Final Report

Upper Slate River Geomorphic Assessment

Gunnison County, Colorado

Prepared for: Coal Creek Watershed Coalition and Upper Slate River Steering Committee

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1.0 Introduction

1.1 Purpose of This Report

EcoMetrics and AlpineEco performed a geomorphic assessment of the Upper Slate River Watershed (**Figure 1**) in summer of 2012 using the Watershed Assessment of River Stability and Sediment Supply (WARSSS) methodology (Rosgen 2006) to aid the Coal Creek Watershed Coalition (CCWC) in its efforts to identify and mitigate sediment pollution in the watershed. Priorities for restoration or mitigation were identified, and include reaches with a high degree of impairment (caused by human-related stressors) that have potential for being alleviated via means that are practical. Based on these criteria, this report includes a prioritized list of mitigation or restoration opportunities to serve as a guide to CCWC for understanding the nature of sediment issues in the watershed, for prioritizing future mitigation efforts, and for preparing a watershed plan.

1.2 Summary of WARSSS Methodology

WARSSS was developed by the Environmental Protection Agency (EPA) and Dave Rosgen as a process for assessing sediment impairment. It is designed to "reveal significant, adverse influences of land uses on stream channel stability, sediment sources, and sediment yield that may affect the material beneficial uses of rivers and streams (Rosgen 2006)." It is intended to be used for watershed planning, Total Maximum Daily Load (TMDL) assessments for clean sediment non-point source pollution, and a stability analysis for river restoration. The WARSSS process consists of three phases of assessment and ongoing monitoring:

Phase 1: Reconnaissance Level Assessment (RLA). This phase is a rapid scan of the watershed to identify locations with land uses that could adversely impact sediment supply or stream stability. In RLA, the watershed is delineated into individual reaches and sub-basins (for the purposes of this report these two terms are synonymous), and each is assessed using specific criteria to evaluate observable impacts to surface erosion, mass erosion, streamflow change, channel processes, and direct channel impacts. Reaches that are determined in RLA to have potential for anthropogenic impacts with sediment or stream stability consequences are assessed in greater detail in Phase 2.

Phase 2: Rapid Resource Inventory for Sediment and Stability Consequences (RRISSC). This phase of WARSSS is a more detailed qualitative assessment of reaches in the watershed for which anthropogenic impacts to sedimentation or stability are suspected. In RRISSC, each reach is classified by stream type. Then, human impact on 11 specific sediment-related factors (grouped into three types of processes) is assessed for each reach, including:

- Hillslope processes (mass erosion, surface erosion, and roads)
- Hydrologic processes (changes in streamflow)
- Channel processes (streambank erosion potential, enlargement, aggregation/ excess sediment, channel evolution, degradation, direct impacts, and in-channel mining)

An explanation of each of these RRISSC factors is provided in **Appendix 1**. For each factor, observable indicators are used to assess risk according to specific criteria outlined in the method. The result is a risk rating for each of the 11 factors for each reach. Based on these factor ratings, an overall RRISSC rating is also assigned to each reach. RRISSC ratings range from 1 to 5 (very low risk to very high risk). Reaches that receive risk ratings of moderate, high or very high are recommended for quantitative assessment in Phase 3, or prescribed for specific treatment.

Phase 3: Prediction Level Assessment (PLA). The PLA phase of WARSSS involves making detailed quantitative studies of specific reaches or groups of reaches with the goal of predicting degrees of channel instability, departure from reference condition, and actual sediment volume yields by source and process. PLA studies are specifically designed to inform management decisions and restoration or mitigation designs by quantifying the potential for improvement by different options.

In addition to the three phases of assessment, the WARSSS process specifies monitoring procedures for validating predictions made in PLA and for evaluating effectiveness of specific management changes, mitigation practices, or restoration activities. The watershed and our knowledge of it are constantly changing and growing. Monitoring provides a means to update and adapt the WARSSS assessment and the recommendations that follow from it are based on increasingly precise quantitative information about sediment processes in general and on understanding the effects of various mitigation measures.

For a more detailed description of the methodology, consult Rosgen (2006).

1.3 Interpretation of WARSSS Risk Ratings

The RLA and RRISSC assessments combine to produce a risk rating for each reach in the watershed, and interpretations of the rating are used for prioritization. Ratings are from 1 to 5, and each category is color-coded as described below:

- 5—Very high risk (red)
- 4—High risk (orange)
- 3—Moderate risk (yellow)
- 1 to 2—Very low or low risk (green)

Reaches that score very high risk (5) are considered "red flags." These are locations where the level of human impact is extreme or there is some reason to believe there is especially acute instability or disproportionately great sediment production. Red flag reaches are the highest priority for advancement to PLA and the most obvious targets for **restoration or mitigation**. Problems on these reaches are often severe enough that direct mechanical treatments may be required to mitigate the hazard. Restoring these reaches or mitigating impacts at these locations may have the greatest positive influence on the system as a whole, but may also be the most invasive and expensive.

Reaches in the high risk (4) category are "orange flags." According to WARSSS protocol, these reaches, like red flags, are also high priority for mitigation or restoration and also recommended for direct advancement to PLA. While secondary to red flag reaches in terms of the degree of impairment and potential for improvement, opportunities on orange flag reaches may be higher priorities since mitigation measures are often simpler and/or less expensive. This is where quantitative PLA assessment methods may be the most useful in decision-making. By quantifying the amount of sediment pollution that can reasonably be mitigated on these reaches, and by investigating the potential for less intensive restoration options, PLA studies may be used for cost-benefit analyses to compare the merits of competing projects.

There are two groups that comprise the moderate risk (3) or "yellow flag" category. Some of the reaches in this category are determined to have significant anthropogenic instability or sediment production, but to a less severe degree than high risk reaches. On these reaches, the degree of impairment is either thought to be acceptable or mitigatable by straightforward treatments or changes to land management. Where the evaluator is confident in the process or factor that is impaired, specific prescriptions for land use change may be made directly, without further study in PLA. The other group of yellow flag reaches contains those for which the degree or nature of human impact could not be determined with confidence in RRISSC. These reaches are considered a low priority for mitigation or restoration, but further assessment in PLA is recommended to make a judgment about whether a higher prioritization is warranted.

Reaches that are low risk (2) or very low risk (1) are "green flags." These tend to be the least-impacted or most stable. They are considered functional and therefore not candidates for mitigation, restoration or additional study in PLA. As functional components of the watershed, green reaches are a high priority for protection. The rationale is that these areas are in good condition and the best thing we can do is protect them from future harm. These well-functioning reaches are also valuable as references to help assess departure of impaired reaches and to direct the form of future restoration. Additionally, they can be used as templates for understanding best management practices and applying these techniques across the watershed.

2.0 Methods

The RLA and RRISSC phases of WARSSS for the Upper Slate River watershed were completed in summer 2012 by Mark Beardsley (EcoMetrics) and Jessica Doran (EcoMetrics), with assistance from Andy Herb (AlpineEco). No PLA work was included in this project.

2.1 RLA Phase

During the RLA Phase, each reach was evaluated individually using topographic maps and aerial imagery such as Google Earth and Bing Aerials, along with results from past reports, to make an initial remote reconnaissance. This assessment was focused on identifying and cataloging past and present anthropogenic land use stressors in the watershed and documenting the location, extent, and severity of these impacts relative to the delineated reaches. Past reports such as HRS (1995) and information gained from local residents were invaluable in the identification of stressors, particularly those that occurred in the past. For the purposes of this study, stressors are defined as human land uses, activities, artificial structures, or geomorphic alterations that impact natural hillslope, hydrologic or channel processes.

2.2 RRISSC Phase

During the RRISSC phase, each of the reaches identified for detailed assessment were visited. The relevant WARSSS variable worksheets were completed in the field and the reaches were assessed for impacts related to the following factors: mass erosion, roads, surface erosion, streamflow change, streambank erosion, in-channel mining, direct channel impacts, channel enlargement, aggradation, channel evolution, and degradation. Then, based on these individual factor scores, an overall RRISSC rating was assigned, and specific recommendations made for each reach.

While the interpretations of WARSSS RISSC ratings may provide direct recommendations for prioritization in a watershed, for this study we use the results simply as evidence to build a defensible professional opinion. The list of priorities that we compiled as the culmination of this study was made by considering the WARSSS scores within a greater context that also includes a more detailed assessment of the cause of the high RRISSC scores (natural versus anthropogenic), and the practicality of restoration or mitigation (the ability to eliminate or correct stressors).

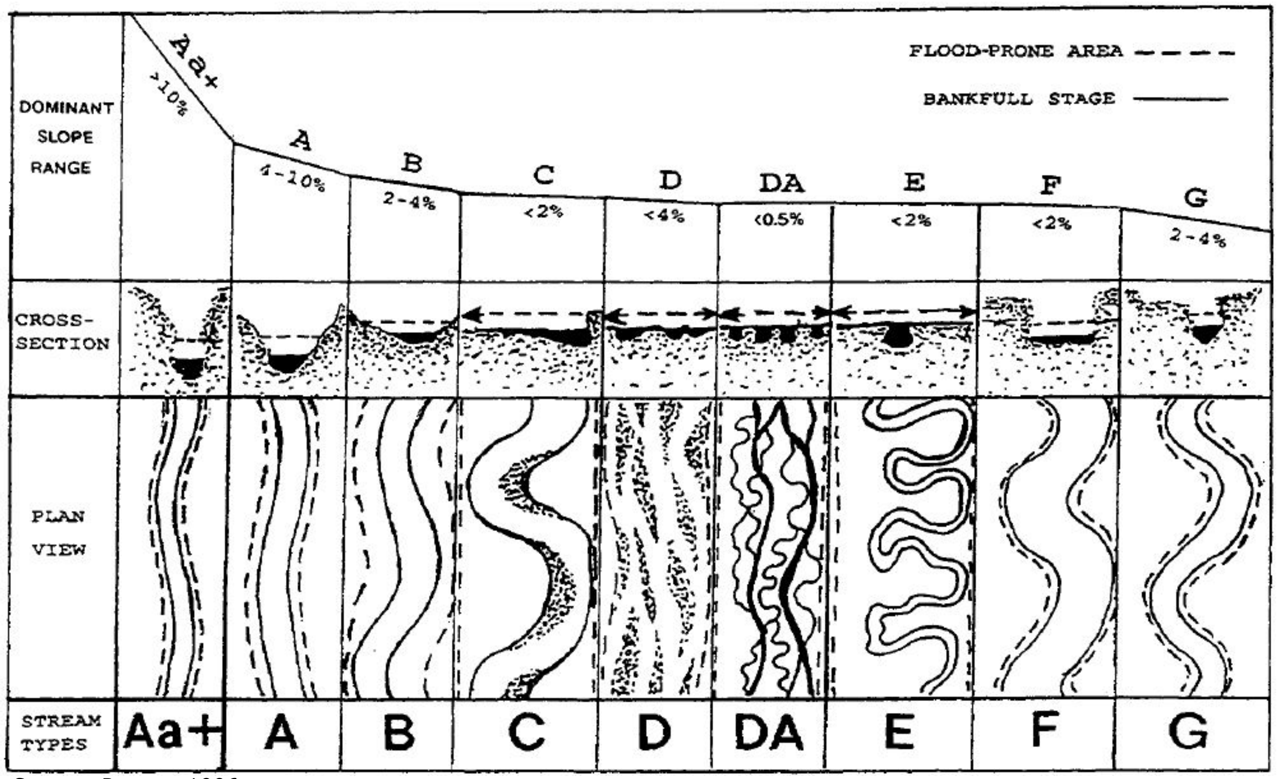
2.3 Access to Private Property

We were able to physically access all of the important properties for the RRISSC assessment, with a few notable exceptions. Due to private property and lack of permission, we did not access the land above Poverty Gulch Crossing (Reach #20a), Slate River Ranch (Reach #31a), or the Kapushion Property (Reach #64). For these sites, we scored RRISSC variables as best we could from aerial imagery, by observing the properties from adjacent lands, and by using information from past reports.

2.4 Stream Classification

Valley and stream types used in this study follow the Rosgen classification system (Rosgen 1996). An additional stream type not described by Rosgen is used, D_B , to represent natural multi-channel streams that are heavily influenced by beaver activity

(Beardsley 2011). The following graphic shows the longitudinal, cross-sectional, and plan views of the major stream types as described in Rosgen (1996):



Source: Rosgen 1996

3.0 Results

The following results identify problem areas in the watershed where more detailed quantitative study at the PLA level might be needed, to inform conceptual design of mitigation treatments, and to serve a framework for prioritization of restoration or mitigation opportunities.

3.1 RLA Phase

During the RLA Phase, the watershed network was divided into 65 reaches or sub-basins among three primary sections of the watershed (**Figure 2; Table 2.7** in **Appendix 2**), including:

- The Headwaters Area, including headwaters of the Slate River, Poverty Gulch, and Oh-Be-Joyful (OBJ) Gulch
- The Main Slate River Glacial Valley (from Poverty Gulch to the Gunsight Bridge)
- The Main Slate River Alluvial Valley (from Gunsight Bridge to the Gothic Road Bridge)

The purpose of the RLA remote reconnaissance was to focus the advanced, more detailed reach-scale field assessments on areas of the watershed where signs of stream instability or unnatural sediment supply could be expected. In the initial remote reconnaissance phase of RLA, we conservatively excluded 10 reaches from further study based on an overwhelming lack of evidence for significant anthropogenic impacts or unusual instability.

In the second phase of RLA, field surveys were conducted to make a better inspection of questionable reaches. During this inspection, an additional 27 reaches were excluded from further study. Thus, on 37 of the total 65 reaches, RLA assessment yielded a WARSSS risk rating of "low" due to the fact that no significant indication of human impact to sediment systems was detected. These 37 reaches were placed in the "low risk" category and excluded from further assessment. Results from the stressor analysis and identification of impacted variables from this phase of RLA are summarized in **Tables 2.1** through **2.6** in **Appendix 2**.

On the remaining 28 reaches, there were significant stressors, signs of instability, or a disproportionate sediment supply suspected. These 28 reaches were advanced to the RRISSC phase. Some of these reaches were further subdivided during RRISSC, so the specific RRISSC procedure was applied to 34 individual reaches in total for this study. Results of the RLA assessment are summarized in **Table 2.7** in **Appendix 2**.

3.2 RRISSC Phase

During the RRISSC Phase, each of the reaches identified during RLA as significant were assessed for impacts and assigned an overall RRISSC rating. The culmination of this assessment is a table of values for each of the individual hillslope and channel process variables, an overall RRISSC rating, narrative description, recommendations, and prescription for advancement to the quantitative PLA of WARSSS for each reach in the watershed. These results are summarized in **Table 3.1** in **Appendix 3**.

Based on these results, a discussion of the overall condition of the watershed from a sediment and stability perspective and a prioritized list of recommended future actions are provided in **Section 5.0 Restoration or Mitigation Opportunities**.

A note about limitations of WARSSS, the assumption of stream stability, and the importance of identifying stressors

The episodic pattern of sediment delivery (mass erosion events) and differential movement of sediment through the Upper Slate River Watershed makes it challenging to assess the system for sources of anthropogenic impacts. The theoretical basis for WARSSS is grounded in the assumption of natural stream channel stability, and while this assumption is generally valid across large time frames and in geologically less active, higher order systems that respond gradually and in a more deterministic fashion, its application to this low order stochastic system becomes complicated and questionable. For instance, WARSSS treats mass erosion events as "unusual" or even unnatural. In RRISSC, geomorphic variables are typically scored based on the degree of human impact, but mass erosion risk ratings are scored simply on the gradient, shape, and location (relative to a stream) of steep slopes. Thus, to base an assessment completely on WARSSS scores, any steep-walled drainage (like most of those of the Upper Slate River) would score high in RRISSC and therefore be considered impaired, even in the pristine un-impacted condition. Likewise, any reaches that show instability in the form of excess deposition or aggradation score high, no matter whether the cause of the deposition is natural.

It is important to recognize this limitation of WARSSS (or, more generally, the assumption of natural stream stability) in understanding the results of this study. There is no reason to believe that mass erosion events such as landslides, debris flows, torrents, and avalanches are unnatural events in the Upper Slate Watershed. Indeed, there is every reason to believe that these are an important part of the natural geology here. Likewise, episodes of rapid sediment delivery and excess deposition (and the channel instability and evolutionary responses to this) are very natural phenomena. If we do not recognize this outright, we would find ourselves evaluating wholly natural processes as somehow impaired, and therefore running the risk of trying to treat or "stabilize" naturally evolving stream channels that are adjusting to accommodate natural sediment loads. Unless there is some good reason for doing so (like protecting infrastructure or human life) it would be futile, or at least expensive, to try to fight these types of natural geologic processes that depend on instability and channel change.

So, in order to avoid an erroneous assessment of watershed condition from the outset, we did not score any of the upper reaches or sub-basins as impaired, or "high risk", for mass erosion unless there was some sign that that the potential for mass erosion was somehow exacerbated by human impacts. For this reason, our assessment of the Headwaters Area and side drainages relies heavily on the observation of stressors, particularly in the evaluation of mass erosion potential. For reaches that exhibit natural stream instability (excess deposition or aggradation, in particular), it is more difficult to identify cases where instability has a direct or indirect human cause. Therefore, our RRISSC assessment will include some reaches that score as impaired, or "high risk" when the true cause of the instability might be 100% natural. Again, it is critical to know the extent and history of land use on these reaches to make an accurate assessment of human impacts. Stressor analysis is the key to determining which reaches are candidates for restoration or stabilization to mitigate human impacts and which reaches are simply undergoing natural geomorphic processes.

4.0 Discussion

4.1 Headwaters Area

The headwaters area of the Upper Slate River Watershed is characterized by steep-walled valleys in high alpine and subalpine environments (**Figure 2**). The main valleys of the three headwaters areas (Slate, Poverty, and OBJ) tend to be steep V-shaped valleys (Rosgen valley type I) with naturally steep, entrenched A and Aa+ channel types that are often scoured to bedrock. The steep side drainages and tributaries also tend to be primarily Aa+ channels that flow intermittently as debris torrents. At places, the valley slopes moderate and are better described as glacial U-shaped valleys (type V), and these reaches tend to have stream types C, D or D_B (beaver-dominated anabranching, ponded systems). At the transition between these two valley types, moderately entrenched B-channel segments exist.

The steeper A1-type channel reaches are extremely efficient at moving sediment, while the lower gradient B, C and D reaches are much less efficient. Because of this, when a massive load of sediment enters the system all at once from a mass erosion event, it can be transmitted rapidly through the A-channel segments. But when the material reaches a wider, lower-gradient section of the valley that has stream types that are less efficient transporting sediment, the sediment is deposited. It is clear in this watershed that aggradation and excess deposition is a common natural phenomenon where steep canyon reaches meet flatter valley floors, at least temporarily. Then, the less efficient channel types on these reaches winnow away the sediment gradually. The observed aggradation on Reach #11 appears to be evidence of this hypothesis.

Hillslopes in the headwaters areas are very susceptible to mass erosion in the form of landslides, earth flows, debris avalanches, debris flows, torrents, and snow avalanches. These massive, episodic geologic sediment sources form the natural background against which human impacts to hillslope processes and sediment contributions must be evaluated. Evidence of recent mass erosion is very common throughout the headwaters.

A good example a large mass erosion event is seen on the drainage that comes off of the east side of Paradise Ridge (Reaches #5 and #6). A recent debris flow originated from a debris avalanche in the upper portion of this drainage (Reach #5) which ran over a bench and into the lower part of the drainage (Reach #6) where it entrained more material and apparently initiated a landslide or earth flow which ultimately deposited somewhere on the order of 10,000 cubic yards (CY) of material across the Slate River Valley. An old mining road crosses the area within Reach #5 through the debris avalanche, but is certainly not the cause of this event.

A look at the WARSSS criteria for assessing mass erosion provides some insight into how widespread this process is in the Upper Slate River. Reaches #5 and #6 were rated as moderate (3) and very high (5), respectively, using the RRISSC criteria for mass erosion. Importantly, nearly every upper reach in the headwaters areas would similarly score moderate to very high for mass erosion, and signs of recent mass erosion events are common throughout the upper watershed. It is clear that the risk or probability of natural mass erosion events is widespread throughout the upper drainage areas of the watershed, and these natural hillslope processes are clearly an overwhelming sediment supply source to the system.

Simply by looking at the distribution and size of recent mass erosion events observed in this study, we can start to arrive at a very coarse estimate of the actual volumes of sediment delivered to the Slate Watershed by this mechanism. By this coarse analysis, we estimate that natural mass erosion contributes somewhere on the order of 1,000 to multiple thousands of cubic yards of sediment to the watershed annually. By comparison, the amount of sediment contributed to the watershed by all other hillslope processes combined is probably less than this by two full orders of magnitude.

To calculate the annual volume of sediment from mass erosion, we used our field observations to estimate the number of contributing drainages at high risk, average size of deposition from mass erosion on the drainages that have recently run, and frequency of activation based on the observed number of drainages that show recent activity. If we say that five drainages run per year, each contributing 300 CY of material, and an additional 500 CY of material is deposited annually from avalanches, that is a rough total of 2,000 CY annual contribution from mass erosion. Note that this is an extremely coarse calculation based on very broad observations. It is meant to provide an order-of-magnitude estimate for the relative amount of sediment produced by mass erosion. Also note that mass erosion events are episodic. In some years, few drainages will activate and sediment contribution from mass erosion might be on the order of 0 to 100 CY. In other years, many drainages will activate or some large event may occur and contribution might be 10,000 CY or more across the watershed.

Anthropogenic stressors in the headwaters areas include hard rock mining and coal mining, which was common in the watershed in the 19th and early 20th century, roads (including both active forest roads and abandoned mine access roads), livestock grazing, and recreation.

4.1.1 Human impacts on mass erosion

As we discussed above, since widespread mass erosion events are very much natural geologic processes with little or no human impact in this watershed, few reaches were formally evaluated in RRISCC for this source. Human land use mechanisms that could affect mass erosion in this watershed include roads or other significant surface disturbance in the areas where debris flows initiate or propagate, areas where steep slopes are effectively under-cut, or areas where these activities could increase the efficiency of transfer of materials to stream channels. Of all the reaches in the headwaters area, only Redwell Basin (Reach #54) was observed to have significant potential stressors of this sort.

4.1.2 Recreation impacts

Recreation activity tends to be concentrated along existing roads and trails and diffuse in the backcountry. Recreation impacts on hillslope or channel processes are insignificant in the headwaters areas. To provide some means of quantifying the impacts of recreation on sedimentation, Breibart (2011) estimated that the trails within OBJ basin were estimated to produce a total of around 110 pounds (.04 CY) sediment annually, which is about four orders of magnitude less than (1/10,000) the estimated annual production of sediment from natural avalanches and debris flows. Likewise, he estimated the annual sediment production from the roads in OBJ (the primary use is recreation access) to be a negligible sediment source at about 1,200 pounds (0.5 CY). For the conversion between sediment volume and mass in this report, we universally use an estimated density of dry gravelly sand, 1.3 tons per CY.

4.1.3 Livestock impacts
Impact from livestock grazing in the headwaters appears to be minimal. Though cattle are present in summer throughout the region, especially on riparian areas along the main tributaries, the relatively low stocking rates and dispersal of the animals probably minimizes any significant damage. Indications of relevant livestock impacts would be seen as riparian vegetation shifts and loss of vegetation cover, surface disturbance, and direct channel disturbance by trampling and hoof shear. None of these indicators were observed at a significant level in any portion of the headwaters areas that we visited.

4.1.4 Sediment from roads
Old mining roads are present on hillslopes of many of the sub-basins, and even in some amazingly steep, high portions of the mountains. For most reaches, these roads appear to be of little importance as stressors to hillslope processes. With few exceptions, road densities in these upper-slope areas are very low and sediment delivery from roads is insignificant. The exceptions might be Reach #54 Redwell Basin, where the open Gunsight Road has many switchbacks and drainage crossings through the upper basin. Another area of potential concern for roads is the drainages off of upper Forest Road (FR) 734 (Paradise Divide access) and FR 811 on the north side of the Slate River (Reaches #17 and #18). These roads were identified by the Breibart (2011) as potentially important sediment sources; and active surface erosion, channel erosion, and gully formation are evident. Finally, road impacts may also be significant on the middle reach of Poverty Gulch (Reach #27). This well-traveled unimproved road is located immediately adjacent to and within the riparian area of Poverty Creek, and it crosses several tributary drainages which efficiently deliver road sediments to the system.

4.2 Main Slate River Glacial Valley

The Main Slate River Glacial Valley area extends from the bottom of a steep V-shaped valley above Pittsburg through two flatter valleys (at the mouths Poverty Gulch and OBJ Gulch, respectively) with another steep, V-shaped canyon segment (valley type I) in between them (**Figure 2**). All of this is situated within a broader U-shaped glacial valley (type V). The longitudinal pattern is similar to the Slate River headwaters in that it is a set of relatively wide, low-gradient valley segments separated by a very steep entrenched canyon section, but the pattern is perhaps more exaggerated here in the sense that the flatter portions of the valley are longer and have lower gradient than what is observed higher in the watershed. Within the steep V-shaped canyon, the Slate River is an entrenched bedrock A1 channel. Through the flatter valley segments, it typically displays channel types C3 and D3, with B3 channels evident at some of the transitions between steep and flat valley sections. F3 and G1/3 channels are present at areas where active channel evolution is taking place near Slate River Ranch and OBJ Campground. The general comments about disproportionate sediment transport efficiency between the different channel types that we explained for the Headwaters Areas are also true here, but to a more exaggerated degree. The side drainages feeding this portion of the Slate are still almost all Aa+ channels.

The "problem" of differential sediment transport efficiency we described earlier in this report is especially evident in this section of the watershed. Widespread aggradation was observed on both of the flatter valley segments at Poverty Gulch (Reaches #20a, #20b, and #31a) and OBJ (Reaches #38a, #38b, #39a, #39b, and #39c) in the form of excess deposition of cobble and gravel. On the upper portion of both of these areas, the sediments have accumulated so rapidly as to aggrade the entire channel and wide portions of the floodplain area, leaving, in both places, no discernible channel at all. On reach #20a above the Poverty Gulch road crossing, a large stand of conifers within the deposition area are dead. We suspect, but are not certain, that these trees died as a result of the deposition. Nevertheless, a huge source of large woody debris (LWD) is now present, in addition to all the loose rock which makes up the deposit. The specifics of the future fluvial geomorphologic response to this event is uncertain, but we expect that a new channel will gradually cut its way through the deposition starting at the lower end and progressing headward. Indeed, head-cuts and channel formation are already evident on the toe of the debris fan near the upper end of Reach #20b.

We found little or no evidence of stressors that would link this effect to anthropogenic causes. The magnitude of this deposition is dramatic, yet it is very likely natural. We have to expect a long period of instability to follow as the natural geomorphologic processes of channel formation and evolution take place on these reaches while the stream "copes" with this recent load. Indeed, natural channel evolution on these reaches must be viewed as a “backdrop” against which any anthropogenic impacts, some of which are severe, must be evaluated. These same observations and conclusions are echoed in a report by Lowclouds Hydrology (2010).

4.2.1 Direct channel impacts at Slate River Ranch

Some very significant stressors are concentrated at the Slate River Ranch Property (Reach #31a) where past gravel mining and channel relocation have apparently induced channel down-cutting that resulted in degradation (lowering) of the channel bed elevation, channel incision, and exacerbated instability both upstream and downstream (HRS 1995). This reach is also one of very few sites in the watershed where riparian vegetation impacts are fairly severe. The density of riparian woody vegetation, which is an extremely important component to channel stability for the C3 stream type (reference for this reach), is conspicuously low here. Riparian vegetation conversion from woody shrubs to grasses and forbs is a common impact on active livestock ranches that is initiated by active clearing and kept in check by intensive livestock grazing. Indicators of intensive grazing on the Slate River Ranch riparian area were evident at the time of the site visit, and HRS (1995) explains that willows had been poisoned along this reach in the past.

These stressors are fairly severe impacts to the channel function variables in RRISSC, all of which score in the high (4) or very high (5) risk categories. The reach also scored 5 for past in-channel mining. It is not clear whether gravel was actively mined on the reach (though the presence of the artificial pond suggests that it was), but we do know from the HRS (1995) report and historic aerials that the channel was relocated and apparently excavated which, for all intents and purposes, has the same effect as mining it. The reach is a red flag for river instability and disproportionate sediment supply.

The Crested Butte Land Trust (CBLT) holds an easement on the private property upstream (Reach #20b) which also scores as a red flag reach, with values of 4 to 5 for most of the channel function variables. These scores reflect instability that is likely caused by the impacts that occurred downstream on the Slate River Ranch, and also, perhaps, by the recent sediment deposition seen upstream. Rapid bank erosion on this reach threatens to compromise FR 734.

Consequences of instability on the Slate River Ranch may also be at play on the adjacent downstream reach (Reach #31b). If channel impacts on Slate River Ranch are as severe as the assessment indicates, these could be translated downstream in the form of downstream migration of the incision (which is possible even though the normal migration of incision is in the headward or upstream direction). This may be the reason that Reach #33 is apparently degraded (down cut), possibly incised, and conspicuously straight. Alternatively, it could be that direct channel manipulation actually extended downstream onto this reach or that the observed condition is natural. Scores for both these reaches indicated a yellow flag status reflecting the uncertainty about the degree of instability and its causes.

Finally, the reach downstream a little further (Reach #35) is also suspect for instability related to the impacts on the Slate River Ranch area. Again, if these impacts are as severe as the assessment indicates, then the reaches immediately downstream would be subject to abnormally high sediment inputs that arise from channel enlargement and erosion going on upstream. This may explain the observed D-type braided channel configuration and the risk of continued excess deposition. While suspect, the true cause of braiding and apparent excess deposition on this reach may not be attributable at all to human-induced instability upstream. By this assumption, the reach scores low in RRISSC and is categorized as a green flag reach. To be sure, the observations of a braided channel here may just as well be a natural response to geologic grade control on the downstream end of the reach where the river eventually plunges into a steep, narrow canyon.

4.2.2 Direct channel impacts and instability around the OBJ Campground area

Direct channel manipulation is evident at the OBJ campground area where long sections of streambank have been armored with rip-rap, apparently as a defense of the campground area against active bank erosion. It is not clear whether these bank hardening treatments were also accompanied by re-shaping or realignment of the channel through the campground area. Either way, direct manipulation is evident and the reach scores high in most of the channel-related RRISSC variables, constituting a red flag rating. Further evidence of aggravated stream energy and the risk of excess scour and erosion is provided in a report by Lowclouds Hydrology (2011) which contends that the range of flows up to the 500-year recurrence interval would be contained within the existing channel, effectively making this an F-type channel, which it very probably is.

The difference between classifying the stream as C versus F, in this case, depends upon the width of the functional floodplain area within the existing larger channel. That is, at some point, a widening F-type channel can become so wide as to enclose a functional C channel and its floodplain within itself. Technically, the determination is made by measuring a somewhat arbitrary parameter known as entrenchment ratio, but functionally, the channel is probably best described as an F-channel, because any incipient floodplain within the larger entrenched channel is narrow.

In watersheds with snowmelt-dominated hydrologic regime, stable streams that are not entrenched (*e.g.* C-channel systems) have access to a floodplain at flows greater than about the 2-year return interval. Floodplain activation effectively acts as a “safety valve” to attenuate stream energy in high-flow events as water spreads over the wider floodplain area. If all of the flows from a huge flood, say the 500-year event, are contained within the channel, then there is no “safety valve” so stream power and scour potential can escalate to extremely high levels. This, of course, begs the question whether the observed entrenchment and instability on this reach are the result of direct channel impacts, some other anthropogenic source, or simply a natural response to geologic events. These details could possibly be worked out in a more detailed assessment based on quantitative monitoring. Based on the information available at this level of assessment, the explanation that best fits the evidence is the latter, that the observed instability is a natural response to geologic events. Another report by Lowclouds Hydrology (2010) seems to concur with the assessment that the observed channel instability on this reach is a result of natural processes.

Beyond the bank stabilization efforts, there is a lot of active fluvial geomorphology in the OBJ campground area. Recent aggradation on the reaches just upstream of the campground (Reaches #38a and #38b) is extreme, and directly analogous to the aggradation seen on the flats above Poverty Gulch. Like the event at Poverty, it is more than a stretch to pin the cause of this aggradation on human impacts, though in the case of the aggradation at OBJ we do have anthropogenic channel instabilities upstream (those centered around Slate River Ranch) to point to as a possible additional sediment source that might have exacerbated a natural aggradation response. On Reach #38b, the aggradation of gravel and cobble appears to have resulted in channel type evolution from a presumed B3 to C3. The valley bottom is filled with coarse sediment, and an incipient channel is formed within it. A future of channel instability is expected as this channel adjusts to its new floodplain. For these reasons, many of the RRISSC variables for channel processes scored high, resulting in red flag status. It is important to note, though, that the overarching causes for instability appear to be natural, and that anthropogenic impacts are likely much less significant by comparison.

More dramatic geomorphologic activity is at play on the reach at the upper end of the campground (Reach #39a). Here, aggradation and flooding caused a channel avulsion which abandoned a whole meander bend, and a new cutoff channel has formed through forested area in a classic Rosgen C to G channel evolution scenario. The shortened, steepened, narrow, entrenched G-type cutoff channel is extremely susceptible to high erosion and bed scour. This new channel will continue to enlarge and cut its way headward into the deposits upstream, entraining a huge amount of LWD (dead and live trees) and sediment as it does so. The RRISSC ratings for channel processes are accordingly high to very high, and again we have a red flag reach. Also again, we are faced with the problem of determining whether any of this instability can be attributed to land use or direct human stress. Like its neighboring reaches, here too we do not see evidence of human stressors of a magnitude capable of explaining the processes. Given the evidence available, we conclude that the high degree of instability and channel evolution present here is primarily a natural channel response to geologic activity.

4.2.3 Road impacts

Road impacts in the Main Slate River Glacial Valley area are limited to one road (FR 734) which runs up the east side of the valley bottom, and one segment of the Gunsight Road as it climbs up the west side of the valley into Wolverine Basin. The amount of sediment produced by roads is negligible, and road impacts, in general, are insignificant except where FR 734 crosses a few side drainages (particularly Reach #36) and where the Gunsight Road is adjacent to the Slate River (Reach #57a). Reach #36 is flagged yellow primarily due to the road crossing which is a "shot-gun" culvert. That is, the outlet of the culvert is perched above bed elevation and therefore at increased risk of scour and gully formation. Reach #57a is flagged orange for several reasons, but primary among these is the direct channel impacts related to the location of Gunsight Road and fill along the left bank of the Slate River. The Gunsight Bridge is another stressor on Reach #57a. The bridge does effectively span the bankfull width of the channel, but fill for the road approaches to the bridge do effectively cut off floodplain flow which may limit sediment transport upstream of the bridge and increase the potential for excess scour and bank erosion. Observed excess deposition is evidence of limited sediment transport efficiency, and recently placed bank armor at the bridge area may be a response to the effects of increased scour and erosion.

Low-water crossings at both the Poverty Gulch Road and OBJ campground are direct channel impacts related to roads, but the effects of these impacts are probably minimal. Another road crossing situation was suggested to us during the study as a possible cause of instability in the area. This is a new bridge across lower Poverty Creek. We assessed this bridge during the RLA field reconnaissance and found it to span the entire canyon through which Poverty Creek flows, from bedrock to bedrock. It is clear that this bridge is not a stressor to channel function or sedimentation, and therefore not a cause of downstream instability on the Slate.

4.3 Main Slate River Alluvial Valley

On the reaches downstream from Gunsight Bridge to past Nicholson Lake, the Slate opens up from a tight glacial valley (type V) to a wide alluvial valley (type VIII) that runs the rest of the length of the study area to Crested Butte, and both stream and floodplain characteristics change accordingly. Alluvial stream channel types are now ubiquitous here, and bed material has graded down from cobble-dominated (or bedrock) to gravel. The presumed reference stable channel type was described by HRS (1995) as C4, which seems reasonable. The side drainages through this section of the watershed tend to be much less steep compared to upper reaches, and the probability of mass erosion events directly affecting the stream is far more remote.

If the C4 stream type is a true natural stable reference condition for this portion of the watershed, we are left to explain the observation of regions where D4 (braided) and F4 (wide and entrenched) channel types dominate and where channel instability is quite obvious. Whereas most of the instability and channel evolution seen in the higher portions of the watershed is largely attributed to natural response to geologic activity (other than that at Slate River Ranch and possibly some impacts at OBJ Campground), the aberrant channel types and observed instability in this lower portion of the watershed can often be directly linked to human disturbance. Sediment loads produced by anthropogenic channel instability on these reaches is estimated to be at a level that approaches or even exceeds the amount of sediment coming into the watershed via natural hillslope processes.

4.3.1 Impacts at McGill Reach and Peanut Lake

The greatest magnitude of land use impacts in the watershed is concentrated on the lands from the Wildbird Bridge to the lower end of Peanut Lake (Reaches #62 and #63). These lands (working downstream from Wildbird Estates) include the Rice Parcel (owned by CBLT), McGill Property, and Peanut Lake (owned by CBLT).

The most severe stressor here is related to past gravel mining operations on these reaches. Past reports (HRS 1995) speak of in-channel gravel mining in the 1970s which lowered the bed elevation of the Slate River causing degradation and down-cutting. Evidence of this is clear on site; the channel is incised, and there is a "perched" abandoned floodplain about 2 to 3 feet higher than bankfull elevation. Our observations are consistent with the HRS (1995) assessment that channel evolution following incision on this F4 reach is a major human-caused stability and sediment impact that has clear negative stability and sedimentation effects that extend both upstream and down. WARSSS assessment for the McGill reach (Reach #62) indicates serious risks that include high rates of bank erosion, channel enlargement, aggradation, and even the potential for further degradation. Thus, the reach clearly deserves red flag status, and in this case the channel instability is undeniably human-caused. The problems are a direct result of past and present land use including in-channel mining, diversion ditches, drainage ditches, and vegetation impacts.

Incision on these reaches is exacerbated by the presence of an elevated road along the left bank of the river that was left behind by the mining operation. This road effectively berms off the entire east side of the floodplain preventing overbank flooding which, in addition to being an obvious geomorphic impact, is also a significant stressor on riparian vegetation. The high bare compacted gravel road/berm prevents the establishment of any riparian plants, and it also contributes to drying the wetlands and riparian floodplain area east of the river as it blocks any overbank flows. Floodplain drying and vegetation impacts are further exacerbated by a drain ditch which was constructed along the perimeter of the property. We assume that the intended function of this ditch was to dry the existing wetland area to make it more useable as pastureland or to support past gravel mining.

Near the upstream end of Reach #62, just upstream of the McGill Property on the Rice Parcel (owned by CBLT), there is a diversion and head gate on the left bank of an outside bend of the river that feeds a large ditch to supply water to an old gravel pit that is now an artificial pond. These features present an extremely serious and immediate threat. Aerial photography shows that this bend of the Slate River has migrated about 50 to 60 feet towards the ditch between 2005 and 2011. Unless this situation is mitigated, the Slate River will likely intercept the ditch and potentially change course. This would obviously have severe stability and sediment consequences that would threaten habitat and infrastructure on the McGill Property and other properties downstream. Recent efforts to stabilize this bend with one very small J-hook vane structure and some rip-rap at the diversion point are grossly insufficient to arrest bank erosion and prevent avulsion into the ditch.

On Reach #63, the Slate River runs along the edge of Peanut Lake (owned by CBLT), and this reach also classifies as an F4. As on the McGill Property (Reach #62), the entrenched condition is very likely a direct result of in-channel mining followed by down-cutting, incision, and channel enlargement. Also, the berm/road on the left bank extends to below Peanut Lake. Like the incised reach upstream, RRISSC assessment indicates a red flag status, with serious risks that include high rates of bank erosion, channel enlargement, aggradation, and even the potential for further degradation. Further degradation may be limited, though, by the presence of a natural bedrock grade control at the lower end of the reach. In addition to all this, the channel instability is a threat to Peanut Lake. The land form separating the lake from the river is as narrow as 15 to 20 feet in places, and time series aerial photography shows a gradual, albeit fairly slow, migration of the river towards the lake, further narrowing this span. Hydraulic connections between the lake and the river already exist and are presently maintained by beavers. Basically, several small beaver dams are all that is preventing Peanut Lake from draining into the Slate River. In short, human-caused instability on the reach is both a systemic source of sediment pollution as well as a serious risk to Peanut Lake.

4.3.2 Bridge impacts

The Gothic Road Bridge is an obvious stressor affecting Reach #65 on the CBLT Property. The impact of this stressor is manifest as a floodplain constriction that prevents the effective transfer of high flows through this point. It appears, and both the HRS (1995) report and historic aerials confirm, that this reach is a backwater at bankfull discharge. This has the effect of creating a huge amount of unnatural sediment deposition on the reach. It is important to note that there are actually three "constriction points" in this area:

- The Gothic Road Bridge (and associated road fill)
- Road fills from the historic road that used to cross the river just downstream of Gothic Road by the cemetery
- A natural geologic constriction/grade control just downstream from there

Clearly, the natural geologic constriction and grade control has always placed some limit on the rate at which flood flows exit the wide floodplain above, but the two unnatural road constrictions upstream of it are much narrower than the natural one, and at locations with flatter valley slope. It is therefore likely that these stressors are an unnatural cause of excess deposition and aggradation, and the enormous sediment bars and braided channel condition observed upstream from the bridge is likely a result of this stressor-induced process. Because of this, the reach has red flag status.

There is also a much smaller pedestrian bridge that spans the Slate River at Wildbird (Reach #61). Road fill at the approaches to the bridge may effectively constrict floodplain area at this location, but the effects on stream stability are much less apparent than what is observed at Gothic Road. Bank erosion on the fills at either end of the bridge span may be the most important impact of this bridge.

4.3.3 Grazing and riparian impacts

There is apparently some fairly concentrated livestock grazing on most of the reaches within this section of the watershed. However, the reaches have largely been spared any serious shrub clearing or wholesale riparian vegetation conversion to pastureland. Overall, the riparian vegetation appears to be in relatively good condition with widespread woody riparian cover dominated by willows (*Salix* spp.). The combination of grazing and other vegetation impacts, while present, is probably of minor importance compared with the greater geomorphologic stressors mentioned above.

5.0 Restoration or Mitigation Opportunities

The purpose of this study is to identify opportunities for restoration or mitigation. We used the results of our WARSSS assessment as a basis for creating a prioritized list of potential candidate projects or management opportunities. This is by no means meant to be an exhaustive or definitive list of actions, but really more of a set of suggested avenues for reducing sediment pollution or anthropogenic instability within the Upper Slate Watershed through mitigation or restoration.

5.1 Highest Priority Opportunity

The opportunities or regions of concern listed in this category are considered to be in need of emergency action to prevent an imminent threat that could have serious consequences. As such, these are really not so much opportunities, but rather "problems" that require action to prevent adverse consequences.

5.1.1 McGill Property (Reach #62)

Bank erosion and rapid channel migration of the Slate River towards a large open ditch is evident. There is a great and increasing risk that the river will intercept and capture this ditch which would likely cause a significant portion (or all) of the Slate River flows to become redirected from the present channel to a course through the ditch and old gravel pit. This could leave the current channel of the river all or partially dewatered through the reach and pose serious instability along what would be the new channel through the McGill Property. It seems likely that the residence on the McGill Property could be at risk if this occurred.

Mitigation measures could include filling and reclaiming the ditch. Of course filling the ditch would necessitate reclamation of the gravel pit on the property as well, perhaps as a groundwater pond or wetland, unless another diversion was constructed elsewhere. A solution could also include measures to prevent channel migration in this direction by increasing the resistance of the left bank to erosion by decreasing bank height, strengthening the bank with bioengineering or possibly more traditional engineering approaches, and improving riparian vegetation. The risk could further be mitigated by relocating the channel back towards the west (to increase the buffer area between the channel and the ditch) and alleviating near-bank stress by increasing radius of curvature on the bend and possibly installing artificial deflection structures. More detailed studies would indicate which of these options would be the most effective and cost efficient, and which would best fit in with the overall vision for the watershed.

5.2 High Priority Opportunities

The opportunities listed in this category are the highest priority due to the presence of disproportionate sediment supply or stream instability that can be linked to human causes. To meet our criteria for high priority, an opportunity or potential project must have an identified problem with important consequences that can be remedied in a practical fashion. These reaches have great potential for improvement as indicated by high levels of impairment to be mitigated and high RRISSC scores.

5.2.1 Gothic Bridge Area (Reach #65)

There appears to be an excellent opportunity to improve sediment transport and to mitigate the impacts of excess deposition and aggradation on the Slate River upstream of the Gothic Road Bridge. PLA monitoring combined with quantitative hydrologic and sediment transport modeling are encouraged as a means for validating (or refuting) this hypothesis before taking action. Installing a wider-span bridge for Gothic Road and opening up the old road constriction downstream are straightforward, but probably expensive treatments. One possible strategy would be to have all the studies and documentation in-hand for the time when the bridge is slated for replacement or maintenance, and then make the argument for the need for a wider span at that time (assuming that the studies support our hypothesis). The amount of excess sediment stored as deposition on the reach upstream from the bridge appears to be in the range of 20,000 CY (estimated by the following: 1,000 yard (yd) stream length x 20 yd width of excess deposition x 1 yd deposition depth = 20,000 CY).

5.2.2 McGill and Peanut Lake Reaches (Reaches #62 and #63)

These reaches offer an excellent opportunity for restoring natural stream and floodplain function that could mitigate serious instability and sediment source issues while protecting some key resources. The stressors identified on these reaches (particularly the diversion, ditch, road/berm, incised channel, vegetation impairment, and the instability associated with them) offer a suite of human impacts that can be remedied in a way that restores the stream and riparian system. A coarse conservative estimate of the amount of sediment produced annually by continued bank erosion, channel enlargement, and expansion of the incised channel over this approximate 1.0-mile reach would be on the order of 1,500 CY (assuming a channel length of 5,000 feet and 2 feet of annual bank erosion with 4-foot bank heights, annual sediment production is calculated as 5,000 feet x 2 feet x 4 feet = 40,000 cubic feet, or approximately 1,500 CY). In addition to the potential reductions in sediment load, restoration of this reach offers the opportunity to improve natural ecological function and protect significant resource values, including Peanut Lake and the associated floodplain wetlands.

Treatments to restore this reach might include the following: removal of the berm/road that parallels the left bank of the river, channel restoration including resizing or relocation (channel relocation would be the preferred option here due to the fact that the existing channel is incised), remediating the existing drain and diversion ditches (and potentially the pond) on the McGill Property, and vegetation treatments to reestablish woody riparian species along streambanks where they are absent. Not surprisingly, this is the same reach that HRS (1995) recommended for treatment. In addition to filling the existing drainage ditches and restoring hydrology to the dried wetlands, they argued for an approach that involved complete channel relocation and reclamation of the existing floodplain wetland area on a grand scale, with an estimated cost around $500,000.

Clearly, there are some real benefits to be gained by restoring these reaches, but doing it correctly will be costly. Before any plans are made for restoration or mitigation, the area should be studied quantitatively to:

- Validate the claims we are making about channel condition and the extent of stressor impacts
- Quantify sediment supply from the reach
- Inform any potential design plan.

It would also be worthwhile to include a better of assessment of the Kapushion reach (Reach #64) as part of the PLA strategy. According to HRS (1995), the impacts from

McGill extend down into the Kapushion reach, and the upper portion of that reach may be incised as much as 1.5 feet. If this is the case, any monitoring or restoration efforts on the McGill and Peanut reaches could be extended to encompass the full length of channel impacts.

5.2.3 Slate River Ranch Area

The Slate River Ranch (Reach #31a) could be combined with the reach upstream (the CBLT easement property at Poverty Gulch, Reach #20b) and the reach downstream on US Forest Service (USFS) property (Reach #31b) to form a potential restoration project. Like the potential McGill project described above, these reaches have serious stability and sediment problems with a direct anthropogenic cause. The estimated sediment load from these impacts is similar to the load calculated for the McGill Reach of 1,500 CY per year.

Like the recommendations for the McGill Property, mitigating the impacts at and around Slate River Ranch in a sustainable way would involve full-scale river and floodplain restoration. In this case though, unfortunately, the riparian condition would require more extensive vegetation rehabilitation to support stable natural channel morphology. Because these efforts would likely be very costly, and because success would depend very much on proper channel design and sizing relative to the watershed, it is highly recommended to make a quantitative assessment using PLA and several years of monitoring prior to any action. As in the McGill area, these efforts are necessary to more accurately quantify the potential sediment load reductions that can be expected, to justify the potentially large expense, and to inform the detailed design criteria necessary to undertake such a complex restoration.

5.3 Medium Priority Opportunities

Medium priority reaches are those for which either the potential load reductions are substantially less than the high priority reaches, or the source of instability or sediment loads may be questionable and in need of clarification or quantification.

5.3.1 OBJ Campground Area

The Slate River at OBJ Campground is obviously unstable. Entrenchment, aggradation, a recent avulsion, and formation of an incised cutoff channel are all clearly evident within the group of Reaches #38a, #38b, #39a, #39b, and #39c. What is not obvious is the source of this instability. Our best assessment is that these channel processes are a result of natural response to geologic activity brought on by a recent huge aggradation event. This makes the opportunity for mitigation far less desirable, since it would not be viewed as restoration (ameliorating anthropogenic impacts), but rather an attempt to alter or manage natural processes.

Nevertheless, there may be reasons for wanting to stabilize portions of this reach, say for instance, to protect the campground and the people that use it. Apparently the Bureau of Land Management (BLM) is actively studying the reach, and monitoring channel geomorphology. This level of quantitative, prediction level assessment is important to help understand the nature of the instability (natural versus anthropogenic), to quantify potential sediment load reductions, and to assess the risk involved in doing mechanical channel alteration or stabilization on a reach that is apparently in the middle of major geomorphic evolutionary change. We included the reach as a priority for CCWC for the opportunity to partner with the BLM in a quantitative PLA analysis and to potentially protect campground resources.

5.3.2 Gunsight Bridge Area (Reach #57a)
The Gunsight Bridge reach is owned by CBLT. A segment of the Gunsight Road on the left bank of the river and the bridge spanning the river are potential sources of anthropogenic stress on the system that are indicated in the RRISSC scores. Despite the high RRISSC ratings, though, it is unclear how much impact these stressors actually have on stream stability or sediment processes. This reach and the reaches immediately upstream (Reach #39c) and downstream (Reach #57b) were all classified as D4, a wide braided stream type which tends to make them score unusually high in RRISSC since the method is somewhat prejudiced towards a C-channel reference in this valley type. Regardless, the presence of a wide, braided channel, along with the identified potential stressors indicates instability and the potential for restoration or mitigation that should be checked with more quantitative means. At this time, our recommendation is to pursue a broad-scale PLA study on this group of reaches to determine impacts of the road and bridge, and to assess the condition of observed braided stream morphology.

5.3.3 Redwell Basin (Reach #54)
This reach is a potential candidate for quantitative PLA analysis of hillslope processes impacted by roads and mines. We suspect that sediment contributions from this source are fairly insignificant compared to natural geologic hillslope processes in this and similar headwaters drainages, but the high RRISSC rating indicates a potential need for more detailed study.

5.4 Low Priority Opportunities

The reaches presented here offer either a chance to investigate questionable reaches that we expect are natural with little need for intervention, or the potential to manage or mitigate small anthropogenic sediment sources.

5.4.1 Slate River above Poverty Gulch (Reach #20a)
Recent widespread deposition that aggraded most of the floodplain on this reach is almost certainly a natural event, and the channel formation and evolution that will likely occur here in the near future are also very much natural geomorphic processes. These processes will probably cause problems with the Poverty Gulch low-water road crossing, however, as the new channel cuts its way through the recent deposits that presently serve as a road surface across the river. We expect that the parties that use this road will require temporary or permanent structural solutions to keep the road useable through these changes. PLA and monitoring are recommended since a good understanding of the channel evolution will be needed to effectively evaluate the suitability of any proposed changes in this area.

5.4.2 North Slate drainage on Paradise Ridge (Reaches#17 and #18)
A recent BLM road hazard study (Breibart 2011) modeled sediment potential from the Slate River Road, indicating that somewhere on the order of 10 tons (approximately 8 CY) of sediment may be produced along this road annually, and most of the contributing road segments are within this drainage system. Though this is not a large amount of sediment compared to the hundreds or thousands of cubic yards that enter the Slate Headwaters system via natural hillslope processes, it is an anthropogenic source that can be controlled. Continued best management practices (BMPs) for road maintenance may keep this figure low, and quantitative monitoring in PLA could be used to quantitatively monitor sediment from this source.

5.4.3 Poverty Gulch below Baxter Basin (Reach #27).
This reach is also highlighted for potentially mitigatable road sediments. The unimproved road FR 552.2 travels adjacent to and within the riparian area of Poverty Creek on this reach. Though actual amount of sediment delivered to the system from the road is probably very small relative to natural sources, there may be local impacts of siltation and turbidity in beaver ponds that could be mitigated by better-managing or maintaining this section of road.

5.5 Protection and Preservation Opportunities

Perhaps the most important result of this study is that the majority of the Upper Slate River Watershed is in very good condition (rated as low to very low risk, or green). The watershed contains extensive areas of excellent riparian habitat with stable, functioning streams. It is also important to note that the significant impacts to stream stability and sedimentation in the watershed are the result of past land uses, mainly gravel mining. By comparison, current land uses appear to be much less of an impact, which is testament to the extensive preservation efforts and overall recent good land management of both the upland drainages and the riparian corridors within the watershed.

Many of the critical resources in the watershed are currently protected from land uses that may threaten them, mainly by CBLT, BLM, and USFS. The watershed provides a good model of sustainable management of public lands and the protection of private lands via acquisition, easements, and cooperative management.

It is important to recognize that part of protection and preservation is the ability to critically evaluate proposed land use changes or other actions in the watershed to ensure that they can be supported without compromising important watershed functions and ecosystem services. Beneficial or extractive land uses don't necessarily have to be limited on protected lands, but uses should be selected and managed with the health and sustainability of the system as the primary directive. We encourage this kind of stewardship, especially on private lands, which are generally more vulnerable to the imposition of stressors via harmful land uses. We recommend protecting as many of the existing functional reaches and adjacent habitats as possible using this model to ensure that those reaches currently rated as green, stay green.

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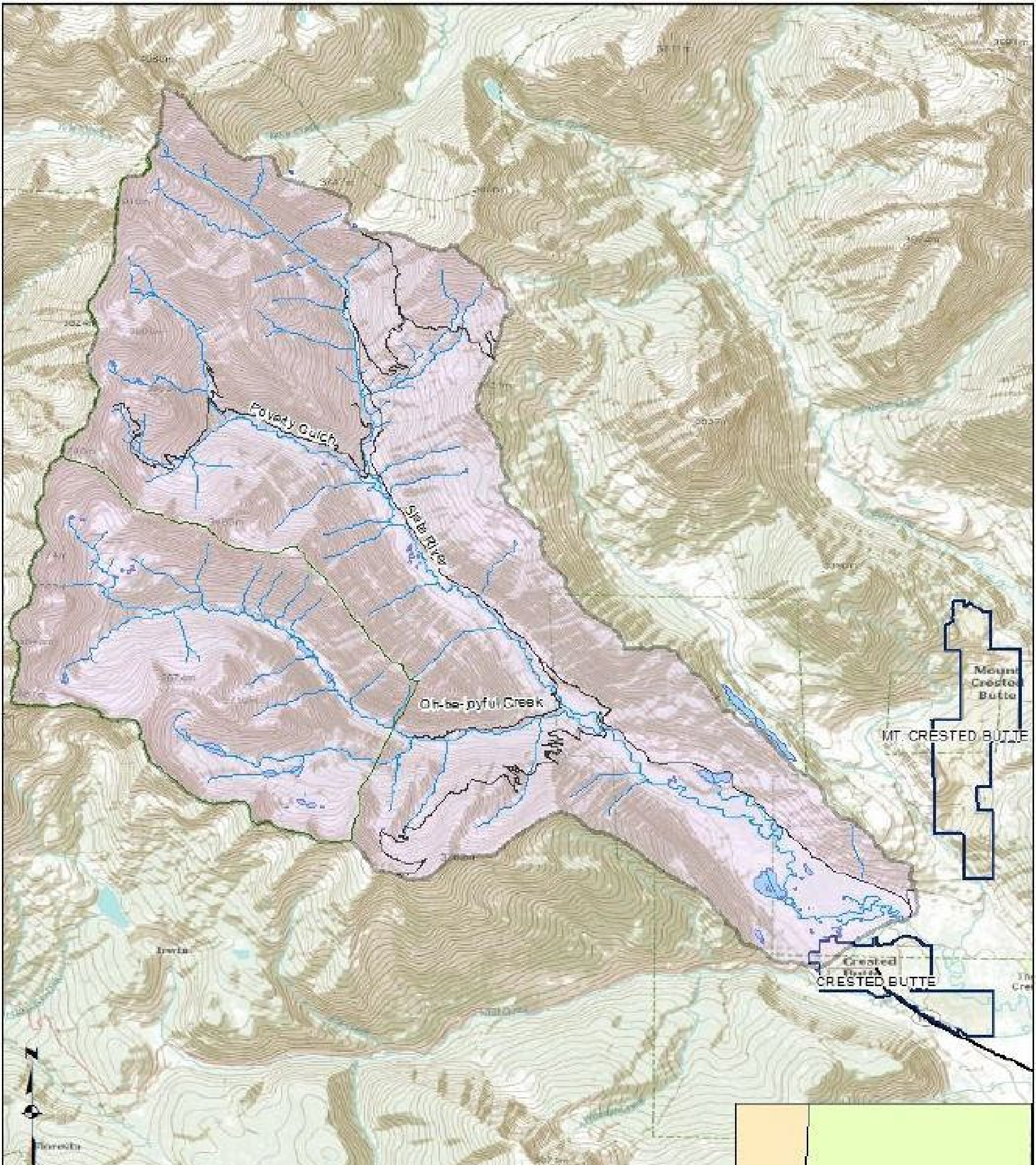


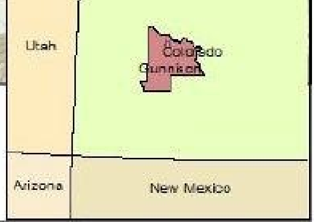
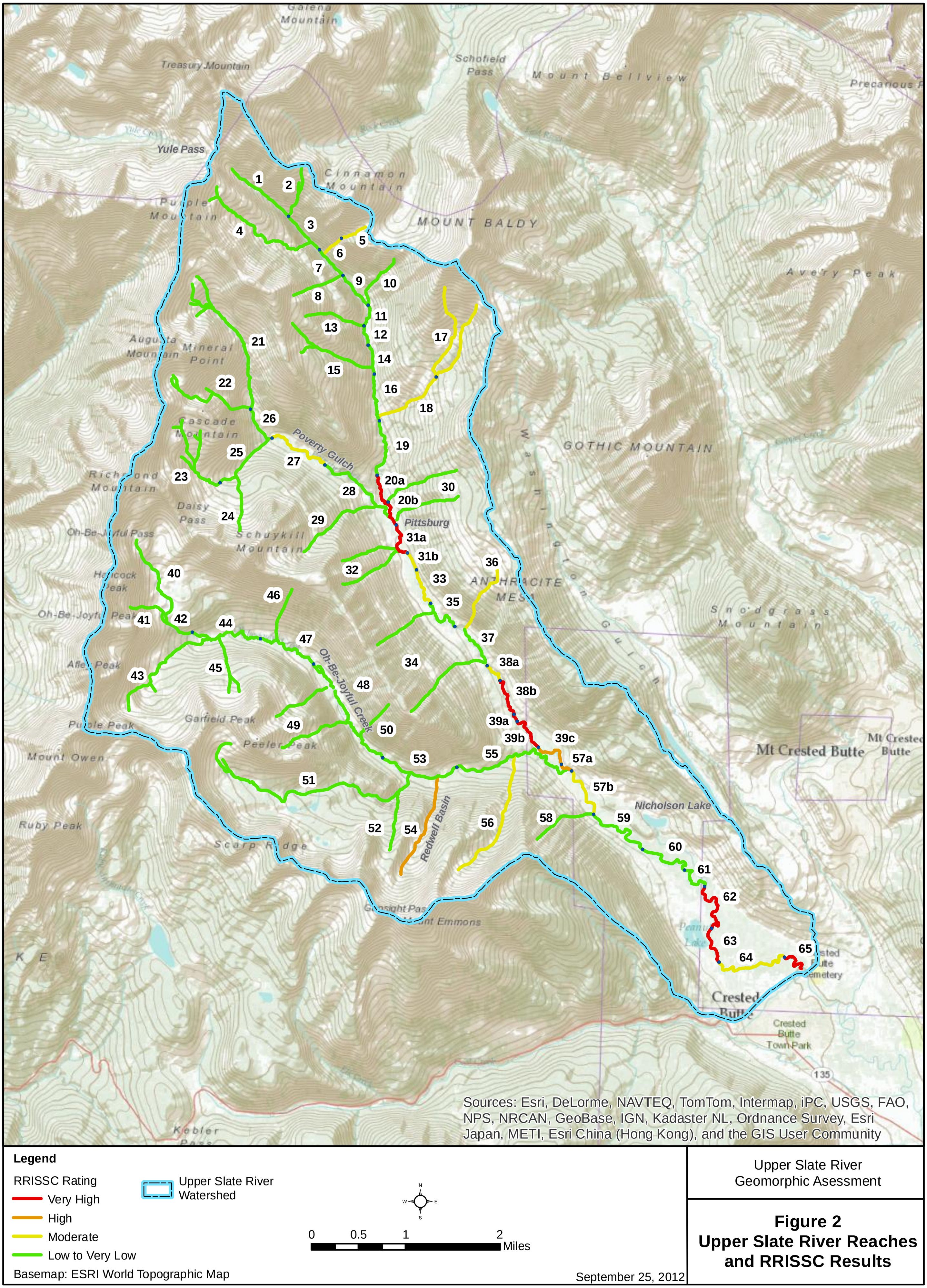


Figure 1. Upper Slate River Watershed near Crested Butte, in Gunnison County, Colorado

USR Watershed   Raggeds Wilderness   USFS Roads

Map Created by Ashley Bembenek for the CCWC Upper Slate River Committee, September 2011



Upper Slate River
Geomorphic Asessment

Figure 2
Upper Slate River Reaches and RRISSC Results

Appendix 1
Explanation of the Primary RRISSC Factors in WARSSS

Explanation of the Primary RRISSC Factors in WARSSS

Mass Erosion

The process of mass erosion describes large scale events that erode hill slopes such as landslides, debris flows, torrents, and avalanches. Where this occurs near a waterway it is a concern for watershed sediment pollution. Mass erosion is a natural geologic process, but it may be exacerbated by activities such as road building, channel relocation, mining, or disturbance to vegetation. The key to evaluating mass erosion in terms of sediment input to a reach for WARSSS is to determine whether the source is natural or anthropogenic. Mass erosion that occurs as a natural geologic process really has to be considered normal, even when it results in channel instability. Stabilizing natural mass erosion on unstable hillsides is a daunting task, as is stabilizing stream channels and fluvial systems that are responding or evolving to adjust to these natural events, but these types of projects may be warranted when human life or infrastructure could be at risk. However, if the cause of mass erosion is anthropogenic, there is high potential for excessive amounts of sediment to be delivered to a system that cannot accommodate it, and this is a true form of systemic sediment pollution.

Roads

Roads can influence the amount and the timing of sediment moving through a system. Excess sediment can be delivered from eroding road fill, cut banks, road surfaces, or from road maintenance efforts such as surfacing and traction sand. Additionally, roads that are constructed of impermeable surfaces may increase or concentrate the amount of surface water runoff and consequently carry more sediment to a stream. Ditched roadsides and culverted crossings also exacerbate erosion by concentrating flow and causing gully formation. The potential effect of a roadway is largely dependent on its proximity to a waterway. Where roads are located some distance from a significant drainage, sediment consequences are not readily transmitted to the system. But where roads are adjacent to waterways, increased sediment yield is directly communicated. In these cases, it is important to consider the quality of road construction and maintenance by looking for indicators of increased sedimentation.

In locations where roads cross streams or drainages, several adverse effects may occur. The elevation and size of bridge or culvert crossings are critical. If the invert elevation is too high or too low it may cause changes to the base elevation of the stream which can have a cascading effect on stream aggradation or degradation both upstream and down. The size of the bridge or culvert also must allow for all ranges of flow to pass in a way that maintains floodplain function and sediment transport.

Surface Erosion

Surface erosion occurs when water (precipitation as rain or snow melt) runs overland carrying sediment with it from uplands to the valley bottom. The rate of surface erosion depends on the slope of the land, vegetation, and geology. Like mass erosion, surface erosion is a natural process that can be impacted by land uses. Activities that increase the percentage of bare ground, increase or dissect slope gradient, or decrease the permeability of soils all increase the potential for surface erosion. Factors that lessen the impacts of anthropogenic surface erosion include the distance from the disturbance to a waterway and the quality of the riparian buffer.

Stream flow Change

This factor is concerned with tracking the impacts of flow augmentation, depletion or timing to the waterway. Changes to the hydrograph can have long lasting and far reaching effects in the watershed. The morphology of a stream channel and its ability to transport sediment load are directly related to the amount and timing of its water source. If these levels are changed the stream will tend to adjust to fit the new hydrologic regime, and this processes of adjustment typically involves long periods of instability and high sediment yield. Flow augmentation is often a result of increased runoff from urban areas or roads (impermeable surfaces) or trans-basin diversions.

Stream bank Erosion

Stream bank erosion rates are related to land uses, riparian vegetation, bank height, bank material and erosive potential (a factor of channel morphology). Streams that have low sinuosity or that are confined to canyons with large rock material experience minimal amounts of bank erosion. Bank erosion is most commonly observed on meandering meadow streams where bank material is generally weak (soil, sand, or gravel) and channels are more sinuous. On these stream types, bank strength and resistance to erosion is highly dependent on the quality, density, and depth of root mass from riparian vegetation. The highest bank erosion rates are observed on meadow streams where naturally occurring riparian vegetation has been eliminated to allow for land use development. In these cases, bank erosion is almost always associated with other factors of instability or sediment yield such as direct channel impact, channel enlargement, aggradation, channel evolution, and degradation.

In-Channel Mining

The effects of in-channel mining are dramatic. These activities can have striking impacts to the form and function of streams, and often involve degradation or down-cutting. Sediment consequences from in-channel mining include channel instability and all the associated sedimentation processes that go with it. Mined reaches typically also have an associated high risk for mass and surface erosion rates due to the level of disturbed soils, exposed hillsides and tailings, and the presence of high-risk roads. In some locations where mining has been abandoned for a long time, systems have managed to recover after years of adjustment. Other reaches are so heavily impacted that the there is virtually no potential for unassisted recovery, and the problems will continue until something is done.

Direct Channel Impacts

Direct channel impacts incorporate a variety of human impacts that directly affect stream channels, such as: 1) changes in riparian vegetation, 2) channel relocation (particularly straightening), 3) channel or bank hardening, and 4) channel blockage including woody debris (LWD) and structures. Interestingly, WARSSS does not discriminate between natural LWD or beaver dams and debris or dams that are introduced unnaturally. Rating this factor is largely dependent on observing what percentage of the stream length has had a vegetation shift, direct manipulation or hardening, or blockage.

Changes to riparian vegetation are often a very important factor of sediment impairment depending on the type of stream and valley system. In meadow streams, riparian vegetation is a driving factor for stream stability, morphology, and erosion rates, and this process is described in detail later in the report. Manipulations to the location, dimension, pattern, or profile of a channel can have important implications to the sediment capabilities of a reach. If stream manipulation results in a change to the gradient or morphology of the channel, the sediment capacity (particle size) and competence (volume) of the reach may be increased or decreased causing excess deposition or scour and instability. There are also often unforeseen consequences from channel hardening and blockage, and ironically sometimes the very treatments made to try to arrest bank erosion and improve sediment pollution (hardened banks, in-stream structures, etc.) end up being sources of instability.

Channel Enlargement

The risk of channel enlargement is based on the potential for a stream to incise (lowering of the base level) or widen. It is usually a response to changing meadow conditions (vegetation), sediment load, or stream flow change; but it may also be caused by direct manipulation of the channel or mining. The process of channel enlargement may produce large amounts of sediment either from bed scour or bank erosion. Beyond the obvious impacts to sediment yield, the process may result in diminished floodplain function and changes to sediment transport ability.

Aggradation/Excess Sediment

The aggradation risk factor is an assessment of the potential for excess sediment to accumulate in a reach. This process may occur as a result of increased sediment volume or because the reach is altered such that it is no longer capable of transporting the amount of sediment that normally moves through the system. Sediment deposition can negatively impact a reach by decreasing habitat quality and initiating processes that can drastically change the morphology of the stream and how it functions. Common causes and effects of aggradation include channel widening, enlargement, braiding, and avulsions. Aggradation is a serious instability concern. When a stream becomes wide and flat, its sediment transport capabilities diminish, sediment continues to accumulate and the process may continue. Conditions that increase risk of aggradation are decreased stream flow, direct impacts to the channel and banks, and artificial blockages or impoundments.

Channel Evolution/Successional State

It is natural for streams to change over time and adjust to shifting climatic conditions. Streams will modify their dimension, pattern, and profile to match changing hydrologic and sediment regimes. These natural processes can occur quickly as a result of a major geologic event or be a gradual process as long term trends shift. When streams are disturbed by anthropogenic forces, the same processes may be put in motion. By understanding these processes it is possible to assess whether a stream is in a stable state or is moving from one form to another in response to changing conditions. Depending on the level and extent of the disturbance, a stream may be able to regain a stable state without producing a large amount of sediment. On the other hand, some channel evolution processes involve long periods of instability and sediment yield.

Degradation

Degradation is the lowering of base elevation of a streambed relative to the surrounding landscape due to excess scour. The result of excess bed scour is down-cutting, and when a channel down-cuts, the height of its banks are increased and the channel becomes disassociated from its floodplain; that is, the channel becomes incised or entrenched. Incision and entrenchment are true channel instability processes that set a host of sediment-related processes in motion, particularly on meadow streams. As the channel adjusts to a new base level, bank erosion rates may be extreme. Indeed the highest bank erosion rates tend to be on recently incised segments. The volumes of sediment produced by an adjusting degraded channel can be enormous.

In the case of degraded channels, the landscape also has to adjust to the new base elevation of the stream, and tributaries rejuvenate to match to the new confluence elevation. That is, tributaries also down-cut and become unstable. All of the sediment produced in this string of events moves downstream where it has negative effects on the rest of the watershed. Conditions that increase the risk of degradation are poorly sized or poorly placed culverts or bridge openings, clear water discharge, stream flow augmentation, channel relocation (straightening), decreasing sinuosity, and avulsions.

Source: Rosgen (2006)

Appendix 2
Reconnaissance Level Assessment Results

Table 2.1: Land Use/ Stressor Impact Analysis: Headwaters Areas (Slate Headwaters, Poverty Gulch, OBJ Gulch)

Land Uses/ Human stressors	Potential Impacts												Notes
	(1) Streamflow changes (magnitude/ timing/ duration)	(2) Riparian vegetation change (composition/ density)	(3) Surface disturbance (% bare ground/ compaction)	(4) Surface/ sub-surface slope hydrology	(5) Direct channel impacts that destabilize channel	(6) Clear water discharge	(7) Loss of stream buffers, surface filters, ground cover	(8) Altered dimension, pattern and profile	(9) Excess sediment deposition/ supply (all sources)	(10) Large woody debris in channel	(11) Stream power change (energy distribution)	(12) Floodplain encroachment channel confinement (lateral containment)	
Urban development	D	D	D	D	D	D	D	D	I	D	D	D	None
Silvicultural (clearcuts, skid trails, etc.)	D	D	D	D	D		D	I	D	D	I	D	There is no evidence of significant logging. The many apparent "clearcut" hillslopes within the watershed are natural avalanche paths.
Agricultural (land conversion)	D	D	D	D	D		D	D	D	D	D	D	None
Channelization	D	D		D	D		D	D	D	D	D	D	None of the major tributaries appear to have been artificially channelized.
Channel hardening/ bank stabilization	D	D		D	D		D	D	D	D	D	D	None of the major tributaries appear to have been artificially channelized.
Fires	D	D	D	D	I		D		D	D			No evidence of major recent fires.
Flood control, levees, dikes	I	D		D	D	I	D	D	I	D	D	D	None
Reservoir storage, hydropower	D	I		I	D	D		I	I/D	I	D		None
Diversions, depletions (-) Imported (+)	D	I		I	D	D			I/D				None
Grazing	I	D	D	D	D		D	D	D	D	D		Cattle grazing is widespread, except within some of the uppermost drainages and steep hillsides. However, the intensity of grazing is generally very low, and severity of impacts is very low.
Roads, crossings, bridges	D		D	D	D		I	D	D	D	D	D	Improved and unimproved dirt roads exist in a portion of the Slate headwaters (FR 734 and FR 811), Poverty Gulch (FR 522.2), OBJ Gulch (FR 754 on the extreme lower portion only), and through Wloverine and Redwell Basins (FR 585) to Gunsight Pass. Additionally, there are numerous old road beds that used to access mines in the extreme upper headwaters basins. Overall, the density of roads in the headwaters is low, and only minimal, localized impacts are seen. Specific areas identified in RLA include sections of the main Slate River Road (FR 734) where it is near the Slate River and where it switchbacks up towards Paradise Basin, one section of FR 552.2 where it is adjacent to the creek in Poverty Gulch, and the Gunsight Pass Road (FR 585) where it climbs through Wolverine and Redwell Basins.
Off-channel mining	D	D	D	D	D		D	D	D	D	D	D	Though mining was a major historic land use within the headwaters areas, mos of the activity was hard rock mining within the upper headwaters areas. Sediment and stream impacts from this use are limited to the mine access roads and leftover overburden/tailings which are rare. An exception may be the Redwell Basin, which is flagged for advanced study in RRISSC (see roads).
In-channel mining, dredging		D		D	D		D	D	D	D	D	D	No evidence of significant recent in-channel mining within the study area.
Direct riparian vegetation impacts		D	D	D	D		D	I	I	D	I		Riparian vegetation impacts within the headwaters area exist, but are very minor. There appear to be no major areas that have been cleared of vegetation or that have seen major vegetation shifts.
Recreation		D	D				D					D	Though the headwaters area are popular recreation destinations, the uses are generally very low impact. Higher impact uses are concentrated on existing roads and accounted for within the "roads" category.

D = Direct potential impact (darkness of shading indicates degree of impact)
I = Indirect potential impact (darkness of shading indicates degree of impact)
Blank = Little to no impact

no impact	minimal	light	moderate	high	extreme

Table 2.2: Land Use/ Stressor Impact Analysis: Main Slate Glacial Valley (Main Slate from Poverty Gulch to Gunsight Bridge)

Land Uses	Potential Impacts												Notes
	(1) Streamflow changes (magnitude/ timing/ duration)	(2) Riparian vegetation change (composition/ density)	(3) Surface disturbance (% bare ground/ compaction)	(4) Surface/ sub-surface slope hydrology	(5) Direct channel impacts that destabilize channel	(6) Clear water discharge	(7) Loss of stream buffers, surface filters, ground cover	(8) Altered dimension, pattern and profile	(9) Excess sediment deposition/ supply (all sources)	(10) Large woody debris in channel	(11) Stream power change (energy distribution)	(12) Floodplain encroachment channel confinement (lateral containment)	
Urban development	D	D	D	D	D	D	D	D	I	D	D	D	None
Silvicultural (clearcuts, skid trails, etc.)	D	D	D	D	D		D	I	D	D	I	D	There is no evidence of significant logging. The many apparent "clearcut" hillslopes within the watershed are natural avalanche paths.
Agricultural (land conversion)	D	D	D	D	D		D	D	D	D	D	D	The only significant land conversion for agricultural use is at the Slate River Ranch (#31a) and associated properties near Pittsburg where riparian areas have been cleared for pasture and an artificial lake was constructed. Willow eradication is documented in (HRS 1995). Additional vegetation impacts are accounted for in the "grazing" and "direct riparian vegetation" categories.
Channelization	D	D		D	D		D	D	D	D	D	D	A segment of the Slate on Slate River Ranch Ranch was realigned and channelized, and an artificial lake was constructed. This event and resulting instability are described in (HRS 1995) and still readily apparent. The straight segment on USFS property (#31b) adjacent to FR 734 is suspect for past straightening or channelization, but the history is unknown.
Channel hardening/ bank stabilization	D	D	D	D	D		D	D	D	D	D	D	Direct physical manipulations of the Slate have been made within the OBJ Campground reach (#39b) including rip-rap hardened banks. Rip-rap hardened banks also exist at the Gunsight Bridge on #57a.
Fires	D	D	D	D	I		D		D	D			No evidence of major recent fires within the study area.
Flood control, levees, dikes	I	D		D	D	I	D	D	I	D	D	D	Fill for Gunsight Bridge and the remaining old railroad grade may act as levees, confining the floodplain area.
Reservoir storage, hydropower	D	I		I	D	D		I	I/D	I	D		No significant impacts.
Diversions, depletions (-) Imported (+)	D	I		I	D	D			I/D				None
Grazing	I	D	D	D	D		D	D	D	D	D		The effects of intense livestock grazing is apparent at Slate River Ranch (#32a) and the adjacent CBLT property upstream (#20b) where mechanical hoof shear, vegetation, and cover impacts are seen.
Roads, crossings, bridges	D		D	D	D		I	D	D	D	D	D	FR 734 parallels Slate River on the east, but has minimal impact. Gunsight road and the Gunsight Bridge are significant impacts on #57a
Off-channel mining	D	D	D	D	D		D	D	D	D	D	D	Coal mining and infrastructure below OBJ Campground and Gunsight Bridge reaches (#39c and #57a).
In-channel mining, dredging		D		D	D		D	D	D	D	D	D	In-channel mining and/or dredging was done to re-align the Slate River and to construct an artificial lake on Slate River Ranch property (see HRS 1995). Impacts are accounted for in the "channelization" category.
Direct riparian vegetation impacts		D	D	D	D		D	I	I	D	I		Willow eradication on Slate River Ranch (see HRS 1995) and livestock grazing on Slate River Ranch (#31a). Grazing on adjacent properties including the CBLT parcel at Pittsburg (#20b). Stream-adjacent road at Gunsight Bridge reach (#57a).
Recreation		D	D				D					D	OBJ Campground. Otherwise minimal impact near roads.

D = Direct potential impact (darkness of shading indicates degree of impact)
I = Indirect potential impact (darkness of shading indicates degree of impact)
Blank = Little to no impact

no impact	minimal	light	moderate	high	extreme

Table 2.3: Land Use/ Stressor Impact Analysis: Main Slate Alluvial Valley (Gunsight Bridge to Gothic Road Bridge)

Land Uses	Potential Impacts												
	(1) Streamflow changes (magnitude/ timing/ duration)	(2) Riparian vegetation change (composition/ density)	(3) Surface disturbance (% bare ground/ compaction)	(4) Surface/ sub-surface slope hydrology	(5) Direct channel impacts that destabilize channel	(6) Clear water discharge	(7) Loss of stream buffers, surface filters, ground cover	(8) Altered dimension, pattern and profile	(9) Excess sediment deposition/ supply (all sources)	(10) Large woody debris in channel	(11) Stream power change (energy distribution)	(12) Floodplain encroachment channel confinement (lateral containment)	Notes
Urban development	D	D	D	D	D	D	D	D	I	D	D	D	The only urban development in the watershed is at the town of Crested Butte, which is downstream of the study area.
Silvicultural (clearcuts, skid trails, etc.)	D	D	D	D	D		D	I	D	D	I	D	None
Agricultural (land conversion)	D	D	D	D	D		D	D	D	D	D	D	Land conversion for pastureland is apparent on McGill property (#62) and possibly at Kapushion (#63).
Channelization	D	D		D	D		D	D	D	D	D	D	Channelization apparent on McGill property (#61), likely on Peanut Lake reach (#62) and possibly on Kapushion (#63).
Channel hardening/ bank stabilization	D	D	D	D	D		D	D	D	D	D	D	Direct physical manipulations of the Slate have been made within the OBJ Campground reach including rip-rap hardened banks. Rip-rap hardened banks also exist at the Gunsight Bridge.
Fires	D	D	D	D	I		D		D	D			No evidence of major recent fires within the study area.
Flood control, levees, dikes	I	D		D	D	I	D	D	I	D	D	D	Only real significant direct geomorphological impacts is the old road (or RR?) fil that runs from Gunsight bridge across floodplain to near Nicholson Lake and th road fill for Gothic Road within the Slate Floodplain. Stream crossings at secondary roads are additional minor impacts.
Reservoir storage, hydropower	D	I		I	D	D		I	I/D	I	D		No significant impacts.
Diversions, depletions (-) Imported (+)	D	I		I	D	D			I/D				Diversion at the Lake near Wildbird Lane is a potential minor impact. No other evidence of significant diversions, depletions, or importations of flow were found within the study area.
Grazing	I	D	D	D	D		D	D	D	D	D		Cattle grazing is widespread in the watershed, except within some of the uppermost drainages, steep hillsides, and various exlosures on the main riparian area of Slate River. However, the intensity of grazing is generally very low, and severity of impacts is very low.
Roads, crossings, bridges	D		D	D	D		I	D	D	D	D	D	Minor bridge on Wildbird reach # 61. Major bridge at Gothic Road (#65).
Off-channel mining	D	D	D	D	D		D	D	D	D	D	D	Gravel mining and creation of gravel pit lake at McGill property (#62) and probably at Peanut Lake (#63). Coal mining impacts near Peanut Lake.
In-channel mining, dredging		D		D	D		D	D	D	D	D	D	No evidence of significant recent in-channel mining within the study area.
Direct riparian vegetation impacts		D	D	D	D		D	I	I	D	I		Riparian vegetation impacts are present on some reaches of the Slate River and the major tributaries OBJ and Poverty Gulch. These impacts are generally not severe, and aro mostly related to grazing (on the few ranches) or isolated areas where recreation imoprovements exist (such as OBJ Campground). There appear to be no major areas that have been cleared of vegetation or that have seen major vegetation shifts.
Recreation		D	D				D					D	Though recreation is popular within the study watershed, impacts from the activities are limited in severity and extent. There appears to be little impact off of the existing roads and trails. These impacts are accounted for within the "roads" category.

D = Direct potential impact (darkness of shading indicates degree of impact)
I = Indirect potential impact (darkness of shading indicates degree of impact)
Blank = Little to no impact

no impact	minimal	light	moderate	high	extreme

Table 2.4: Variable Influence Analysis: Headwaters Areas (Slate Headwaters, Poverty Gulch, OBJ Gulch)

Variables Influenced	Potential Erosional Process Impacts										
	Surface erosion	Mass erosion	Gully erosion	Streambank erosion	Channel enlargement	Aggradation	Degradation	Channel succession state	Sediment delivery efficiency	Notes	reaches/sub-basins of concern
(1) Streamflow changes (magnitude/ timing/ duration)		I	D	D	D	D	D	D	I	None	
(2) Riparian vegetation change (composition/ density)			D	D	D	D	D	D	I	Grazing, off-road travel	11, 12, 14, 27
(3) Surface disturbance (% bare ground/ compaction)	D	I (debris torrents)	D (rills-gully)	I	I	I	I	I	D	Human surface disturbance (mining, roads) have minimal impact to natural sediment supply which is largely a function of debris flows and avalanches. Road areas may increase sediment delivery efficiency at specific areas.	27, 31a, 39b, 54, 56, 57a,
(4) Surface/ sub-surface slope hydrology	D	D	D	I	I	I	I	I	D	Roads may impact the degree of infiltration and concentration of surface flow to cause gully formation in specific locations.	17, 18, 27, 54
(5) Direct channel impacts that destabilize channel			D	D	D	D	D	D	I	No significant impacts.	
(6) Clear water discharge			D	D	D	I	D	D		No significant impacts.	
(7) Loss of stream buffers, surface filters, ground cover	D		I						D	Few locations where vegetation impacts or proximity of roads or recreation areas to streams limit buffering capacity.	12, 14
(8) Altered dimension, pattern and profile				D	D	D	D	D		Potential impacts at road crossings.	20, 39, 57, 62
(9) Excess sediment deposition/ supply				D	D	D	D	D		Obvious signs of excess deposition or aggradation on Slate River, lower gradient valley segments.	7, 9, 11, 12, 14
(10) Excess large woody debris in-channel		D	D	D	D	D	D	D		LWD is common on the Slate, OBJ Creek and Poverty Gulch tributaries. The source of these materials is likely result of avalanches and debris torrents and a natural component of river geomorphology.	many
(11) Stream power change (energy redistribution)			D	D	D	D	D	D		Stream power appears to be a function of natural geology (valley slope and type) and stream type. Few anthropogenic impacts are suspected.	
(12) Floodplain encroachment channel confinement (lateral containment)		I	I	D	D	D		I	D	Raad crossings at tributary drainages	17, 18, 30, 31a, 36

D = Direct potential impact (darkness of shading indicates degree of impact)
I = Indirect potential impact (darkness of shading indicates degree of impact)
Blank = Little to no impact

no impact	minimal	light	moderate	high	extreme

Table 2.5: Variable Influence Analysis: Main Slate Alluvial Valley (Gunsight Bridge to Gothic Road Bridge)

Variables Influenced	Potential Erosional Process Impacts										
	Surface erosion	Mass erosion	Gully erosion	Streambank erosion	Channel enlargement	Aggradation	Degradation	Channel succession state	Sediment delivery efficiency	Notes	reaches/sub-basins of concern
(1) Streamflow changes (magnitude/ timing/ duration)		I	D	D	D	D	D	D	I	No significant impacts. Diversion for lake at Wildbird probably has minimal impact on stream or floodplain hydrology.	61
(2) Riparian vegetation change (composition/ density)			D	D	D	D	D	D	I	Significant impacts to riparian vegetation composition are apparent only at the ranched areas near Pittsburg and possibly at OBJ Campground.	20a, 20b, 31a, 31b, 39b, 57a
(3) Surface disturbance (% bare ground/ compaction)	D	I (debris torrents)	D (rills-gully)	I	I	I	I	I	D	Human surface disturbance (mining, roads) have minimal impact to natural sediment supply which is largely a function of debris flows and avalanches. Road areas may increase sediment delivery efficiency at specific areas.	31a, 39a, 39b, 57a
(4) Surface/ sub-surface slope hydrology	D	D	D	I	I	I	I	I	D	No significant impacts.	
(5) Direct channel impacts that destabilize channel			D	D	D	D	D	D	I	Channel mining and realignment segments. Hardened channels and banks.	31a, 39b, 57a
(6) Clear water discharge			D	D	D	I	D	D		No significant impacts.	
(7) Loss of stream buffers, surface filters, ground cover	D		I						D	Few locations where vegetation impacts limit buffering capacity. Several locations where proximity of roads or recreation areas to streams limit buffer capacity.	31a, 39a, 39b, 57a
(8) Altered dimension, pattern and profile				D	D	D	D	D		Potential impacts at road crossings.	20, 39, 57, 62
(9) Excess sediment deposition/ supply				D	D	D	D	D		Obvious signs of excess deposition or aggradation on Slate at Poverty Gulch road crossing and OBJ cmpground area. Suspect that this is natural geomorphological process within this dynamic sediment system. Additional excess adeposition on segments related to anthropogenic instability	7, 9, 11, 12, 14, 20, 31, 33, 35
(10) Excess large woody debris in-channel		D	D	D	D	D	D	D		LWD is a natural component of this system. The amounts of LWD are consistent with natural geologic processes of avalanches and mass erosion events.	present throughout the main Slate
(11) Stream power change (energy redistribution)			D	D	D	D	D	D		Realigned segments, mined segments, and bridge impacts effect stream power	31a, 31b, 39a, 39b, 57a
(12) Floodplain encroachment channel confinement (lateral containment)		I	I	D	D	D		I	D	Fill for Gothic Road at the bottom of the study area confines the floodplain to within a bridge span. Minimal encroachment by roads at Gunsight Bridge area and within Poverty Gulch. Fill for road or RR from Gunsight Bridge across floodplain to Nicholson Lake area.	57, 59, 62

D = Direct potential impact (darkness of shading indicates degree of impact)
I = Indirect potential impact (darkness of shading indicates degree of impact)
Blank = Little to no impact

no impact	minimal	light	moderate	high	extreme

Table 2.6: Variable Influence Analysis: Headwaters Areas (Slate Headwaters, Poverty Gulch, OBJ Gulch)

Variables Influenced	Potential Erosional Process Impacts									
	Surface erosion	Mass erosion	Gully erosion	Streambank erosion	Channel enlargement	Aggradation	Degradation	Channel succession state	Sediment delivery efficiency	Notes	reaches/sub-basins of concern
(1) Streamflow changes (magnitude/ timing/ duration)		I	D	D	D	D	D	D	I	No significant impacts. Diversion for lake at Wildbird probably has minimal impact on stream or floodplain hydrology.	61
(2) Riparian vegetation change (composition/ density)			D	D	D	D	D	D	I	Pasture areas and dewatered wetland floodplain areas	62, 63, 64, 65
(3) Surface disturbance (% bare ground/ compaction)	D	I (debris torrents)	D (rills-gully)	I	I	I	I	I	D	Wetland drying/conversion and mining operations.	62, 63
(4) Surface/ sub-surface slope hydrology	D	D	D	I	I	I	I	I	D	No significant impacts.	
(5) Direct channel impacts that destabilize channel			D	D	D	D	D	D	I	Channel mining and realignment segments. Hardened channels and banks. Bridges and road fill.	61, 62, 63, 65
(6) Clear water discharge			D	D	D	I	D	D		No significant impacts.	
(7) Loss of stream buffers, surface filters, ground cover	D		I						D	Few locations where vegetation impacts limit buffering capacity. Several locations where proximity of roads or recreation areas to streams limit buffer capacity.	20, 27, 31
(8) Altered dimension, pattern and profile				D	D	D	D	D		Mined, realigned, and bermed segments. Bridges	62, 63
(9) Excess sediment deposition/ supply				D	D	D	D	D		Excess sediment deposition is obvious at Gothic Road Bridge, apparent at other areas where the channel was disturbed.	61, 62, 63, 64, 65
(10) Large woody debris in-channel		D	D	D	D	D	D	D		LWD is a natural component of this system. The amounts of LWD are consistent with natural geologic processes of avalanches and mass erosion events.	present throughout the main Slate
(11) Stream power change (energy redistribution)			D	D	D	D	D	D		Realigned segments, mined segments, and bridge impacts effect stream power	61, 62, 63, 65
(12) Floodplain encroachment channel confinement (lateral containment)		I	I	D	D	D		I	D	Fill for Gothic Road at the bottom of the study area confines the floodplain to within a bridge span. Floodplain encroachment at Wildbird Bridge. Fill forRR from Gunsight Bridge across floodplain to Nicholson Lake area.	57, 59, 62

D = Direct potential impact (darkness of shading indicates degree of impact)
I = Indirect potential impact (darkness of shading indicates degree of impact)
Blank = Little to no impact

no impact	minimal	light	moderate	high	extreme

Table 2.7: RLA Summary

Sub-watershed/ reach location ID		Step 6a Check location selected for RLA field re-con	Step 7: Surface erosion Circle selected guidance criteria number (Table 3-3)*	Step 8: Mass erosion Circle selected guidance criteria number (Table 3-4)*	Step 10: Streamflow change Circle selected guidance criteria number (Table 3-5)*	Roads	Step 11: Channel processes Circle selected guidance criteria number (Table 3-6)*	Step 12: Direct channel impacts Circle selected guidance criteria number (Table 3-7)*	Step 15 Check location selected for advance-ment to *RRISSC***	Priority concerns
1	Uppermost Slate River	Yes		(1)(2)(4)					No	High risk for natural mass erosion.
2	Drainages off east ridge	Yes		(1)(2)(4)					No	High risk for natural mass erosion.
3	Upper Slate to Paradise Divide drainage	Yes		(1)(2)(4)					No	High risk for natural mass erosion.
4	Drainage off west ridge	Yes		(1)(2)(4)					No	High risk for natural mass erosion.
5	Upper portion of drainage on east side from Paradise Ridge	Yes		(1)(2)					Yes	Recent landslide and debris flow.
6	Lower portion of drainage on east side from Paradise Ridge	Yes		(1)(2)(4)					Yes	Recent landslide and debris flow.
7	Slate River down to Peeler Lakes drainage	Yes	(2)	(1)(2)(4)			(4)		Yes	Excess deposition/aggradation. Wider and lower gradient valley.
8	Peeler Lake drainage, west side of valley	Yes		(1)(2)(4)					Yes	Natural debris torrents. Recent debris flow.
9	Slate River down to start of dirt road on west side of valley	Yes		(1)(2)(4)			(4)		Yes	Excess deposition/aggradation. Wider and lower gradient valley.
10	Drainage from east side, confluence at road	Yes							No	Natural debris torrents.
11	Slate river wide area	Yes		(4)			(4)(6)		Yes	Excess deposition/aggradation. Wider and lower gradient valley.
12	Slate River at road crossing	Yes	(1)(2)				(4)(6)	(1)	Yes	Road crossing and close location.
13	drainage off west ridge	No							No	Natural debris torrents.
14	Late River adjacent to CR 734 to start of narrow canyon	Yes		(1)(2)					Yes	D channel with adjacent road, also possible impacts from road climbing the east side of valley
15	Drainage off south ridge	Yes							No	Natural debris torrents.
16	Slate River in canyon above Pittsburg	Yes	(1)	(1)(2)(4)					No	Steep narrow canyon.
17	Upper portion of drainage on north side near FR 811	Yes	(1)(2)	(1)(2)(5)					Yes	CR 811 crosses 2 drainages. Possible accellerated hillslope erosion. BLM study indicates high sediment from roads
18	Lower portion of drainage on north side near FR 811	Yes	(1)(2)	(1)(2)(5)					Yes	Impacts from upper portion of drainage (17). Drainage crossings at FR 734. BLM study indicates high sediment from roads
19	Slate River in canyon above Pittsburg	Yes							No	Steep narrow canyon.
20a	Slate down to Poverty Gulch road crossing	Yes	(4)				(4)(6)	(2)	Yes	Excess deposition/aggradation, bank erosion threatening road, road impacts, riparian vegetation impacts
20b	CBLT easment property at Poverty Gulch	Yes	(4)				(4)(6)	(2)	Yes	Excess deposition/aggradation, bank erosion threatening road, road impacts, riparian vegetation impacts
21	North fork of upper poverty gulch	Yes	(2)	(1)(2)(4)					No	
22	South fork of upper poverty gulch	Yes		(1)(2)(4)					No	
23	Upper Baxter Basin	Yes							No	
24	South Baxter Basin	Yes							No	
25	Lower Baxter Basin	Yes		(1)(2)(4)					No	
26	Poverty Gulch to Baxter Basin	Yes		(1)(2)(4)					No	
27	Poverty Gulch below Baxter Basin	Yes	(1)(2)						Yes	Road impacts where FR 552.2 is adjacent or within riparian area.
28	Poverty Gulch to confluence with Slate	Yes		(1)(2)					No	It was suggested that a new bridge on this reach could be causing problems downstream. The bridge actually spans the entire
29	Drainage from Schuylkill Mtn to Poverty Gulch	No							No	
30	2 drainages off Anthracite Mesa	No							No	
31a	Slate River Ranch parcel	Yes	(4)				(4)(6)	(1)(2)	Yes	Riparian vegetation and grazing impacts, excess deposition/aggradation
31b	Slate River on USFS along FR 734 to beaver ponds area	Yes	(4)				(4)(6)	(1)(2)	Yes	Riparian vegetation and grazing impacts, excess deposition/aggradation
32	Drainages from west side of valley	Yes		(1)					No	
33	Slate River on USFS through beaver complex	Yes		(1)					Yes	
34	Drainage from west side of valley	Yes		(1)					No	
35	Slate river below beaver complex to single channel start	Yes						(2)	Yes	Transition from Db to B or C channel. Wide braided channel. Recreation development in floodplain? Veg shift on lower left ban
36	Drainage from east side of valley	Yes		(1)(4)					Yes	Road crossing at CR 734
37	Slate River down to Gunnison Natl Forest boundary	Yes		(1)					No	Tight steep canyon, no local impacts.
38a	Slate River lower canyon	Yes		(1)			(4)		Yes	Transition zone within canyon.
38b	Slate River lowest portion of lower canyon	Yes		(1)			(4)		Yes	Transition zone from steep canyon to low gradient valley. Aggradation appears to be B3 to D3 within the canyon
39a	Slate River at OBJ campground avulsion segment	Yes	(4)	(1)			(4)	(1)(2)	Yes	Recent avulsion. Excess deposition/aggradation, bank erosion and bank hardening, road crossing, surface impacts
39b	Slate River at Campground to just above OBJ confluence	Yes	(4)	(1)			(4)	(1)(2)	Yes	Wide C4 segment within the campground area. Hardened banks, obvious recent aggradation
39c	Slate River from just above OBJ confluence to Gunsight Road	Yes	(4)	(1)			(4)	(1)(2)	Yes	Bradided segment. Aggradation and channel braiding.
40	Democrat Basin, upper OBJ creek	No		(1)(2)					No	
41	Dippold Basin drainage	No		(1)(2)(4)					No	
42	OBJ creek to Blue lake drainage confluence	No							No	
43	Blue Lake drainage	No		(1)(2)(4)					No	
44	OBJ creek	No							No	
45	Drainage from Garfield Peak	Yes		(1)					No	
46	Drainages from Schuylkill Mtn ridge	Yes		(1)(2)(4)					No	
47	OBJ creek	Yes		(1)(4)					No	
48	OBJ creek in beaver dams	Yes		(1)					No	
49	Peeler Peak drainages	Yes		(1)(2)(4)					No	
50	Drainage off south facing slope	No		(1)					No	
51	Upper Peeler Basin	No		(1)					No	
52	Lower Peeler Basin	No		(1)(2)(4)					No	
53	OBJ creek	Yes		(1)(2)(4)					No	
54	Redwell Basin drainage	Yes	(2)(3)(4)	(1)(2)(3)(4)(5)		(6)			Yes	Extensive roads in drainage, lots of old mine activity. Mine tailings and waste.
55	OBJ to confluence with Slate River	Yes		(1)					No	
56	Wolverine Basin drainage	Yes	(4)			(6)			Yes	Hillslope processes impacts from roads, one road crossing.
57a	Slate River at Gunsight Road and bridge	Yes	(4)				(4)	(1)(2)	Yes	Road and bridge impacts to channel and floodplain, deposition.
57b	Slate River below Gunsight Bridge	Yes	(4)				(4)	(1)(2)	Yes	Road and bridge impacts to channel and floodplain, deposition.
58	Drainages from west side of valley	Yes		(1)					No	
59	Slate River to Nicholson Lake	Yes							Yes	mostly C channel with associated beaver complex. Wide fp. Adjacent rural development.
60	Slate River Nicholson Lake to Wildbird	Yes							Yes	Floodplain impacts from old road/RR fill
61	Wildbird property to bend above diversion	Yes						(1)(2)	Yes	bridge
62	McGill property (including one bend upstream)	Yes			diversion			(1)(2)	Yes	gravel mining, berm, channel processes, ditches, diversion
63	Slate River at Peanut Lake	Yes							Yes	Channel processes, proximity to Peanut Lake
64	Kapushion property	Yes						(1)(2)	Yes	Grazing, channel processes, aggradation
65	CBLT property at Gothic Road Bridge	Yes						(1)(2)	Yes	Bridge, obvious aggradation or excess deposition

Appendix 3
Rapid Resource Inventory for Sediment and Stability Consequences Results

Table 3.1: RRISSC Results

Sub-watershed/ reach location ID		Step 2: stream channel type	Geographic Location				Stream Type Location							RRISSC Summary			
			Step 6: Mass erosion (Worksheet 4-3)	Step 7: Roads (Worksheet 4-4)	Step 8: Surface erosion (Worksheet 4-5)	Step 11: Streamflow change (Worksheet 4-6)	Step 13: Streambank erosion (Worksheet 4-7)	Step 14: In-channel mining (Worksheet 4-8)	Step 15: Direct channel impacts (Worksheet 4-9)	Step 16: Channel enlargement (Worksheet 4-10)	Step 17: Aggradation/ excess sediment (Worksheet 4-11)	Step 18: Channel evolution/ successional states (Table 4-5)	Step 19: Degradation (Worksheet 4-12)	Overall RRISSC Rating	Narrative summary	Recommendation	advance to *PLA*
1	Uppermost Slate River	A2/3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	The drainages of the Slate Headwaters all have high natural potential for mass erosion. Anthropogenic impacts to sediment sources are little to none, especially compared to the massive natural sediment potential.	Maintain effective management.	No
2	Drainages off east ridge	Aa+2/3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			No
3	Upper Slate to Paradise Divide drainage	A3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			No
4	Drainage off west ridge	A1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			No
5	Upper portion of drainage on east side from Paradise Ridge	Aa+3/4	3	3	1	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3	A recent debris flow originated from a debris avalanche in the upper portion of this drainage (5) which ran over a bench and into the lower part of the drainage (6) where it entrained more material and apparently initiated a landslide or earthflow which ultimately deposited somwhere on the order of 10,000+ CY of material across the Slate River Valley. We suspect that this event temporarily dammed a portion of the valley. When the dam breached, an enormous load of this sediment would have been released down the Slate in a rapid pulse, or slug.	Re-evaluate assumption that mass erosion events are natural, and not somehow caused or exacerbated by anthropogenic impacts. Quantify natural sediment yeild from mass erosion.	No
6	Lower portion of drainage on east side from Paradise Ridge	Aa+1/3	5	1	1	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3			No
7	Slate River down to Peeler Lakes drainage	A3	4	1	2	1	1	1	3	2	4	1	3	2	Very steep V shaped valley with high natural sediment load. Minimal impacts with no significant consequences. Observed aggradation process is apparently natrual.	Maintain effective management.	No
8	Peeler Lake drainage, west side of valley	Aa+1	5	1	1	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	A natural debris flow channel with evidence of recent activity. No sugnificant anthropogenic impacts.		No
9	Slate River down to start of dirt road on west side of valley	A3	4	1	2	1	1	1	3	2	4	1	3	2	Very steep V shaped valley with high natural sediment load. Minimal impacts with no significant consequences. Observed aggradation process is apparently natrual.		No
10	Drainage from east side, confluence at road	Aa+4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	High potential for natural mass erosion. No impacts.		No
11	Slate river wide area	D3	1	1	1	1	2	1	2	2	2	1	1	2	This is a wider, lower gradient valley portion with evident recent aggradation that is likely natural and geologic in origin. Anthropogenic impacts are minimal. The D3 channel classification is assumed to be the a natural reference channel type.		No
12	Slate River at road crossing	B3	3	2	1	1	1	1	1	1	1	1	1	1	A moderately steep and entrenched canyon valley with B-channel. No significant impacts.		No
13	drainage off west ridge	Aa+3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	High potential for natural mass erosion. No impacts.		No
14	Late River adjacent to CR 734 to start of narrow canyon	B3	3	2	1	1	1	1	1	1	1	1	1	1	A moderately steep and entrenched canyon valley with B-channel. No significant impacts.		No
15	Drainage off south ridge	Aa+1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	High potential for natural mass erosion. No impacts.		No
16	Slate River in canyon above Pittsburg	Aa+1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	A1 stream in tight, steep canyon. No significant impacts.		No
17	Upper portion of drainage on north side near FR 811	Aa+4	3	0	1	1	1	1	1	1	1	1	3	3	Density of road and crossings over Aa+ gullies presents a potential risk. BLM surveys indicate high erosion and sediment production from these reaches.	Assess degree of road impacts to surface erosion and gully formation, prescribe treatments if necessary.	Yes
18	Lower portion of drainage on north side near FR 811	Aa+4	4	0	1	1	1	1	1	1	1	1	3	3			
19	Slate River in canyon above Pittsburg	Aa+1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	A1 stream in tight, steep canyon. No significant impacts.	Maintain effective management.	No
20a	Slate down to Poverty Gulch road crossing	D3/4	1	0	1	1	2	1	5	0	5	5	5	5	Extreme deposition completely filled the channel and most of the floodplain on this reach. We suspect that this event may be related to the large landslide/earthflow that recently occured on the flanks of Paradise Ridge. Thus, the source of the aggradation appears to be natural. There are no signs that anthropogenic stressors caused the event. A large stand of conifers in this deposition area are dead. We suspect, but are not certain, that these trees died as a result of the deposition. Nevertheless, a huge source of LWD is now present. The future fluvial geomorphological response to this event is uncertain, but we expect that a new channel will gradually cut its way through the deposition starting at the lower end and progressing headward. Indeed, headcuts and channel formation are already evident on the toe of the debris fan near the upper end of reach 20b. Consequences of this channel response following this natural event include potential future problems with the road crossing (especially as a channel cuts its way through the existing flat low-water crossing), habitat loss, and a future large sediment and LWD source for downstream as a new channel forms within these sediments.	Monitor aggradation area. Re-evaluate assumption that the aggradation is a result of natural geologic processes. Consider treatments for Poverty Gulch Raoad crossing that will deal with evential channel cutting.	Yes
20b	CBLT easment property at Poverty Gulch	D3/C3*	1	0	2	1	4	1	5	0	5	5	5	5	Major channel adjustments are in progress due to natural deposition upstream and historic impacts including base level change immediately downstream. Grazing is signifcant impact on lower part of reach. Consequences include channel instability, coarse and fine sediment source, bank loss including possible road damage to CR 734.	Address bank erosion that threatens FR 734 road. Assess and monitor stream stability.	Yes
21	North fork of upper poverty gulch	A1-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	Headwaters of Poverty Gulch are susceptible to mass erosion. Significant human impacts include grazing and old mine roads which are negligible cmpared to natural sediment sources.	Maintain effective management.	No
22	South fork of upper poverty gulch	Aa+1/ A3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
23	Upper Baxter Basin	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
24	South Baxter Basin	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
25	Lower Baxter Basin	Aa+1/3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
26	Poverty Gulch to Baxter Basin	A1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
27	Poverty Gulch below Baxter Basin	DB	3	3	1	1	1	1	2	1	2	1	2	3	Poverty Gulch road parallels the drainage near or within the riparian area. This natural-survace dirt road crosses many sub-drainages that may increase efficiency of sediment delivery from the road to Poverty Gulch.	Assess road impacts for potential mitigation.	Yes
28	Poverty Gulch to confluence with Slate	A1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	These drainages into Poverty Gulch are susceptible to mass erosion. No significant human impacts	Maintain effective management.	No
29	Drainage from Schuylkill Mtn to Poverty Gulch	Aa+	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
30	2 drainages off Anthracite Mesa	Aa+	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
31a	Slate River Ranch parcel	D3	3	1	1	1	4	5	5	5	5	5	5	5	We did not access this property for a detailed RRISSC assessment, but were able to observe most of the reach from FR 734 and from up-and downstream. There are serious channel stability and sediment transport problems on this reach that are a direct consequence of anthropogenic impacts including a recent channel realignment, vegetation shift and heavy livestock use of the riparian area. Channel adjustments following incision create exacerbated bank erosion, channel enlargement, aggradation, and risk of further degradation, all of which may compromise habitat and threaten human property and infrastructure such as the ranch buildings and FR 734 which is adjacent.	Many major impacts and instability are apparent. Assess for specific diagnosis and treatment.	Yes

Table 3.1: RRISSC Results

31b	Slate River on USFS along FR 734 to beaver ponds area	B3	3	1	1	1	1	1	3	1	3	1	4	3	The straight alignment of this reach is suspect, but there is no direct indication that it was artificially straightened. The channel is moderately entrenched (B3), with an abandoned floodplain about 2 feet higher than bankfull, suggesting possible recent downcutting. The cause of this seemingly recent degradation is unclear, but given the fairly severe channel stability concerns just upstream, we suspect that anthropogenic impacts are at play. The valley at this location has a huge natural alluvial fan/debris cone entering from the west which could also be the cause of these observations.	Assess cause of straight channel alignment and observed incision/abandoned floodplain.	Yes
32	Drainages from west side of valley	Aa+3/4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	Natural debris torrent channels with larke debris cones/alluvial fans at the valley floor.	Maintain effective management.	No
33	Slate River on USFS through beaver complex	D3	3	0	1	1	1	1	1	1	5	1	1	3	Wide braided channel with in and off channel beaver activity. The braided condition appears to be natrual channel form. Well connected floodplain with good veg. Advance to PLA because of proximity to historic downcutting and potential to be a C stream.	Assess potential for excess deposition and whether observed D-channel is stable/natural.	Yes
34	Drainage from west side of valley	Aa+3/4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	Natural debris torrent channel with recent deposition from a relatively small flow event.	Maintain effective management.	No
35	Slate river below beaver complex to single channel start	B3	3	0	1	1	1	1	3	1	3	1	3	2	Transition from low gradient valley to steeper canyon. Possible excess deposition in upper portion. Mass erosion inputs appear natural, vegetation shift on left bank evident from historic aerials.	Maintain effective management.	No
36	Drainage from east side of valley	Aa+3/4	2	0	1	1	1	1	1	1	1	5	3	3	Shot-gun culvert under FR 734 has potential for causing scouring and gully formation.	Monitor shot gun culverts for gully formation.	Yes
37	Slate River down to Gunnison Nat Forest boundary	A1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	Tight A1 canyon.	Maintain effective management.	No
38a	Slate River lower canyon	B3	4	1	1	1	2	1	2	1	4	1	2	3	Recent aggradation has filled the valley bottom in the lower portion of the of this canyon where the grade flattens, but the channel is still a B3 along this segment	Monitor aggradation and/or formation of new channel within recent deposits.	Yes
38b	Slate River lowest portion of lower canyon	C3	1	1	1	1	3	1	5	2	5	5	5	5	Recent aggradation resulted in channel type evolution from presumed B3 to C3. The valley bottom is filled with coarse sediment, and an incipient channel is formed within it.	Monitor aggradation and/or formation of new channel within recent deposits.	Yes
39a	Slate River at OBJ campground avulsion segment	G1/3	1	1	2	1	5	1	5	5	3	5	5	5	C->G channel evolution as cutoff channel is forming at avulsed meander loop. These processes are secondary to recent aggradation that apparently completely filled the channel that existed at this segment prior. The existing channel condition is obviously unstable, but the causes of instability can be understood as a natural geomorphological channel response to an extreme episodic natural geologic event. Anthropogenic factors that would exacerbate instability here are so far minimal.	Monitor progression of channel evolution as avulsion G-channel segment enlarges to accommodate flow. Monitor any efforts to stabilize this process.	Yes
39b	Slate River at Campground to just above OBJ confluence	C4	1	2	3	1	3	1	5	3	5	4	5	5	The impacts of recent aggreadation and excess deposition are evident in this section of very wide channel. Though classified as a C4, the channel is probably borderline D4. Risk of further aggradation is high due to channel instability and sediment source immediately upstream. Again, the source of these instabilities and sediment sources appears to be natural. Consequences of channel instability on this reach include some threat to the existing layout of the campground.	Monitor stream stability. Prescribe treatments to protect campground areas from channel scour if desired.	Yes
39c	Slate River from just above OBJ confluence to Gunsight Road	D4	1	1	1	1	1	1	3	2	5	1	5	4	On this segment, downstream from OBJ Campground near the mouth of OBJ Creek, the Slate is a fully braided D4 stream. The D4 channel type here could be explained by a natural valley constriction at the lower end of this reach or by the tight bend that the stream makes at Gunsight Road to accomodate the narrower valley. Also, the D4 channel type appears to be present on historic aerials. However, the channel here shows evidence of recent aggradation and deposition that may be exacerbated as a consequence of upstream instability. The issue should be studied further in PLA.	Monitor channel stability, particularly the potential for aggradation.	Yes
40	Democrat Basin, upper OBJ creek	Aa+	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	Upper OBJ and headwaters drainages have no significant human inpats. Most of the area is within the Raggeds wilderness. Like most of the other drainages in this watershed, the potential for natural mass erosion events exists.	Maintain effective management.	No
41	Dippold Basin drainage	Aa+	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
42	OBJ creek to Blue lake drainage confluence	Aa+	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
43	Blue Lake drainage	Aa+	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
44	OBJ creek	B3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
45	Drainage from Garfield Peak	Aa+	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
46	Drainages from Schuylkill Mtn ridge	Aa+	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
47	OBJ creek	A1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
48	OBJ creek in beaver dams	DB	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
49	Peeler Peak drainages	Aa+	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
50	Drainage off south facing slope	Aa+	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
51	Upper Peeler Basin	varies	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
52	Lower Peeler Basin	Aa+	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
53	OBJ creek	B1/3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1			
54	Redwell Basin drainage	N/A	5	5	3	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4	Roads are the most significant impact to sediment in the drainage. It appears that the majority of the roads are located in naturally occuring steep talus slopes. There may be some increase in sediment delivery to the drainage but the amounts are probably negligible compared to natrual inputs.	Assess to quantify road and mining impacts.	Yes
55	OBJ to confluence with Slate River	A1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	Tight A1 canyon with no significant impacts.		No
56	Wolverine Basin drainage	N/A	3	3	2	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3	The Gunsight road occupies significant acreage within the drainage, but sediment delivery from this source may be negligible compared to natural sources.	Assess to quantify road impacts.	Yes
57a	Slate River at Gunsight Road and bridge	D4	1	4	2	1	4	1	5	3	4	2	5	4	The Slate takes a 90° turn here on the east valley edge against Gunsight road impinges on the valley. The channel type changes here from D4 to a wide C4. The road and bridge constrictions are significant direct human impacts on channel form and sediment source.	Assess direct channel impacts including road and bridge constriction. Determine impacts to upstream reach as possible cause of braiding	Yes
57b	Slate River below Gunsight Bridge	D4	3	1	1	1	1	1	1	1	3	1	1	3	Below Gunsight Bridge, the channel again resumes a D4 form. Like Reach 39c, we assume that this could be a natural reference channel type which could be explained by a tight natural valley constriction and geologic grade control at the lower end of the reach. Also like 39c, we suspect that excess deposition and aggradation could be exacerbated by upstream instability and their resulting sediment sources.	Monitoring this reach to determine whether unnatural active aggradation is taking place.	Yes
58	Drainages from west side of valley	Aa+	1	1	1	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	Potential for natural mass erosion. No impacts.	Maintain effective management.	No
59	Slate River to Nicholson Lake	C4	1	1	1	1	1	1	1	1	1	1	1	2	These reaches are a relatively narrow C4 channel type. The primary anthropogenic impact on this reach is the fill for the old railroad that serviced an historic coal mining operation upstream. The consequences of this 100+ year old impact on channel stability and sedimentation appear to be minimal, though it does likely finction as a levee that would limit function of the floodplain .	Potential reference reaches, assess degree of impact from RR fill.	No
60	Slate River Nicholson Lake to Wildbird	C4	1	1	1	1	1	1	1	1	1	1	1	2			
61	Wildbird property to bend above diversion	C4	1	1	1	1	1	1	2	1	1	1	2	2	C4 channel type. The primary human impact is the Wildbird Road fill and bridge that effectively constrict the floodplain. This impact would cause backwater issues (excess deposition, etc.) upstream of the bridge and energy increases (excess scour and bank erosion, etc.) at and below the bridge, WARSSS RRISSC assessment indicates minimal impact.	Monitor bank erosion and channel processes at bridge constriction.	No

Table 3.1: RRISSC Results

62	McGill property (including one bend upstream)	**F4**	**1**	**1**	**1**	**1**	**5**	**5**	**5**	**5**	**5**	**5**	**5**		**5**	Past reports speak of in-channel gravel mining in the 70s which lowered the bed elevation and indiced degradation and downcutting. Evidence of this is clear on the site as a perched floodplain and incised channel. We agree with the 1995 HRS assessment that channel evolution following incision on this F4 reach is a major human-caused stability and sediment impact that has clear negative effects that extend both upstream and down. The RRISSC assessment indicates serious risks that include high rates of bank erosion, channel enlargement, aggradation, and even the potential for further degradation. Incision is exacerbated by the the presence of an elevated road along the left bank of the river that was left behind by the mining operation. This road effectively berms off the entire east side of the floodplain preventing overbank flooding which is a severe impact on riparian vegetation. The high bare compacted gravel road/berm prevents the establishment of any riparian plants, and it also effectively dries the wetlands and riparian floodplain area east of the river. Floodplain drying and vegetation impacts are further impacted by a drain ditch which was constructed along the perimeter of the property. A diversion and huge ditch come off of the left bank on an outside bend of the Slate at the upper end of this reach to feed a gravel pit po	Addressing the bank erosion issue at the diversion requires emergency response before the Slate River erodes into ditch system and lake. Assess the rest of the reach to determine specific restoration opportunities to correct artificial incision and instability, and to reconnect floodplain.	**Yes**
63	Slate River at Peanut Lake	**F4**	**1**	**1**	**1**	**1**	**5**	**1**	**5**	**5**	**5**	**5**	**5**		**5**	The reach of Slate River along Peanut lake classifies as F4, which is likely a consequence of incision caused by historic in-channel mining on the McGill property. Also, the berm/road on the left bank extends to below Peanut Lake. Like the incised reach upstream, RRISSC assessment indicates serious risks that include high rates of bank erosion, channel enlargement, aggradation, and even the potential for further degradation. Further degradation may be limited, though, by the presence of a natural bedrock grade control at the lower end of the reach. In addition to all this, the channel instability is a real threat to Peanut Lake. The land form separating the lake from the river is as narrow as 15-20 ft in places, and time series aerial photography shows a gradual, albeit fairly slow, migration of the river towards the lake, further narrowing this span. Hydraulic connections between the lake and the river exist and are presently maintained by only by beavers which has so far kept Peanut Lake from draining into the Slate.	Assess to prescribe a treatment to protect Peanut Lake and to address channel instability issues.	**Yes**
64	Kapushion property	**C4**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**3**	**1**	**1**		**3**	Due to access limitations, we were not able to make detailed observation of this reach. Observations of aerial photography indicate that the severe stability issues that exist upstream and downstream of the reach may not be present here. Our RRISSC rating of 3 (moderate) on this reach is based on this assumption, and we therefore highly recommended more detailed study of this reach.	Gain access to property to make a better initial RRISSC assessment.	**Yes**
65	CBLT property at Gothic Road Bridge	**D4**	**1**	**1**	**1**	**1**	**3**	**1**	**1**	**1**	**5**	**5**	**4**		**5**	The Gothic Road bridge is an obvious stressor affecting this reach. The impact is manifast as a floodplain constriction that prevents the effective transfer of high flows through this point. It appears, and the 1995 HRS report and historic aerials confirm, that this reach is a backwater at bankfull discharge, and this has the effect of creating extreme unnatural sediment deposition on the reach. It is important to note that there are actually three "construction points" in this area: the Gothic Road Bridge (and associated roadfill), road fills from the historic road that used to cross the Slate just downstream of Gothic Road by the cemetary, and a natural geologic constriction/grade control just downstream from there. Clearly, the natural geologic constriction and grade control has always placed some limit to rate at which flood flows exit the wide floodplain above, but the two unnatural road constrictions upstream of it are both much narrower that the natural one, and at locations with flatter valley slope. It is therefore likely that these stressors are an unnatural cause of excess deposition and aggradation. There is also some impact from grazing on the reach, but vegetation appears to be in relatively good condition and these impacts, while p	Assess impacts from bridge constriction including obvious excess deposition and aggradation. Prescribe wider spans for bridge and constriction and/or floodplain drains.	**Yes**