ATTACHMENT B – MEMORANDUM TO FWP FROM APPLIED GEOMORPHOLOGY IN REGARDS TO THE CLARK CANYON CREEK FIELD VISIT, SEPTEMBER 13, 2011

DEQ Comments on Attachment B: This attachment is an independent document that is included here without edit. This attachment is included because it provides significant information that was used to further inform the C factors for the DEQ's *Upland Sediment Source Assessment (***Appendix F***)* BMP cover scenario; and contains recommendations for sediment reductions that may help stakeholders when implementing the TMDL. However, some statements contained herein regarding observations of bank erosion are inconsistent with the results from the DEQ's *Streambank Erosion Source Assessment (***Appendix E***)*. In 2010, the DEQ conducted the *Streambank Erosion Source Assessment* at three 500 ft reaches on Clark Canyon Creek. During this assessment, Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) measurements were collected (bank height, bankfull height, root depth, root density, bank angle, and surface protection). As noted in the memorandum, results from DEQ's bank assessment were not available at the time this memorandum was completed. It is the opinion of DEQ that the DEQ's 2010 Streambank Erosion Source Assessment is a more thorough and accurate characterization of streambank conditions than the one's presented in this Attachment. Additionally, the memo's usage of "point source" language is inconsistent with the DEQ definition of "point source." DEQ defines a point source as a discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, or vessel or other floating craft, from which pollutants are or may be discharged "(§75-5-103, MCA). The DEQ's definition of point source should be considered and distinctions made whenever "point source" is encountered while reading this attachment.

Karin Boyd, P.G.
Applied Geomorphology, Inc.
Specializing in Fluvial Geomorphology

211 N. Grand Ave.
Bozeman, MT 59715
(406) 587-6352

MEMORANDUM

To:	Matt Jaeger, Montana Fish, Wildlife and Parks
From:	Karin Boyd, Applied Geomorphology, Inc.
Date:	September 13, 2011
In Regards To:	Clark Canyon Creek Field Visit

1. Introduction

Clark Canyon Creek is a tributary to the Upper Beaverhead River, entering the Beaverhead approximately 1.5 miles downstream of Clark Canyon Reservoir (Figure 1). The creek is the first major tributary below the dam, entering a robust tailwater fishery at its confluence with the Beaverhead. High sediment loading from Clark Canyon Creek has impacted this fishery due to an occasional imbalance between sediment loads delivered by the creek and transport capacities in the Beaverhead River. The problem has been most pronounced when accelerated sediment delivery on Clark Canyon Creek coincides with low flow releases from Clark Canyon Reservoir. When sediment loading from the tributary is high and flows in the river are low, extensive deposition of fine sediment has occurred in the Beaverhead River, and these events have been associated with declines in fish counts.

The sediment sources within the 11,000 acre Clark Canyon Creek watershed have not been clearly identified. In an effort to identify those sources and develop conceptual sediment management strategies, Applied Geomorphology Inc. (AGI) was retained by Montana Fish Wildlife and Parks (MTFWP) to perform a reconnaissance level site visit and cursory geomorphic assessment. To that end, this document describes observations made during a site visit to Clark Canyon Creek on August 16, 2011. The site visit was attended by myself (Karin Boyd), Matt Jaeger (MTFWP) Katie Tackett (Beaverhead Watershed Committee), Beau Downing (MTFWP), Carl Malesich (Beaverhead Conservation District, BWC Chairman), Tom Miller (R.E. Miller and Sons) and Frank Snellman (Clark Canyon Ranch).

This investigation was reconnaissance in nature and did not include any data collection or analysis. As such, this summary is based purely on field observations, discussions with people familiar with the watershed, and a cursory review of existing information including geologic maps, aerial photography, a Bureau of Reclamation (BOR) sediment transport study, and TMDL-related documents.

Clark Canyon Creek has just over eight miles of mapped channel (MDEQ, 2010). This includes two primary forks, referred to herein as South Fork Clark Canyon Creek and North Fork Clark Canyon Creek (Figure 1). North Fork Clark Canyon Creek drains the flanks of Gallagher Mountain, joining the South Fork approximately four miles upstream of its confluence with the Beaverhead River.

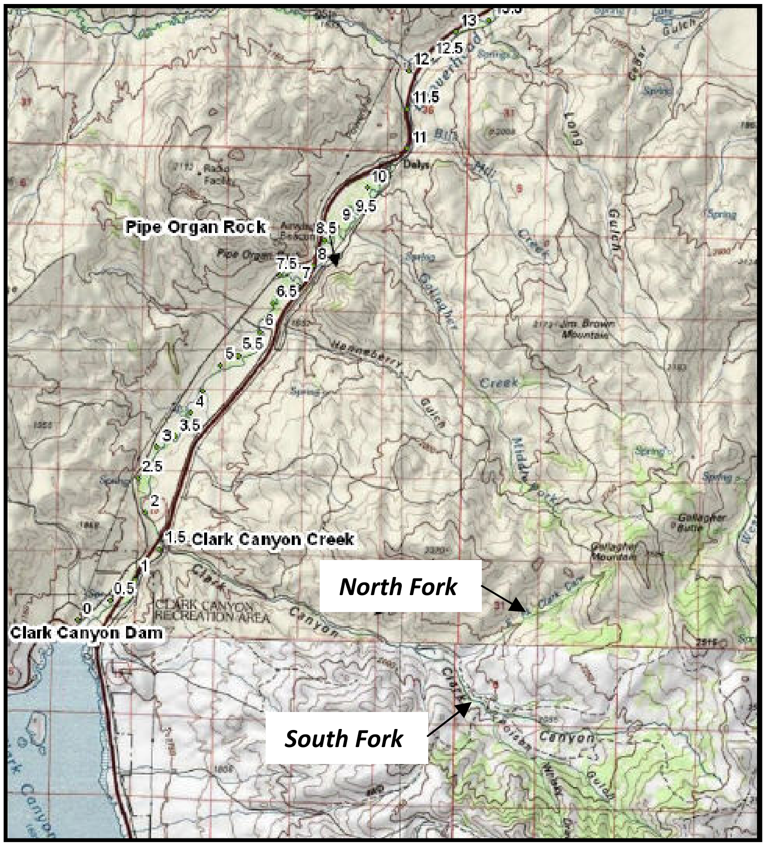

Figure 1. Location map of Clark Canyon Creek with River Miles as distance downstream of dam (BOR, 2010).

Primary findings of this assessment include the following:

- Geologic mapping and field observations indicate that the Clark Canyon Creek watershed is prone to high sediment production rates due to highly erodible source areas and widespread hillslope instability.

- Sediment production is most pronounced from ash-laden Tertiary volcanics. These units are sparsely vegetated, alter to bentonitic clays, and are prone to landsliding and debris flow formation.

- TMDL-related sediment source assessments support the conclusion that uplands are the primary sediment source in the basin. The primary source area appears to be the North Fork of Clark Canyon Creek.

- The ongoing application of BMPs to reduce anthropogenic sediment sourcing from both roads and streambanks should be continued, however these sources are volumetrically minor relative to the hillslope-derived load.

- TMDL source evaluations indicate a potential 50% reduction in hillslope-derived sediment loading with upland BMPs in place, however the BMP condition assumes 85% vegetative cover for scrub/shrub and grassland areas, which may not be achievable on the clay-rich soils.

- Due to the high clay content in the sediment, settling basins are likely not feasible as a sediment control measure.

- Check dams or gully plugs in ephemeral drainages/gullies may help reduce some upland sediment source delivery to Clark Canyon Creek.

- Inducing sediment deposition on a broad fan surface at the mouth of the North Fork may effectively reduce fine sediment loading to the Beaverhead River during flood events.

- Maintaining sufficient flushing flows on the Beaverhead River when Clark Canyon Creek is producing high sediment loads may be the most cost-effective means of minimizing the impacts of these natural inputs on the Beaverhead fishery. Flushing flows should be pursued, and perhaps further evaluated in terms of cross section inundation, to identify the range of flows that result in shallow inundation of the cross section margins. Any flow range that consistently results in shallow inundation of relatively flat channel margin surfaces should be avoided.

2. Geology and Soils

The Clark Canyon Creek watershed straddles two geologic mapping areas, including the Lima 1:100,000 scale map (Lonn and others, 2000), and the Dillon 1:250,000 scale map (Ruppel and others, 1993). Due to the different scales, dates, and authors of the maps, the geologic contacts and rock units are not consistent across the boundary. In order to evaluate the general geology of the area, the two maps were brought into a GIS project, and map units were color coded to match correlative rock types (Figure 2). The results show that the basin consists of the Cretaceous/Tertiary Beaverhead Group (green: Tkb and Tkbq), which consists of massive conglomerate. This unit is overlain by Tertiary-age volcanic rocks (pink and red: Tvu, Trvb and Trvp). Large landslide deposits (cross-hatched) are also mapped in the upper portion of the Clark Canyon Creek basin. The red line on the map is a fault line mapped on the Lima Quadrangle. This northwest trending fault line closely follows the strike of South Fork Clark Canyon Creek.

The geology of the Clark Canyon Creek watershed appears to play a critical role in watershed geomorphology and rates and patterns of sediment production. The Beaverhead Group is exposed in the lower portion of Clark Canyon Creek, where it is locally capped by resistant volcanic rocks, which are mapped as Trvb (Figure 3). Further upstream, relatively erodible layers in the volcanic units are exposed where the valley widens out forming a broad headwaters basin. Large extents of these volcanics have been remobilized as landslides. These landslides locally appear to have formed as debris flows or earth flows, in which a saturated matrix has resulted in gravity-induced mass failure (Figure 4). Bartholomew and others (1999) concluded that late Quaternary landslides, some of which are currently active, have periodically blocked, constricted, or diverted the Beaverhead River in Beaverhead Canyon. They note that “the abundance of landslides in the lower canyon is related to bedrock consisting mostly of mixed volcanic rocks”.

Tertiary-age volcanic rocks are exposed in the valley wall and upland areas within the North Fork of Canyon Creek sub-basin, commonly outcropping as a sparsely vegetated, gullied landform. On the Lima map, which is shown in the southern portion of Figure 2, the primary volcanic unit (pink) is described as air fall and pyroclastic flow tuff and tuffaceous mudstones that are commonly altered to bentonitic clays (Lonn and others, 2000). The authors also note that “landslides commonly develop in this unit”.

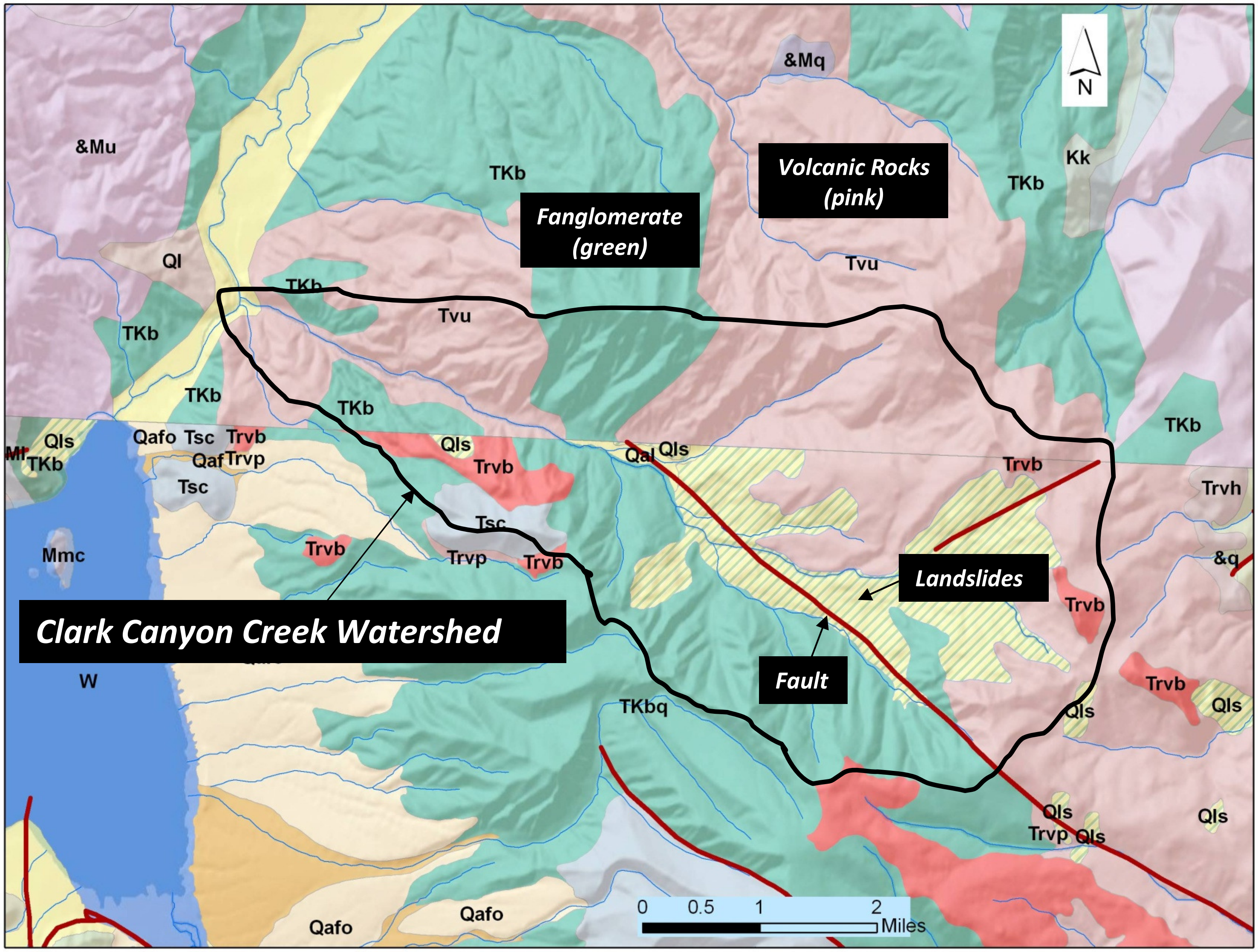

Figure 2. Geologic map of Clark Canyon Creek basin showing major rock types; see text for descriptions.

Figure 3. South valley wall of Clark Canyon Creek showing coarse fanglomerate overlain by a basalt cap.

Figure 4. Landslide/debris flow deposits exposed near confluence of North and South Forks of Clark Canyon Creek.

Figure 5. View upstream of North Fork of Clark Canyon Creek showing exposure of massive fine grained volcanic unit in valley wall.

The fine grained, soft volcanic units appear to create significant slope instabilities in the Clark Canyon Creek watershed. Extensive landslide deposits have been mapped in the upper drainage where the soft volcanic rocks predominate. One such area is shown in Figure 6 where massive instability has resulted in a pinching of the creek between the mass failure and the north valley wall.

2.1 Soils

USDA soils mapping in the Clark Canyon Creek basin support the observations of general hillslope instability associated with the Tertiary-age volcanic rocks. The volcanic exposures within the North Fork Clark Canyon Creek sub-basin are associated with Butchill, Doolittle, and Slagamelt soils, which are described as landslide deposits that are derived from rhyolite (Butchill and Doolittle) or form alluvium and/or debris flow deposits derived from igneous or sedimentary rocks (Slagamelt).

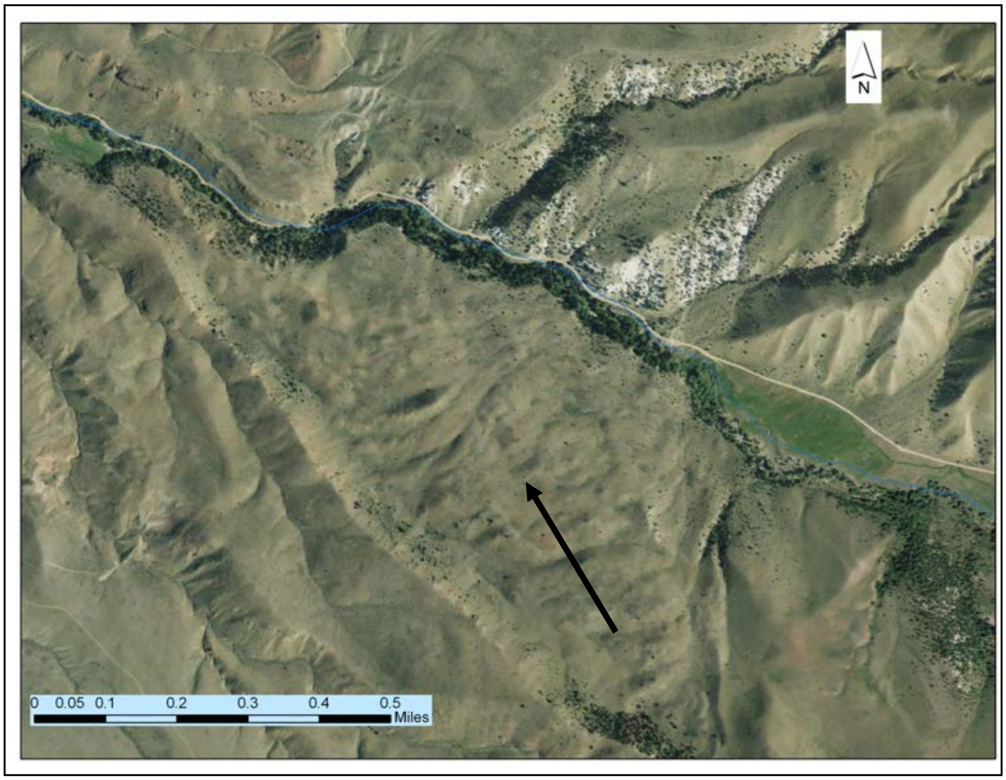

Figure 6. Closeup view of massive earthflow on south valley wall, Clark Canyon Creek; arrow depicts general direction of movement.

3. Sediment Sources in Clark Canyon Creek

One primary objective of this assessment is to consider the sediment sources within the Clark Canyon Creek basin. It is clear from the discussion above that background sediment loading from unstable hillslopes and erodible volcanic units is high. Although hillslopes appear to be a major sediment source in the basin, it is important to consider other potential sources, including streambanks and roads.

3.1 Streambanks

Clark Canyon Creek drains a watershed of approximately 11,000 acres, with a mapped channel length of just over 8 miles (MDEQ, 2010). The main stem of the creek, which extends from the confluence of the north and south forks to the mouth, generally supports a moderately dense woody riparian corridor that is locally confined by the valley wall, a road bed, and/or hillslope failures (Figure 7). Where the valley bottom is relatively wide, it is commonly irrigated for pasture, although during the reconnaissance investigation there was no evidence of accelerated sediment production from streambanks due to livestock. The sediments in the valley bottom are coarse grained and topographically irregular throughout the channel and adjacent floodplain, with local woody debris recruitment and flood deposits evident. Flood deposits are evident as sediment slugs and woody debris accumulations that have locally aggraded the valley bottom and buried the base of cottonwoods. These features indicate that sediment pulses are delivered to the stream corridor during floods.

Figure 7. View upstream of the mainstem of Clark Canyon Creek showing coarse substrate, road bed, and woody vegetation corridor. Photo is taken from recently maintained diversion structure.

As part of the Beaverhead Planning Area TMDL development, a riparian corridor quality assessment was performed by the Montana Department of Environmental Quality. The resulting ratings indicate that on Clark Canyon Creek, 97 percent of the stream length has a “moderately good” to “good” riparian quality (Confluence, 2011). These ratings reflect relatively good riparian conditions on Clark Canyon Creek in relation to the entire Beaverhead Planning Area; out of 20 listed streams in the planning area, 16 were rated as having a majority of stream length classified as a “fair” to “poor” riparian condition.

The only accelerated bank erosion observed in Clark Canyon Creek was where the creek abuts steep valley walls. Even in these areas, however, coarse sediment tended to self-armor the bank toe. The rate of sediment production from these areas has not been quantified, but it appears to be relatively small in comparison to other sources.

3.2 Roads

The mainstem of Clark Canyon Creek is paralleled by a gravel access road that follows the north valley wall. This road has experienced damage during flood events, and multiple culverts have been installed to improve conveyance of both sediment and water from the hillslopes to the valley bottom. In places, the culverts deliver water and sediment to a wide buffer, however in some areas the culverts discharge very close to the stream. Where there is no buffer between the road and the stream, sediment delivery rates from roads are markedly higher.

Although buffer widths are locally narrow such that road sediment is delivered directly to the stream, it is important to consider the overall volume of sediment delivered from roads relative to other sources. The TMDL assessment for the Beaverhead Planning Area included an assessment of sediment delivery from unpaved roads (Atkins, 2011). The results of this assessment indicated that Clark Canyon Creek has 3 road crossings that produce a mean annual load of 0.18 tons of sediment. Two crossings are on private land and one is on BLM property. This is an average of 0.06 tons per crossing, which is equal to the average production rate for assessed crossings throughout the Beaverhead TMDL Planning Area.

For unpaved parallel road segments, the analysis determined that for the entire planning area, approximately 0.0023 tons of sediment are delivered per every 100 ft of road segment located within 150 feet of the stream channel. On Clark Canyon Creek, a 1.25 mile long road segment was identified as contributing, which translates to a mean annual load of 0.15 tons of sediment.

The total mean annual sediment load from unpaved roads in Clark Canyon Creek, which includes both crossings and parallel road segments, is 0.33 tons per year (Atkins, 2011). Atkins estimated that with the application of roads BMPs, this contribution could be reduced by 67% to 0.11 tons per year. The reduction noted in the TMDL document is achieved by "reducing contributing road lengths at unpaved road crossings to 100 feet from either side of the crossing and by reducing contributing road lengths along unpaved parallel road segments to 100 feet" (Atkins, 2011).

At approximately 1.45 tons per cubic yard for rock/soil, the 0.33 tons per year is equivalent to approximately 0.2 cubic yards of sediment per year. For comparison, a standard dump truck has a capacity of 10-12 cubic yards.

3.3 Hillslopes

The TMDL development effort for the Beaverhead Planning area includes an assessment of sediment contributions from hillslope erosion (Confluence, 2011). This assessment consists of a modeling effort using the Universal Soil Loss Equation (USLE) and a sediment delivery ratio to estimate the quantity of hillslope-derived sediment delivered to Clark Canyon Creek, which was modeled as a distinct sub-basin in the analysis. USLE analytical parameters include rainstorm runoff characterization, soil erodibility, slope, overland flow length, vegetative cover, and conservation practices.

Results of the assessment indicate that the upland sediment load for existing conditions in the Clark Canyon Creek watershed is the order of 146.3 tons per year. An evaluation of potential reductions in loading via BMP applications in both upland and riparian areas estimated the potential reduction at 54% of the total load to a total production rate of 67 tons per year. The riparian BMPs apply an improved riparian assessment condition, and the upland BMPs consider improved grazing and cover management.

3.4 Summary of Sediment Sources

The results of the TMDL-related sediment source analysis indicates that the quantity of hillslope-derived sediment delivered to Clark Canyon Creek is several orders of magnitude higher than that derived from unpaved roads (Table 1).

Table 1. Summary of estimated sediment loads to Clark Canyon Creek (Confluence, 2011; Atkins, 2011).

Sediment Source	***Existing Conditions Sediment Production Rate (tons/yr)***	***Sediment Production Rate with BMPs in Place (tons/yr)***
Streambanks	Unknown	Unknown
Roads	0.33	0.11
Hillslopes	146	67

A quantified summary of bank-derived sediment is not yet available for Clark Canyon Creek, however that effort is evidently underway (http://montanatmdlflathead.pbworks.com/w/page/41735489/Beaverhead%20Documents). Field observations and geologic mapping indicate, however, that bank-derived sediment volumes are likely small relative to hillslope-derived sediment. Once the bank erosion inventory analysis is completed by MTDEQ, the results of that investigation can be compared to results of the roads and upland assessments to identify potential opportunities to significantly reduce sediment loading from banks.

In summary, the primary sediment sources to Clark Canyon Creek are highly erodible upland areas that are prone to mass failure and fluvial erosion. These areas appear to be concentrated in the North Fork Clark Canyon Creek sub-basin (Figure 8 and Figure 9). The headwaters of the North Fork contain distinct areas of mass failure. This channel contains evidence of debris flow deposition, with very coarse sediment deposits that are supported by a fine clay matrix (Figure 10). Where these deposits are exposed in the main channel corridor, the fine matrix is commonly eroded out, leaving the coarse material as a distinct depositional form. Additionally, eyewitness accounts of flooding in the basin include observations of very high turbidity in the North Fork flows versus clear water in the South Fork (Frank Snellman, pers. comm.) And lastly, whereas the South Fork of Clark Canyon Creek is reported to support diverse macroinvertebrate populations, the North Fork is largely devoid of macroinvertebrates (Matt Jaeger, pers. comm.). This is likely indicative of high fine sediment loading from the North Fork Clark Canyon Creek sub-basin.

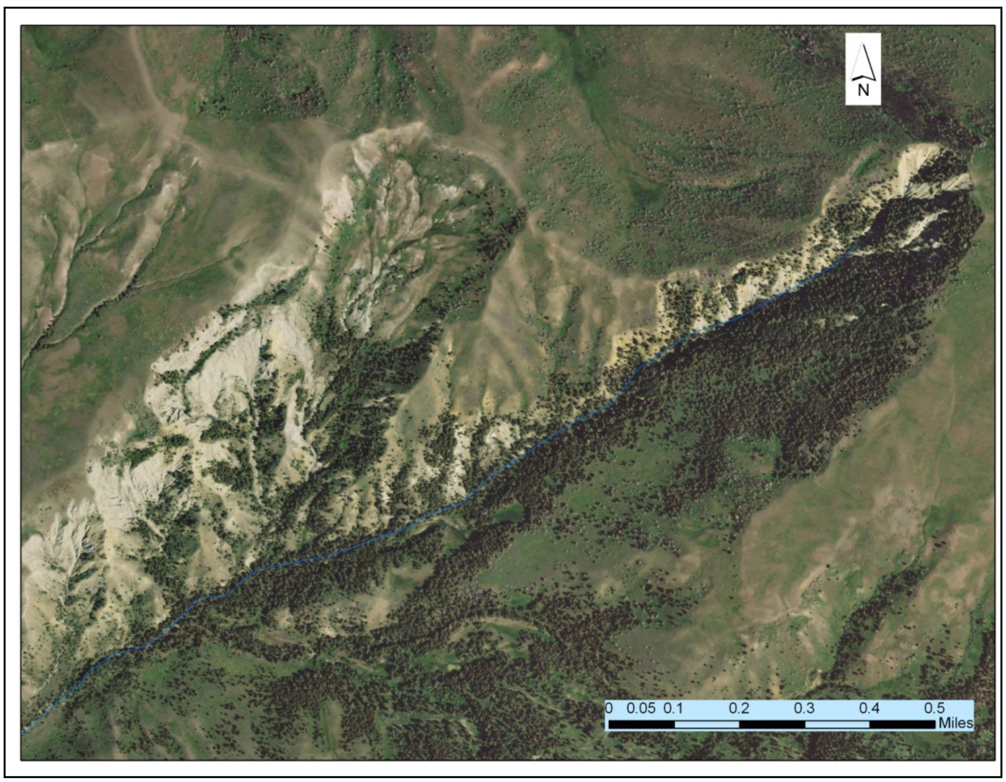

Figure 8. Aerial view of upper basin showing hillslope erosion on North Fork Clark Canyon Creek.

Figure 9. Exposure of Tertiary volcanics in North Fork Clark Canyon Creek (Matt Jaeger).

Figure 10. View upstream of North Fork Clark Canyon Creek showing coarse debris flow deposits.

4. Conceptual Alternatives for Sediment Management

The following section provides a series of conceptual approaches to reducing the impacts of fine sediment loading from Clark Canyon Creek on the Upper Beaverhead River trout fishery. The approaches are highly conceptual in nature and would require more extensive feasibility and engineering analysis to determine feasibility, cost, and anticipated benefit.

There proposed basic approaches to reducing sediment impacts to the Upper Beaverhead River fall into the three following categories:

1. Reduce sediment inputs at their source
2. Trap and/or store sediment en route
3. Flush sediment through the impacted reach

4.1 Reduce Sediment Inputs

The sediment delivered to Clark Canyon Creek is derived from streambanks, roads, and upland areas. Available data indicate that the riparian corridor is in relatively good shape and sediment production from roads is relatively low. BMPs are currently in place on both the roads and in riparian grazing areas. As such, although the implementation of riparian and roads BMPs should be continued, the sediment sources cannot be significantly reduced without addressing upland inputs.

An analysis of sediment contribution from hillslope erosion (Confluence, 2011), estimated that the hillslope-derived load currently delivered to Clark Canyon Creek could be reduced by over 50% with upland and riparian BMPs. This improvement reflects a 10% increase in ground cover for areas classified as grasslands/herbaceous, shrub/scrub, pasture/hay, and woody wetland, and a 20% increase for cultivated crop areas. In the Clark Canyon Creek basin, the primary land cover types are grassland/herbaceous (38%), shrub/scrub (27%) and evergreen forest (33%). The upland BMPs assume no change in cover for the evergreen forest type, but an increase in ground cover from 75% (existing) to 85% (improved) for both the grassland/herbaceous and shrub/scrub cover types.

The National Land Cover Dataset map for the Beaverhead TMDL Planning area indicates that the land cover types associated with the erodible volcanic materials along the North Fork of Canyon Creek are primarily shrub/scrub, with some grassland/herbaceous cover. Due to the geologic and soils conditions in this area, there is some question as to whether these cover types currently support 75% cover, and whether they would support 85% cover in a BMP scenario. Currently, there are numerous areas where vegetative cover on the clay-rich volcanic units and associated mass failures are sparse, with much less than 75% cover (Figure 9). The current BMP status of these areas is unknown, but no other evidence of excessive grazing impacts were noted in the field. It is recommended, however, that the potential for increased vegetative cover on grazing lands be considered as a means to help reduce sediment inputs from sensitive upland areas.

The results of this reconnaissance-level assessment indicate that although the treatment of upland sources through land use BMPs should be considered in any land use plan, it is unlikely that 85% vegetative cover is achievable in this landscape, or that sediment production rates could be reduced by over half with land use modifications.

4.2 Trapping Sediment

The concept of trapping sediment focuses on intercepting upland-derived loads before they reach the Upper Beaverhead River. This can be achieved using in-stream structures such as gully plugs, off-stream structures such as settling basins, or by promoting floodplain aggradation and storage.

When sediment trapping is considered, it is important to note that the sediments that negatively impact the Upper Beaverhead fishery are very fine grained. The description of the Clark Canyon Creek basin soils as derived from rhyolite ash, rich in clay, and prone to alteration to bentonite, suggests that the trapping of this sediment out of the water column would require very long residence times, hence very large basins. Another challenge with sediment trapping lies in the fact that the coarser bedload delivered to the Upper Beaverhead River is beneficial to the fishery, in light of the fact that Clark Canyon Reservoir otherwise traps all bedload entering the reach. So the objective for sediment trapping is to trap fine sediment while allowing coarser bedload (gravel and cobble) to reach the Beaverhead River.

Another important consideration in the evaluation of trapping mechanisms is the fact that the sediment loads are only problematic when Clark Canyon Creek experiences a flood event and Upper Beaverhead flows are too low to effectively transport that material (~350cfs; BOR, 2010). As such, sediment trapping is only necessary when those specific conditions are met.

Check dams and Gully Plugs

The north side of the Clark Canyon Creek watershed is dissected by numerous ephemeral channels that appear capable of producing large volumes of fine sediment during high runoff events (Figure 11). A potentially appropriate sediment control measure for these areas is grade stabilization structures that form check dams, commonly referred to as “gully plugs”. These structural measures may be built out of woven-wire, brushwood, logs, logs stone, and boulders; they are typically temporary and used to facilitate the growth of permanent vegetative cover (www.fao.org/forestry). If these treatments are further considered, it would be appropriate to map all major point sources of sediment from such drainages, and survey the drainage to assess the size and number of structural features that would be necessary. One challenge with these features is the potential for plug failure and rapid delivery of sediment slugs downstream.

Figure 11. Gully formation in volcanic rock units (Matt Jaeger).

Riparian Buffers

Riparian zones can be effective at trapping upland sediment before it reaches a stream channel. The amount of sediment trapped is related to the size and condition of the riparian corridor. Confluence (2011) estimated that on Clark Canyon Creek, the total upland sediment load could be reduced by 46% if both riparian and upland BMPs are employed. However, with regard to the riparian BMPs, there is some question as to the potential for significantly increasing riparian vigor or buffer extent in the reach.

The riparian health assessment on Clark Canyon Creek, which was based on an evaluation of air photos, ranked 70% of the corridor as in "moderately good" condition, and 27% as "good" condition. Under a BMP scenario, it is estimated that 97% of the corridor would achieve a "good" rating (Confluence, 2011). This riparian improvement would then reduce sediment loading to the creek by increasing the "Riparian Buffer Sediment Reduction Efficiency" (SRE), as is shown in Figure 12. These SRE values reflect the riparian condition of a "nominal 100-ft wide riparian buffer", and indicate that whereas a buffer with a good riparian condition will reduce the sediment load by 75%, a poor condition reduces delivery by only 30%. As a result, by improving the condition of a riparian corridor, more upland sediment is trapped in the riparian zone.

As the riparian condition of Clark Canyon Creek was only evaluated at a reconnaissance level for this effort, the potential for major improvement with land use modifications is not clear. Trapping efficiency in the riparian zone is limited by buffer widths, which are commonly less than 100 ft in the narrow stream valley. Locally the valley bottom is irrigated and some clearing has taken place; these areas may provide some opportunities for improved sediment trapping. Overall, however, the existing riparian condition, buffer size, and upland yields indicate that the projected reduction in sediment loading with BMPs is likely overestimated. It is recommended, however, that a riparian specialist be contacted to discuss potential BMP applications in the stream corridor that will improve the sediment trapping efficiency of the riparian area.

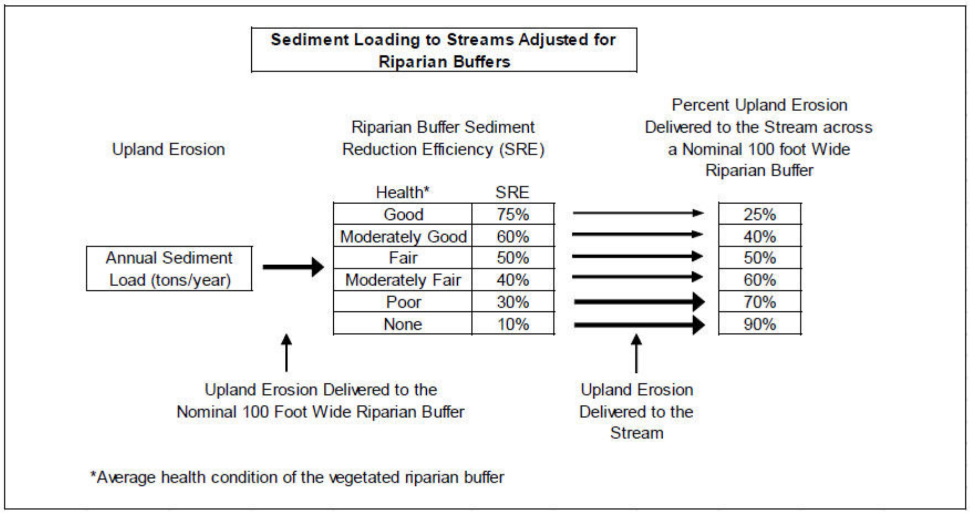

Figure 12. Upland sediment load delivery adjusted for riparian buffer capacity, Beaverhead TMDL Planning Area (Confluence, 2011).

Settling Basins

Settling basins, when properly designed, retain water long enough for coarse suspended solids to settle. Typically, however, in fine grained systems, storm overflows cannot be treated through sedimentation due to the presence of suspended clay particles that require much longer storage times to settle. Typically, sediment basins are only practically effective in removing sediment coarser than fine silt and clay (CASQA, 2003). Systems with a high clay load commonly require chemical treatment in addition to the sediment basin. Even with a silt load, a detention time of 24 to 48 hours is typically necessary to allow 70 to 80% of the sediment to settle (CASQA, 2003). As settling basins do not effectively capture fine silts and clays during storm events, and are expensive to both construct and maintain, the use of these structures in Clark Canyon Creek appears largely unfeasible.

Induced Floodplain Aggradation/Storage

In natural stream systems, floodplains tend to aggrade due to fine sediment deposition. The aggradation occurs during flood events when suspended material is carried out over the floodplain, where shallow water and high roughness create conditions conducive to flow infiltration and fine sediment settling. In the Clark Canyon Creek basin, it is the fine fraction of sediment that is in suspension during flood events that is the target for sediment trapping. As such, it is appropriate to consider induced floodplain aggradation as a potential means of downstream suspended sediment load reduction.

Based on observations made during the field reconnaissance, it appears that the most practical location to consider floodplain sediment storage is in the lowermost section of the North Fork Clark Canyon Creek, just upstream from the gravel road crossing over the North Fork (Figure 13 and Figure 14). This area currently consists of a broad fan-shaped depositional surface that has old spreader dikes, indicating historic irrigation practices. Possible sediment measures on the surface would include managed high flow dispersal into an alluvial fan environment, or potentially dispersal into stepped depressional wetlands. It is not clear as to whether this landform is a deactivated alluvial fan, however the high sediment loads and valley bottom widening in this area suggest that this feature was historically an alluvial fan. No distinct abandoned channel features are visible on the fan surface, however the presence of spreader dikes suggests that land uses may have included topographic modification of the depositional surface.

Alluvial fan restoration is becoming increasingly common in the stream restoration industry. I have personally worked on a proposed fan reactivation project on Hellroaring Creek in the Centennial Valley, in an effort to increase overall channel stability and habitat complexity while reducing sediment delivery downstream. On the Lower Mohawk River in New Hampshire, reactivation of alluvial fan channels was proposed as a means of reducing sediment loading downstream (Field Geology Services, 2007). The concept proposed was to restore flow to abandoned channels on the fan, to spread flow over a wider area and decrease flow velocities within the active main channel. To prevent flow from re-entering the main channel, the proposal included the placement of large woody material in the existing channel. The flow was to be diverted onto the fan through a notch in the existing bank, and partial blockage of the main channel.

The activation of alluvial fan depositional processes at the mouth of North Fork Clark Canyon Creek would require engineering design to assess overall trap efficiency of the surface, and to design outflow points and return flow points. Special attention would have to be paid to the road crossing on the downstream end of the fan, as strategically-placed culverts may be necessary to convey flow towards the South Fork Canyon Creek confluence.

Figure 13. View upstream of lower North Fork Clark Canyon Creek showing potential overflow area.

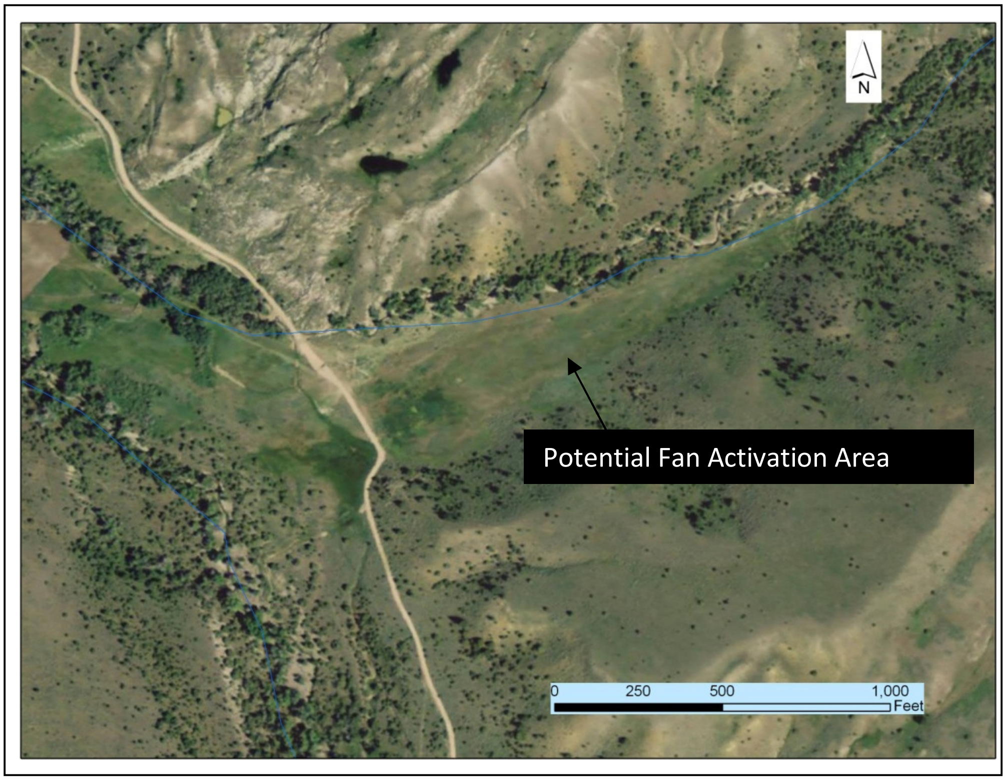

Figure 14. Aerial view of lower North Fork Canyon Creek showing broad fan area south of main channel.

The alluvial fan aggradation concept is different from a settling basin in that the alluvial fan approach relies on a larger surface area, higher roughness, and flow infiltration into the ground surface. Approaches to spreading flows might include structural dispersal of flow across the fan through notched grade controls that are oriented perpendicular to the fan axis, or reactivation of old spreader dikes. Notched grade controls could define overflow areas down the fan surface to prevent channel avulsion, and could be constructed of wood fence, or relatively portable hard structures such as trenched jersey barriers.

4.3 Flushing Flows on Upper Beaverhead River

Clark Canyon Creek has a high natural sediment load due to the presence of fine grained volcanic units that are prone to clay alteration, landslides, massive slope instabilities, and debris flow formation. Due to the extensive exposure of these deposits on the northern portion of the watershed, it is impossible to treat the exposures as point sources. Rather, it may be most appropriate to accommodate the sediment load by ensuring sufficient flushing flows on the Beaverhead River.

The sedimentation problems stemming from Clark Canyon Creek typically occur during the spring, when Clark Canyon Reservoir releases are kept low to optimize storage for irrigation. From 2005 to 2009, the April-May flow releases from Clark Canyon Reservoir have ranged from less than 100 cfs to 900 cfs (BOR, 2010).

The issue of flushing flows has been evaluated by the Bureau of Reclamation. In their analysis, the BOR concluded that a discharge of 350 cfs would mobilize a 20.4mm particle size (based on Shields method), which is larger than the median particle size collected near Clark Canyon Dam (18.3mm). The incipient mobility of bedload was used as a basis for defining conditions at which smaller material was in motion. As stated in the BOR report, "The assumption is that if the underlying bed material will mobilize then it will also carry the smaller size particles downstream allowing flushing of the sediment".

The results of the BOR study (BOR, 2010) indicate that a 350 cfs flushing flow below Clark Canyon Dam should provide effective bedload transport below the Clark Canyon Creek confluence. This will prevent the fine grained channel infilling that is characteristic of very low flows (<~200cfs). Even at 350 cfs, however, the potential for fine sediment accumulation on relatively shallow channel margin areas should be considered. With more detailed cross sections collected in areas prone to deposition, an evaluation of the change in wetted perimeter with increasing discharge would help identify the discharge range that correlates to shallow inundation of channel margin areas. That is, inundation of any low sloping features on the channel cross section would create a rapid increase in wetted perimeter with a small increase in discharge. If shallow inundation of the channel margins occurs at a consistent flow range at multiple cross sections, that flow range could be avoided. Thus the flushing flow could include a minimum discharge, and an optimal range of discharges above that minimum.

A plot of the minimum mean daily discharge measured during the months of April and May on the Beaverhead River at Barretts (downstream of Clark Canyon Creek) shows that minimum flows of less than 350 cfs are fairly common during those spring months. Since 1908, at least one day with a mean daily flow of less than 350cfs was measured at Barretts 73% of the time in April, and 58% of the time in May. Clark Canyon Dam was built in 1964, and flows were commonly less than 350cfs in April and May prior to dam construction, especially during the 1930s and early 1960s. This indicates that sediment transport limitations on the Beaverhead have occurred both prior to and following the construction of Clark Canyon Reservoir.

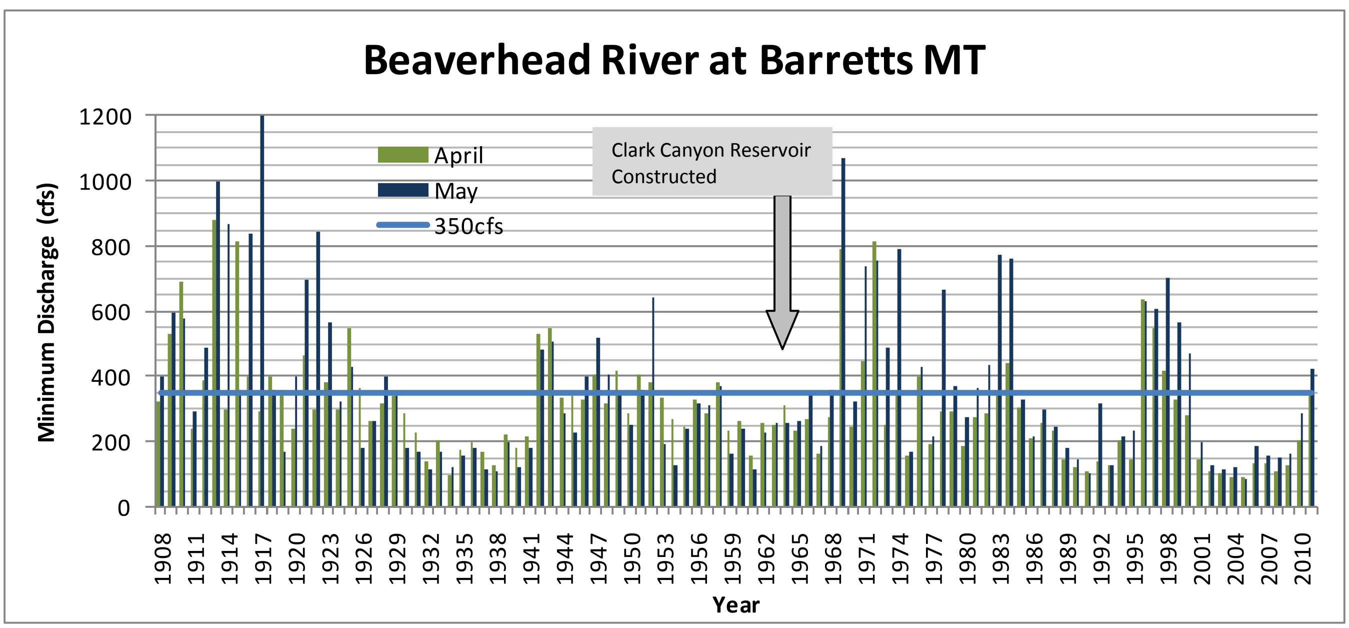

Figure 15. Minimum April and May discharge (mean daily flow) measured since 1908 at USGS Gage 06016000 at Barretts, MT.

5. Summary

Clark Canyon Creek has a high natural sediment load due to inherently unstable aspects of basin geology. Sediment loading is especially elevated during storm events when fine grained volcanic rocks become saturated and prone to surficial erosion or mass failure. If flows in the Beaverhead River are simultaneously low, a sediment transport imbalance occurs and sediment deposition occurs downstream of the mouth of Clark Canyon Creek.

Land uses in the basin include some grazing and road development. BMPs should be continued with these land uses. However, it is apparent that high sediment loads should be expected from the Clark Canyon Creek basin even in the absence of any agricultural land use or road development.

Means of substantively reducing sediment impacts on the Beaverhead include control of point sources, trapping of sediment below the source, and flushing of sediment through Beaverhead Canyon. Any significant control of point sources appears unfeasible due to the sheer extent of hillslope contributions. Additional BMP implementation in either upland or riparian areas may reduce loading, however due to an erodible geology, naturally narrow riparian buffer areas, and existing BMPs, it is unlikely that land use modifications alone will solve sediment loading problems in Beaverhead Canyon. Rather, induced deposition of fine sediment in floodplain areas of Clark Canyon Creek, in combination with flushing flows on the Beaverhead appear to provide the most optimal conceptual alternatives to reduce fine sediment impacts to the Beaverhead fishery. The feasibility and anticipated benefit of induced deposition would require additional analysis related to design requirements and sediment trapping efficiencies in overbank areas. Flushing flows have been evaluated (BOR, 2010), however further analysis of cross section/wetted perimeter relationships may help convert the minimum flow value to an optimal range of flushing flows that will maintain fine sediment transport through Beaverhead Canyon.

6. References

Atkins, 2011. Road Sediment Assessment and Modeling, Beaverhead TMDL Plannign Area: Report prepared for Montana Department of Environmental Quality, Helena MT, May 2011, 18p.

Bartholomew, M.J., S.E. Lewis, G.S. Russell, M.C. Stickney, E.M. Wilde, and S.A. Kish, 1999. Later Quaternary history of the Beaverhead River Canyon, southwestern Montana, *in*: Hughes, S.S. and G.D. Thackray, eds., Guidebook to the Geology of Eastern Idaho: Idaho Museum of Natural History, p. 237-250.

Bureau of Reclamation (BOR), 2010. Beaverhead River Flushing Flow Study, Clark Canyon Dam, MT. Montana Area Office, Billings, MT, June 2010.

California Stormwater Quality Association (CASQA), 2003. California Stormwater BMP Handbook –Construction. SE-2.

Confluence Consulting, Inc. 2011. Beaverhead TMDL Planning Area Sediment Contribution from Hillslope Erosion: Report prepared for Montana Department of Environmental Quality, Helena MT, May 10, 2011, 51p.

Field Geology Services, 2007. Lower Mohawk River Stream Restoration Planning in Colebrook, NH, Final Report prepared for Connecticut River Joint Commission, Charleston, NH, 16p. (http://des.nh.gov/organization/divisions/water/wmb/was/documents/lower_mohawk_wbp.pdf)

Lonn, J.D., B.Skipp, E.T. Ruppel, S. U. Janecke, W.J.Perry Jr., J.W.Sears, M.J. Bartholomew, M.C.Stickney, W.J.Fritz, H. A. Hurlow, and R.C. Thomas, 2000. Preliminary Geologic Map of the Lima 30' X 60' Quadrangle, Southwest Montana: Montana Bureau of Mines and Geolog Open File Report MBMG 408.

Montana Department of Environmental Quality (MDEQ), 2010. Water Quality Standards Attainment Record Assessment Record MT41B002_110 (http://cwaic.mt.gov/wqrep/2010/assmtrec/MT41B002_110.pdf).

Ruppel, E.T., J.M. O'Neill, and D.A. Lopez, 1993. Geologic map of the Dillon 1°X2° Quadrangle, Idaho and Montana: United States Geological Survey Miscellaneous Investigations Series Map I-1803-H.