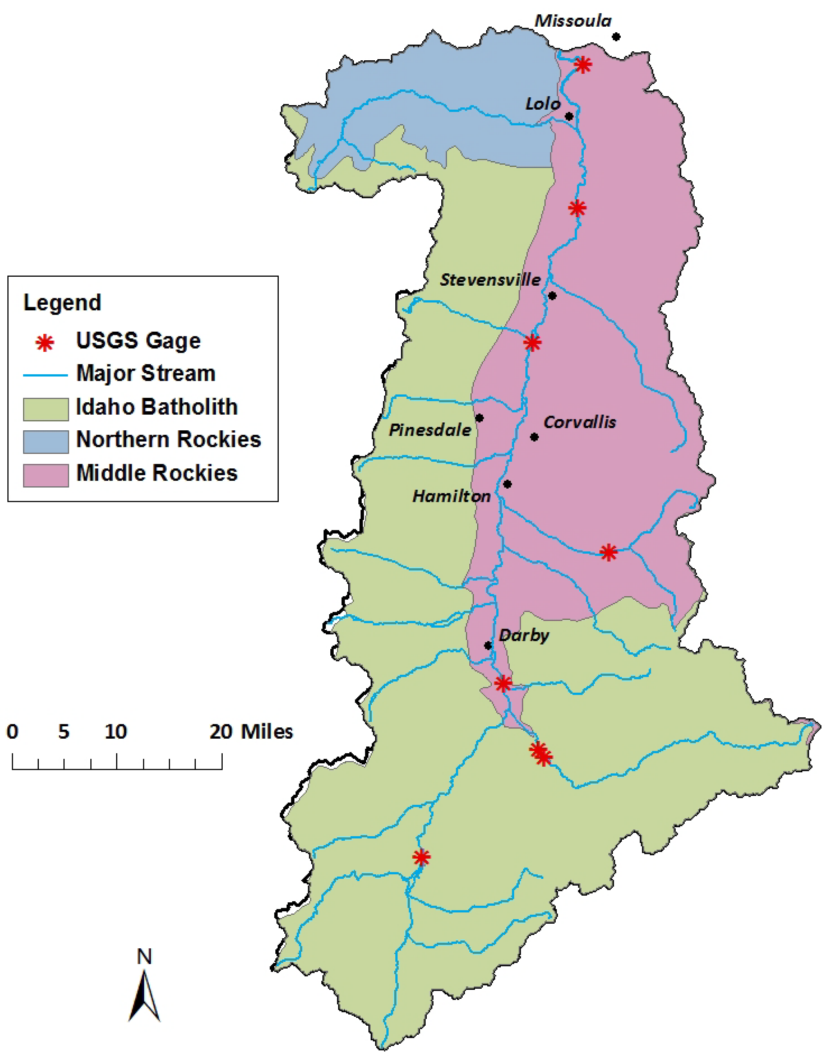

Figure 2. Level III ecoregion map of the Bitterroot watershed.

In Klimetz et al. (2009), sediment transport conditions for rivers in EPA Region 8 were compared by evaluating suspended sediment load relationships for stable and unstable river systems. This was done by first developing the load-discharge transport regression (i.e., equation relating daily suspended sediment load in tonnes per day with daily discharge in m^3/s) and then either by (1) directly comparing this curve to stable or unstable systems within the ecoregion, or (2) computing an effective discharge (or $Q_{1.5}$) and using this value to compute daily load ($L_{1.5}$) and subsequently daily yield ($Y_{1.5}$, i.e., tonnes per day per km^2). The second method fails to account for the fact that a single sediment transport curve with constant unit area discharge will produce different yields due solely to discharge (i.e., $Q_{1.5}$). Hypothetically then, for two different watersheds having the same sediment load production for a given flow (i.e., the same concentration *vs.* flow or load *vs.* flow curve), but differing $Q_{1.5}$, a different $Y_{1.5}$ can result. This makes comparison using the $Q_{1.5}$ approach difficult.

Because of the above difficulty, we chose to directly make comparisons using the load-discharge rating curves (see **Section 2.3.1** below). Accordingly, we tabulated data USGS 12352500 Bitterroot River near Missoula, MT, which is in the lower reach (see Appendix). Discharge and suspended sediment measurements (pcodes 61 and 80155) were regressed following conversion to metric units and results are shown in **Figure 3**. Accordingly, the Bitterroot River falls on the regression line for "stable" Middle Rockies ecoregion rivers and is within the 25-75th percentile of the Northern Rockies ecoregion. We have also plotted two river sites in the Idaho Batholith (USGS 13302500 Salmon River at Salmon, ID and USGS 13338500 SF Clearwater River at Stites, ID), which seem to suggest there is little discernible difference in the load-discharge curve between the Bitterroot River and Idaho Batholith. Hence it is concluded generally, that the Bitterroot River is a "stable" system.

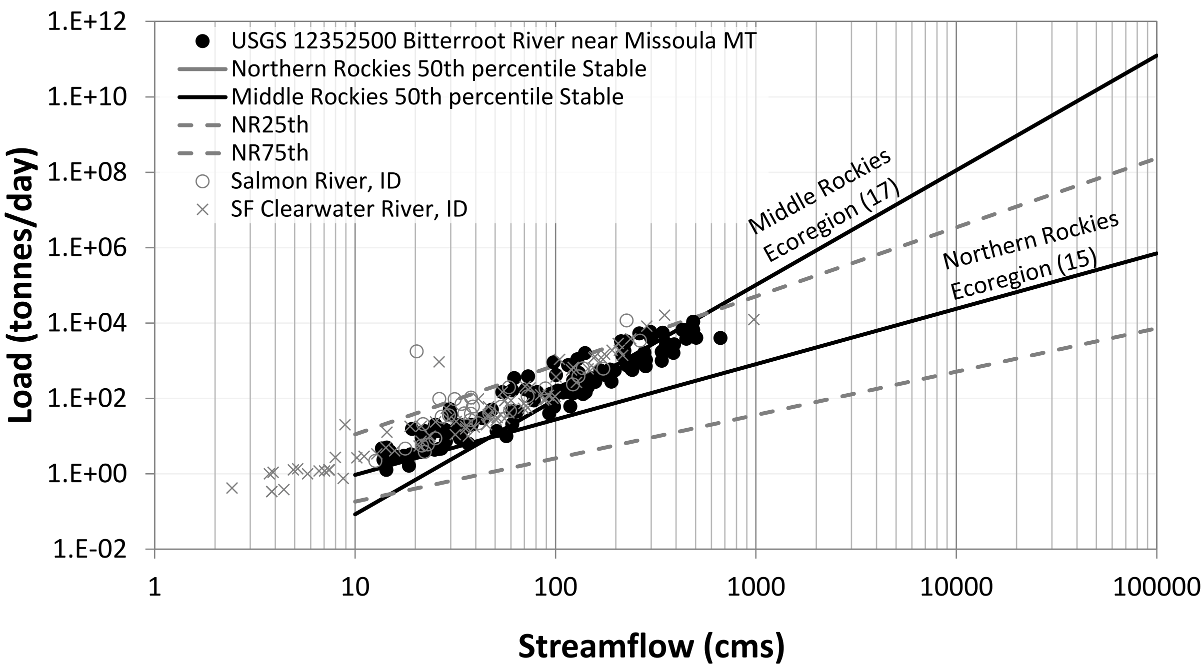

Figure 3. Comparative analysis suspended sediment load-discharge relationships for the Bitterroot River (near Missoula) with that of stable streams and rivers in the Middle Rockies and Northern Rockies ecoregions (Klimetz et al., 2009) and two rivers within the Idaho Batholith of similar size.

Although these results are convincing, characterization of stable and unstable streams in the Klimetz et al. (2009) study is still questionable, as they completed only limited site characterization to determine stability (i.e., observations made only near the gage), and likewise they were unable to find a statistically significant difference in the slope of the regression between stable and unstable sites within the Middle Rockies ecoregion. Because of this, a second analysis is completed in the next section with an unimpaired site from the Bitterroot River watershed (using an identical approach).

2.3.1 Bitterroot River Watershed Reference Sediment Transport Comparison

A comparison between the sediment load-discharge curves in the lower watershed with a reference location was done to assess spatial changes in the watershed that may suggest anthropogenic impacts. In this regard, the river's headwaters were judged to be reference (i.e., 12344000 Bitterroot River near Darby; not impaired by sediment on the 2012 303(d) list), which were compared with USGS 12352500 Bitterroot River near Missoula, MT, which is in the lower watershed (currently listed as impaired). The analysis was done for the period of 1997-current, which represents all available data.

Results are shown in **Figure 4**. They exhibit similarity with origin of 0 and slope (e.g., exponent) of unity meaning that nearly a 1:1 relationship exists between flow and sediment load in the watershed. This means very little difference exists in suspended sediment transport for a given flow regardless of location.

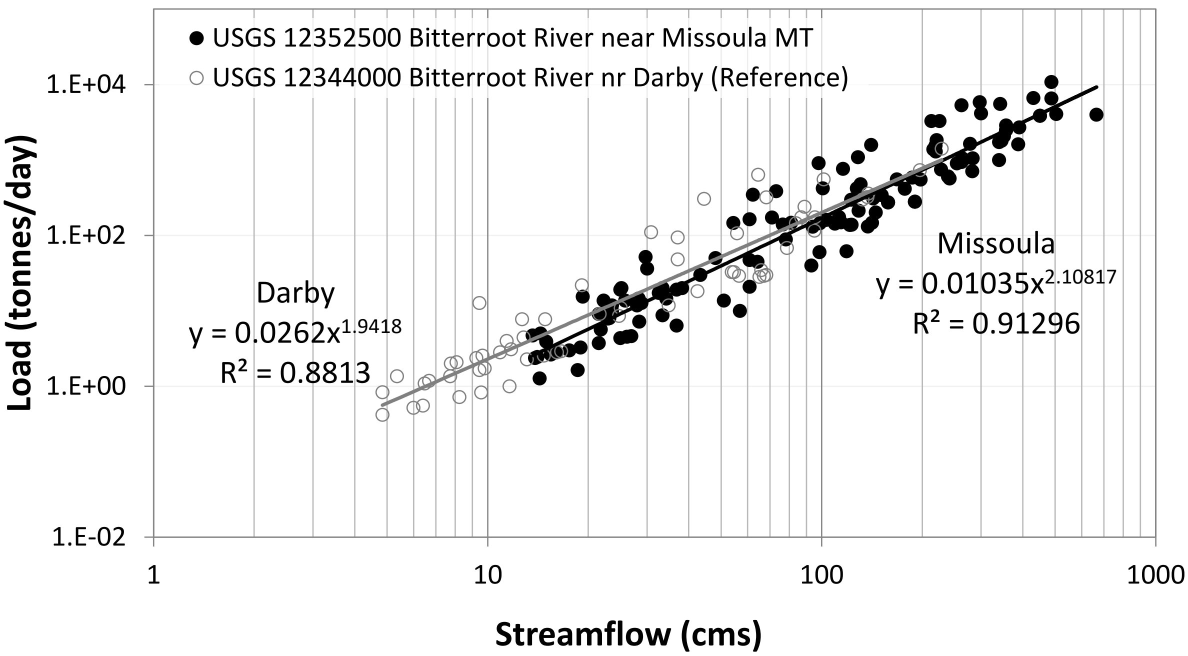

Figure 4. Comparison between the suspended sediment rating curves for (a) USGS 12344000 Bitterroot River near Darby and (b) USGS 12352500 Bitterroot River near Missoula, MT. There is a large difference in the streamflow magnitude at the two sites, yet the rating curves have similar slopes (≈1) and an intercept of 0 (if log transformed). Slopes are statistically different ($p<0.001$).

The magnitude of the exponent in **Figure 4** is of utility as it describes the response of the channel to high and low flow events (Klimetz et al. 2009). In this instance, they were nearly identical indicating that no appreciable shift in sediment transport or loading occurs between the upper and lower watershed. In this regard anthropogenic impacts are likely minimal. To test whether the two sites are identical, a two-sample t-test was constructed with the null hypothesis that there was no difference between the slopes of the sites (i.e., b_1-b_2 = 0). In this case, there was a difference at the 0.01 level ($p<0.001$) [1], hence sediment-discharge is not identical at both Darby and Missoula. Unfortunately such a test does not

[1] The standard deviation for each regression's slope coefficient was determined according to Devore (2012).

discern the cause why (i.e., it could be either natural or anthropogenic) and thus we consult further lines of evidence in subsequent sections (**Section 3.0**).

2.4 Sediment Assessment Summary

Based on the sediment assessment results presented in **Section 2.0**, DEQ believes there is sufficient evidence to suggest that Bitterroot River segments MT76H001_020 and MT76H001_030 are not impaired from sediment. General conclusions include the following:

- Channel form and function appear sufficient to support fish habitat via pool and dynamic channel structure. Additionally, there are few human influences along the river margin. Hence stream channel form and function appear to be supporting their intended uses (fish and aquatic life).

- The most recent fine sediment measures from all sites (both the middle and lower segment) were below the sediment targets developed in the Bitterroot Tributary TMDL. Both riffle pebble and pool tail targets were below their desired value at any location. Hence fine sediment deposition is not occurring and does not appear to be exceeding thresholds that would affect aquatic life use.

- Analysis of the suspended sediment-discharge indicates that the lower Bitterroot River is within the 75^{th} percentile of the Northern and Middle Rockies ecoregions for stable streams and is very similar to that measured in both the Salmon and SF of the Clearwater Rivers in Idaho (Idaho Batholith). Comparison of load-discharge curves with a reference gage in the watershed indicates minimal deviation in load-discharge curve.

Based on the review of physical data, we conclude the river is comparable in channel form and function to stable reference locations within the State (and elsewhere).

3.0 Aquatic assessment

Montana Fish Wildlife and Parks (FWP) has been collecting fish population data from 4 sampling reaches in the Bitterroot River mainstem since 1989. Analysis of population trends over the period of record were used to quantify aquatic health at different locations of the river. In addition, macroinvertebrate data collected within the last 10 years were also used to assess aquatic life health based on species sensitivity to environmental conditions.

3.1 Effects on Fish

Two different approaches can be taken to assess fishery use support: (1) analysis of the actual trends in fish populations in the river and (2) comparison of sediment conditions in the river with that of the literature. Only the former was used due to the site-specific nature of the available data.

3.1.1 Fish Population Trend Analysis

The Montana Department of Fish, Wildlife, and Parks (FWP) routinely samples rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) through electrofishing at several different locations in the mainstem Bitterroot River to characterize population stability (**Table 3)**. Analysis is focused on rainbow trout and brown trout because more sensitive fish species, such as bull trout (*Salvelinus confluentus*) and Westslope cutthroat trout (*Oncorhynchus clarkia lewisi*), are rare in the Bitterroot River and are not present at all throughout much of the year (MFISH, 2013). Sampling typically occurs in late September/early October; the exception is near Missoula which is sampled in the early spring[2]. Data from FWP were analyzed for trends by trout species (rainbow, brown) and by location (Darby, Bell Crossing, Stevensville, Missoula) using a Mann-Kendall nonparametric test to determine whether the fishery was stable, improving, or declining. Analysis was completed for the sample population (e.g., all captured fish from 8+ inches) which was constrained to the electrofished reaches.

Table 3. Summary of rainbow and brown trout population data for the Bitterroot River mainstem in western Montana (MFISH, 2013).

Sampling reach (upstream to downstream)	Trout species	Sampling timeframe	Total years of available data[a]
Darby	rainbow	1982-2012	13
	brown	1983-2012	12
Bell Crossing	rainbow	1989-2011	9
	brown	1989-2011	9
Stevensville	rainbow	1989-2011	10
	brown	1989-2011	8
Missoula	rainbow	1999-2009	7
	brown	2000-2009	3

[a] Given the small sample size statistical analyses were not conducted for brown trout in the Missoula Reach (n=3 years).

The Mann-Kendall test (Helsel and Hirsch, 2002) is a nonparametric test that can be used to identify whether population (Y) tends to increase or decrease with time (T) in a monotonic way (i.e., either increasing or decreasing, but not both). The null (H_0) and alternative hypothesis (H_a) are,

H_0: Prob $[Y_j > Y_i] = 0.5$, where time $T_j > T_i$.
H_a: Prob $[Y_j > Y_i] \neq 0.5$

where i and j are subscripts denoting subsequent observations in time. The presence of a trend (i.e. meaning the null hypothesis would be rejected) is based on evaluation of whether subsequent observations are systematically different than previous ones. Kendall's tau (τ) provides evidence for the direction of the trend, and the significance of the test is judged on whether Kendall's S is further from 0 than expected (i.e., meaning the null hypothesis is to be rejected). The test requires no assumptions of normality and determines whether the median changes over time. In this case, a level of significance of 0.10 (α=0.10) was used[3].

Results of the analysis are shown in **Table 4** (on a per site basis[4]) for the period of record 1989-2011.The Mann-Kendall test found significant (α=0.10) upward trends in fish populations for rainbow or brown

[2] The Missoula reach dataset includes only adult fish estimates as juveniles are often too few in number to calculate population estimates. The lack of juvenile capture data in the Missoula reach is directly related to the timing of the sampling in early spring.
[3] Note: such a test does not determine whether sediment is the underlying cause of the population trend, only that a trend occurs. Thus it is merely another diagnostic that can be used to confirm that a population is in stable condition, but not identify the reason why.
[4] An intercomparison between locations was not completed for 2 reasons: (a) there was no way to adjust data for physical differences between the sites (i.e. temperature, land use, habitat) and (b) different reaches were sampled

trout at both the Bell Crossing and Stevensville sampling reaches. There were no significant (α=0.10) downward trends observed for rainbow or brown trout in any of the 4 sampled reaches (meaning they were stable). These findings suggest either stable or improving conditions are present in the middle and lower segments of the Bitterroot River. There were no apparent trends at the control site (Darby), which is considered reference. Subsequently, while many factors affect fish populations (e.g., sediment, temperature, habitat, etc.) results of the trend test suggest that the sampled reaches in the river have been either stable or improving over the last 20 years (at the 0.10 percent confidence level).

While more sensitive species of fish, such as bull trout and Westslope cutthroat trout, are not abundant in the mainstem of the Bitterroot River much of the year (M-FISH, 2013), it should be noted that this is not attributed to excess fine sediment. Fine sediment data presented in **Section 2.2**, show percent fines at levels low enough to protect even sensitive fish species (Bryce, 2010). Additionally, fine sediment data collected on the middle and lower segments of the Bitterroot River are all below the sediment targets identified in the Bitterroot Temperature and Tributary Sediment Total Maximum Daily Loads and Framework Water Quality Improvement Plan (2011), which were developed to protect these sensitive fish species. Given the low percentage of fines throughout the middle and lower sections of the Bitterroot River, and the fact that fisheries biologists suggest the abundance of sensitive fish would not be widespread in the main-stem river, these results are not surprising.

Table 4. Results of Mann-Kendall hypothesis tests to evaluate trends in fish population in the Bitterroot River. Tests carried out according to Helsel and Hirsh (2002).

Site and Period of Record	*n*	Rainbow Trout			Brown Trout		
		Ho: No trend	Accept	Reject	Ho: No trend	Accept	Reject
Darby (1989-2012)	10 | 9	τ_K=-0.11 P<0.728	X		τ_K=0.39 P<0.18	X	
Bell Crossing (1989-2009)	10 | 9	τ_K=0.64 P<0.0092		X, ↑	τ_K=0.56 P<0.0440		X, ↑
Stevensville (1989-2011)	10 | 8	τ_K=0.11 P<0.728	X		τ_K =0.75 P<0.0099		X, ↑
Missoula (2005-2009)	5 | na	τ_K=0.00 P<1.184	X		Insufficient data		

Accept: Fail to reject the null hypothesis (i.e., the population is stable).
Reject: Sufficient evidence exists to reject the null hypothesis (at the 0.10 level), ↑=increasing trend; ↓ = decreasing trend

3.2 Effects on Other Aquatic Life (Macroinvertebrates)

Macroinvertebrate communities were also assessed to determine other potential impacts to aquatic life uses. DEQ typically applies a version of the Observed/Expected (O/E) model to determine impacts from sediment (and other pollutants) to macroinvertebrate communities. However, the O/E model for Montana is only pertinent to specific waterbody sizes (Montana Department of Environmental Quality, 2006; Montana Department of Environmental Quality, 2012) and unfortunately the Bitterroot River is not one of these. As a consequence, we used a species-specific analysis approach towards assessment.

---

in different years thus making direct comparisons difficult. However, trends at each site could be evaluated to determine whether any long term changes had occurred within the sites.

The dataset used in our evaluation contained 34 samples collected at 9 different locations along the river (**Table 5**). Samples were collected between 2000 and 2005 in mid to late summer. Although the compilation represents data from all river segments, 65% of the samples were collected near Maclay Bridge close to the mouth with the Clark Fork River.

Table 5. Summary of available macroinvertebrate data for the Bitterroot River

Segment	Assessment Unit ID	Bitterroot River location description	Number of Samples	Years of Collection
Lower	MT76H001_030	At Maclay Bridge near mouth	22	2001-2005
		At Riverside Park (Lolo)	1	2005
		East of Lower Chief Looking Glass Road	1	2005
Middle	MT76H001_020	At Stevensville Bridge	1	2005
		At Victor Crossing	1	2005
		At Hamilton Bridge	1	2005
Upper	MT76H001_010	At Old Darby Road Bridge	5	2003-2005
		At Hannon Fishing Access	1	2005
		Downstream of confluence of East and West Forks	1	2003

Based on these samples, there were a large number of both sediment tolerant and intolerant invertebrates collected. According to Relyea et al. (2000), the sediment sensitive taxa collected from the river included: *Megarcys* sp., *Arctopsyche* sp., *Claasenia sabulosa*, and *Tricorythodes* sp. Their relative percentage tended to decrease in the lower segment compared to the middle segment. This largely is expected based on the River Continuum Concept (Vannote et al., 1980). There were also several invertebrates found that can handle moderate instream fine sediment levels including: *Antocha* sp., *Hydropsyche* sp., *Drunella grandis*, *Baetis* sp., *Brachycentrus americanus*, *Acentrella* sp., *Glossosoma* sp., *Optioservus* sp., and *Zaitzevia* sp., which were present at all sites. Finally, several invertebrate taxa adapted to thrive in streams with high fine sediment levels were found including: *Cheumatopsyche* sp., *Simulium*, sp., and *Tipula* sp., again at all locations. Hence the results are fairly inconclusive, but seem to indicate a relatively consistent situation in terms of fine sediment in the Bitterroot River with a wide diversity of species found at all sites.

3.3 Aquatic Assessment Summary

Based on the aquatic assessment, it appears sediment conditions on the Bitterroot River are supporting intended uses based on the fish assessment. Primary determinations are as follows:

- The trend in rainbow and brown trout populations in the mainstem suggest either stable or improving conditions in the middle and lower segments of the Bitterroot River with no apparent trends at the control site (Darby). Personal communication with FWP fishery biologist Chris Clancy suggests that sediment is likely not a factor with respect to the fishery (2013).

- A review of available macroinvertebrate data was inconclusive. In all 3 river assessment units, the macroinvertebrate community was comprised a mix of sensitive and tolerant organisms. Therefore it is difficult to assess macroinvertebrate community with respect to fine sediment.

4.0 CONCLUSIONS

The Bitterroot River is a medium-sized system with significant power and seasonal flows capable of transporting large volumes of suspended sediment and sorting sediment size fractions within the channel. Based on our analysis of stream channel form and function, fine benthic sediment analysis, suspended sediment transport evaluations against reference conditions, and biological data review, it is concluded that sediment conditions in the middle and lower segments of the Bitterroot River are supporting their intended beneficial uses. Physical channel attributes were not outside the expected target ranges in all instances, and while there may be discrete locations where channel influences are present, evidence to support the de-listing includes the following:

- Channel form and function appear sufficient to support fish habitat via pool and dynamic channel structure.

- The most recent fine sediment assessment from all sites (both the middle and lower segment) was below the sediment targets developed in the Bitterroot Tributary TMDL. Both riffle pebble and pool tail targets were below their desired value at any location.

- Analysis of the suspended sediment-discharge indicates that the lower Bitterroot River is within the 75th percentile of the Northern and Middle Rockies ecoregions for stable streams and is nearly identical to that measured in both the Salmon and SF of the Clearwater Rivers in Idaho (Idaho Batholith). Furthermore, comparison with a reference gage in the watershed indicates that only a small increase in the load transport capacity occurs which suggests few, if any, anthropogenic sediment sources exist in the middle and lower watershed.

- A review of available fish and macroinvertebrates suggest populations of rainbow and brown trout in the middle and lower segments are stable or improving over time. No conclusive results were obtained through macroinvertebrate analysis.

As a consequence, we conclude in recommending that segments MT76H001_030 (lower Bitterroot River) and MT76H001_020 (middle Bitterroot River) be assessed as fully supporting all beneficial uses with respect to sediment conditions.

5.0 REFERENCES

BOYD, KARIN AND TONY THATCHER. 2008. BITTERROOT RIVER GEOMORPHIC SUMMARY: MAINSTEM CHANNEL AND BRIDGE CROSSINGS RAVALLI COUNTY, MONTANA. HELENA, MT: MONTANA DEPARTMENT OF TRANSPORTATION.

BRYCE, SANDRA A., GREGG A. LOMNICKY, AND PHILIP R. KAUFMANN. 2010. PROTECTING SEDIMENT-SENSITIVE AQUATIC SPECIES IN MOUNTAIN STREAMS THROUGH THE APPLICATION OF BIOLOGICALLY BASED STREAMBED SEDIMENT CRITERIA. *THE NORTH AMERICAN BENTHOLOGICAL SOCIETY*. 29(2):657-672.

CARTIER, KENN D. 1984. SEDIMENT, CHANNEL MORPHOLOGY, AND STREAMFLOW CHARACTERISTICS OF THE BITTERROOT RIVER DRAINAGE BASIN, SOUTHWESTERN MONTANA. MASTER THESIS.: UNIVERSITY OF MONTANA.

CLANCY, CHRISTOPHER C. 2013. PERSONAL COMMUNICATION.

HELSEL, DENNIS R. AND ROBERT M. HIRSCH. 2002. "STATISTICAL METHODS IN WATER RESOURCES," IN *TECHNIQUES IN WATER-RESOURCES INVESTIGATIONS*, CH. BOOK 4, CH. A3, (RESTON, VA

HOROWITX, A. J. 2003. AN EVALUATION OF SEDIMENT RATING CURVES FOR ESTIMATING SUSPENDED SEDIMENT CONCENTRATIONS FOR SUBSEQUENT FLUX CALCULATIONS. *HYDROLOGICAL PROCESSES.* 17(17): 3387-3409.

KLIMETZ, L, ANDREW SIMON, AND J SCHWARTZ. 2009. CHARACTERIZATION OF SUSPENDED-SEDIMENT TRANSPORT CONDITIONS FOR STABLE, "REFERENCE: STREAMS IN SELECTED ECOREGIONS OF EPA REGION 8. USDA-ARS. TECHNICAL REPORT 61.

LAMBING, JOHN H. AND THOMAS E. CLEASBY. 2006. WATER-QUALITY CHARACTERISTICS OF MONTANA STREAMS IN A STATEWIDE MONITORING NETWORK, 1999-2003. RESTON, VA: U.S. GEOLOGICAL SURVEY. SCIENTIFIC INVESTIGATIONS REPORT 2006-5046.

MFISH. (2013). MONTANA FISHERIES INFORMATION SYSTEM. HTTP://FWP.MT.GOV/FISHING/MFISH/

MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY. 2006. SAMPLE COLLECTION, SORTING, AND TAXONOMIC IDENTIFICATION OF BENTHIC MACROINVERTEBRATES. HELENA, MT: MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY WATER QUALITY PLANNING BUREAU. STANDARD OPERATING PROCEDURE WQPBWQM-009. HTTP://DEQ.MT.GOV/WQINFO/QAPROGRAM/PDF/WQPBWQM-009REV2_FINAL_WEB.PDF.

-----. 2012. SAMPLE COLLECTION, SORTING, TAXONOMIC IDENTIFICATION, AND ANALYSIS OF BENTHIC MACROINVERTEBRATE COMMUNITIES STANDARD OPERATING PROCEDURES. STATE OF MONTANA. WQPBWQM-009 REV #3. HTTP://DEQ.MT.GOV/WQINFO/QAPROGRAM/PDF/SOPS/WQPBWQM-009.PDF:

Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau. 2011. Bitterroot Temperature and Tributary Sediment Total Maximum Daily Loads and Framework Water Quality Improvement Plan: Final. Helena, MT: Montana Department of Environmental Quality. C05-TMDL-03aF.

PBS&J. 2007. Aerial Photography Interpretation for the Bitterroot River Basin Shade/Temperature Model: Methods and Results

Relyea, Christina D., G. W. Minshall, and Robert J. Danehy. 2000. Stream Insects As Bioindicators of Fine Sediment. *Proceedings of the Water Environment Federation.* 2000(6): 663-686.

Rosgen, David L. 1994. A Classification of Natural Rivers. *Catena.* 22: 169-199.

Runkel, Robert L., Charles G. Crawford, and T. A. Cohn. 2004. "Load Estimator (LOADEST): A FORTRAN Program for Estimating Constituent Loads in Streams and Rivers.," in *Techniques and Methods*, Ch. Book 4, Ch. A5, (Reston, VA: =United States Geological Survey;)

United States Department of Interior, Geological Survey. 2013. USGS Water Data for the Nation - NWIS. Washington, DC: U.S. Geological Survey. http://nwis.waterdata.usgs.gov/nwis/nwisman. Accessed 6/10/2013.

Vannote, Robin L., G. W. Minshall, Kenneth W. Cummins, James R. Sedell, and Colbert E. Cushing. 1980. The River Continuum Concept. *Canadian Journal of Fisheries and Aquatic Sciences.* 37(1): 130-137.

APPENDIX A

A.1 Analysis of the Suspended Sediment-Discharge Relationship

The relationship between suspended sediment concentration (SSC) and flow-discharge is often important to river sedimentation to fill detail between sparse observations. A large percentage of rivers in the United States (U.S.) are data-limited with respect to suspended sediment and therefore methods to make continuous estimates of sedimentation are needed. Two retrospective[5] options exist: (1) rating curves (Horowitx, 2003) which relate suspended sediment concentration (SSC) to discharge, or (2) more sophisticated methods such as the U.S. Geological Survey's (USGS) Load Estimator (LOADEST) program (Runkel et al., 2004). Both were considered for the Bitterroot Rive, which is data-limited with respect to suspended sediment observations within the watershed (United States Department of Interior, Geological Survey, 2013).

A.1.1 Rating Curve Determination

For the rating curve approach, an SSC-discharge relationship was developed for several sites on the river (1997-current): (1) USGS 12344000 Bitterroot River near Darby (**Figure 2a**) and (2) USGS 12352500 Bitterroot River near Missoula MT (**Figure 2b**). Locations were chosen to compare between the river's unimpacted headwaters (e.g., near Darby) and the middle and lower river (where the sediment impairment listings are) could be made. The sediment rating curve takes the form of,

Equation A-1 $$SSC = aQ^b$$

where *SSC*=suspended sediment concentration (mg/L), *a*=empirically derived coefficient (dimensionless), *Q*=streamflow discharge (cfs), and *b*=an empirically derived exponent (dimensionless). This relationship can be readily determined by log-log linear regression[6].

---

[5] We use the terminology retrospective as sedimentation assessments often necessitate looking at historical data to provide a frame of reference. That said, continuous monitoring instrumentation (e.g., turbidity probes or ISCO samplers) can in fact provide a true continuous sediment record which may be useful in some instances.

[6] $\log(SSC) = b\log(Q) + \log(a)$, where *b* is the slope of the log-linear regression and *a* is the y-intercept.