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Boulder County Parks and Open Space
Small Grant Program

Rapid Stream Stability Assessment Validation Study
South St. Vrain River, Hall-II
St. Vrain River, Western Mobile

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EXECUTIVE SUMMARY

After the September 2013 floods, hundreds of miles of streams and associated floodplains experienced substantial geomorphic and biological impacts along the Colorado Front Range. Restoration and bank stabilization projects are either underway or in a proposal or design stage via master planning efforts in the impacted watersheds. Monitoring the success of these restoration projects will play an important component in the overall watershed restoration effort.

AloTerra Restoration Services, LLC has developed a protocol for a visual-based stream stability assessment (SSA) that quantifies riparian, stream bed and stream bank stability over sub-reaches (100 – 200ft) using rapidly-assessed metrics (e.g., percent coverage by vegetation class, bank and bed material composition, percent actively eroding bank, etc.). Data is integrated into an overall stability score for an entire project reach (Appendix A). This monitoring protocol integrates information across longer reach lengths and can be carried out more rapidly compared to others in use such as the Bank Erosion Hazard Index (BEHI) protocol developed by Rosgen (2001), which provides stability information at a cross section only.

The SSA protocol requires field-testing for calibration and validation to ensure the data it provides accurately reflects observed conditions. Calibrating the SSA requires multiple years of monitoring to capture channel adjustment and recovery over time. The Boulder County Parks and Open Space Small Grant Program has funded the first year of this validation allowing us to establish a baseline assessment of channel stability. We applied this protocol to monitor various reaches of the St. Vrain River (Hall-II, Western Mobile) where channel restoration projects are planned. We compared the results of our protocol with BEHI in the same reaches for comparison of our methodology to existing accepted methods.

Our results indicate the reaches assessed at the Hall-II and Western Mobile sites have relatively unstable banks largely due to lack of vegetation growing on the banks or the adjacent riparian zone. Relatively recent scour and deposition from the 2013 floods has left both reaches over-widened, aggrading in areas (Western Mobile), and with newly-formed banks mostly composed of non-cohesive cobble, gravel, and sand material. Though the banks along these reaches are moderately to highly unstable, the beds appear to be stable at both sites. Because the BEHI is conducted at the most severe point along a reach, the BEHI procedure tends to over-estimate bank instability relative to the SSA method. Implementation of BEHI assessments at multiple cross sections may provide stability scores closer to those produced from the SSA method. Notwithstanding, early results indicate the two methods correlate well. Future monitoring, if desired by BCPOS, will be necessary to achieve the multi-year objective of calibrating this protocol.

BACKGROUND

Existing streambed and stream bank stability monitoring protocols either rely on coarse measurements of selected cross sections and longitudinal profiles or fine scale and labor intensive channel change and bank stability measurements. An existing protocol for assessing bank stability has been developed and tested by Rosgen (2001): the Bank Erosion Hazard Index. However, these indices are evaluated at a cross section, are time intensive if applied to the reach scale (100's - 1,000's of feet), and may not provide the desired level of accuracy when extrapolated or applied to a reach scale. More qualitative bank stability approaches have been published (e.g., Pfankuch, 1975, and Thorne 1992). The Pfankuch Channel Stability Evaluation (1975) is a visual-based approach that aggregates multiple bank stability parameters and scores them based on expert opinion. In our opinion, it relies too heavily on a subjective scoring approach. Further, because Pfankuch method aggregates multiple stability parameters into its scoring procedure, discerning the root cause of stability later is made difficult. Thorne's (1992) bank stability protocol is comprehensive but qualitative. It requires substantial time in the field and expert interpretation of field data to evaluate bank stability. Finally, the Bureau of Reclamation's Proper Functioning Condition (PFC) assessment for lotic systems is a narrative-based assessment that, although thorough, relies on expert judgement in the field and does not explicitly quantify the various geomorphic factors that influence channel stability (BLM, 2013). Repeated implementation of the PFC by different personnel with different backgrounds would likely result in different interpretations of channel condition.

A visual-based, rapid bank and bed stability assessment protocol that is quantitative, does not rely on expert interpretation of results, and integrates information over an entire reach is currently lacking. Further, given the extent of restoration and monitoring necessary in flood-impacted areas, a monitoring protocol is desired that can provide consistent data year to year when collected by a variety of observers, from volunteers to government agency staff, to seasonal employees of consulting firms.

The rapid, visual-based stream stability assessment (SSA), developed by Aloterra, LLC attempts to fill this gap. This protocol relies on visual estimation of percent length by category of channel and bank stability parameters. It quantifies, relatively, bed and bank stability over sub-reaches (100 – 200ft) using rapidly-assessed metrics such as the percent of bank and riparian area coverage by vegetation type, bank and bed material composition, and percent length of actively eroding bank. These visual estimates can be obtained by workers from a wide variety of backgrounds with minimal training. Quantitative estimates of percent coverage and length of stability parameters are then integrated into an overall stability score for each sub-reach evaluated as well as for the entire project reach (Sholtes & Giordanengo, 2014, Appendix A). Personnel trained in geomorphology are required to interpret the results.

The stability parameters of the SSA can be directly observed unlike some of the stability parameters used in the BEHI protocol, which require inferences of bank properties that are not readily observable and require expert judgement in the field. For example, BEHI relies on estimation of plant root depth into the bank. BEHI is implemented on a cross-section basis and multiple BEHI assessments are required to integrate the same information evaluated within the SSA. Finally, the SSA procedure is transparent, meaning that weights applied to each stability parameter in the integrated stability score can be adjusted according to the user's knowledge of the relative importance of each. This differs from the BEHI methodology, which relies on relationships between BEHI parameters and channel stability developed by Rosgen (2001) and based on expert opinion.

OBJECTIVES

We tested the SSA on two sites affected by recent flooding and slated for restoration: (1) the South St. Vrain through the Hall-II property and the St. Vrain adjacent to Western Mobile. Both sites are located in the foothills near Lyons, CO. The Hall-II site has a relatively steeper river reach with slightly coarse bed material. Downstream at Western Mobile, the channel is slightly milder in slope but still has coarse bed material, ranging from gravel to boulder.

Due to the short grant performance period, the present study serves only as a baseline stability analysis of the study reaches prior to restoration efforts. Using cross-section and longitudinal topographic surveys in conjunction with the SSA, our first year objectives are to characterize the relative stability of these reaches, identify areas and sources of instability, and field test and refine the SSA protocol. Should funding be made available for subsequent studies, we will be able to collect inter-annual data and compare visual and surveyed channel changes over time with the SSA scores to further refine the methodology and weighting scheme used by the SSA.

METHODS

Implementing the SSA protocol involves dividing a reach of interest into subreaches. For the present study, our subreaches were 200 to 400 feet in length. Moving from up to downstream, subreaches at Hall-II are denoted as Hall-1, Hall-2, and Hall-3. At Western Mobile the two assessed subreaches are WM-1 and WM-2. Maps showing the location of surveyed subreaches are included below (Figures 3 - 6).

Due to the fact that this protocol is in field testing stage, and because we were comparing this protocol to the BEHI, we first measured cross-section and longitudinal channel topography using a tape, level, and rod. One cross section and longitudinal profile were surveyed at each subreach. Cross-sections were surveyed between rebar benchmarks installed on either side of the channel and the location of these benchmarks was estimated with GPS (Appendix C). These surveys will provide numeric measurements of channel adjustment if repeated, allowing for comparison with SSA results.

We then conducted the SSA on each subreach. This involved visual observations of percent cover of vegetation along the banks and on the adjacent floodplain as well as composition of bed and bank material for each sub-reach. In addition, we assessed percent length of active erosion as well as severity of active vertical and lateral erosion or deposition. These percent length values of various stability factors are then combined and averaged to create a relative stability score for each sub-reach and averaged across all sub-reaches for a reach-average score. Because this is the first year of validation, we are not able to assign categories of relative risk to the particular SSA scores resulting from this work. Rather, stability is assessed on a relative basis for each stream and from season to season. This meaning that one can use these stability scores to track channel stability over time and among reaches and rivers. Though relatively inexperienced personnel may collect the observations required to conduct the SSA, personnel with experience in fluvial geomorphology are required to interpret the results.

Stream Stability Assessment Protocol

This stream bank and bed assessment protocol was developed to allow a field crew of one or two people to assess the stability of a stream reach rapidly, thoroughly, and in a spatially explicit manner so that stability concerns may be identified and located along a reach. The field team will ideally comprise at least one person with experience in fluvial geomorphology and another with experience in field botany. Factors leading to bank stability (or risk of instability) included in this protocol are: bank and channel material composition, bank angle, bank and riparian vegetation type and percent coverage, evidence of active or recent bank erosion, channel bed composition, bed morphology, and evidence and severity of recent vertical incision.

This protocol was designed to allow inter-annual comparison and tracking changes over time, possibly after a restoration effort. It is largely a visual assessment, conducted along a 100 – 200 ft. sub-reach within which channel and bank information is aggregated. The length of the sub-reach may vary according to the channel size, but its length should be on the order of 10 to 20 times the bankfull width of the channel. Each category of the stability assessment may be evaluated separately to identify specific factors leading to stability issues within a sub-reach or along the entire project reach. These factors are also aggregated to identify unstable sub-reaches within the larger reach. For example, lack of bank and riparian vegetation, combined with vertical banks, may be a leading cause of risk of instability along the project reach. Bank instability may only be an issue for select areas within a project reach, and not a pervasive problem. This assessment protocol will aid in identifying each of these.

The general assessment procedure involves laying a measuring tape along a stream bank for the specified length of the sub-reach and characterizing bed and bank properties along this sub-reach. A handheld GPS may be used to mark the starting point of each sub-reach as well as the location of any failed stream restoration or bank stability structures. Stream stability information may be later incorporated into a GIS database allowing the stability metrics to be mapped (Figure 6). Photos should be taken in the middle of each sub-reach (upstream, downstream, leftbank, right bank), and should note other key observations, such as a particularly severe example of erosion or a failed restoration structure. In addition to using the accompanying field sheet to document each sub-reach, notes should be taken of the photo numbers, any waypoints collected on the GPS, as well as one to two sentences of narrative describing the sub-reach.

The following is a description of each assessment category:

Bank Composition
Visually and tactilely (use your hands) assess the relative size of the bank material. Assign percent of sub-reach length to each material category. Note that cohesive banks are composed of soil, which has a certain percentage of silt and clay. Non-cohesive banks lack silt and clay, though can be a mixture of sands, gravel, cobbles, etc. Table 1 contains descriptions and lengths associated with each sediment class.

Table 1. Grain size descriptions

	Cohesive	*Non-Cohesive*			
Type	***Silt / Clay (soil)***	***Sand***	***Gravel***	***Cobble***	***Boulder***
Grain Size	< 0.062 mm	0.063 to 2 mm	2 to 64 mm	64 to 256 mm	256 + mm
Description	Fine texture, cohesive, smooth when rubbed between fingers	Fine sugar to kosher salt sized particles	Peppercorn to egg sized	Baseball to grapefruit sized	Melon sized and larger

Bank Angle
The bank angle categories are as follows: *Mild* (0°-30°), *Moderate* (30°-60°), *Steep* (60°-90°), and *Overhang* (> 90°). Evaluate percent of each sub-reach having each bank angle category.

Vegetation: Bank and Riparian Zone
Start each field day by following a line-intercept procedure (Herrick et al., 2005) over a representative 100-foot section of bank in order to calibrate the observers' cover estimates. Assess percent of bank and stream edge (riparian zone) covered by *bare earth* (soil, rock, and/or organic litter), *nascent vegetation* (annual or biennial grasses or forbs, and juvenile perennial vegetation), *perennial grasses and forbs*, and *shrubs* and *trees*. This may represent the most challenging component of the stability assessment. Use of a vegetation density transect method may assist in estimating the relative percentages of cover within each vegetation category. Avoid looking upstream to assess vegetation coverage, as oblique visual assessments of vegetation cover often lead to gross cover overestimates. Rather, walk the bank while looking down and note the percent cover for that transect (measured distance of the cover for each vegetation category divided by the total transect length). For instance, if a combined 10 feet of a 100 foot transect is comprised a combination of annual forbs and grasses and/or 1-year-old (juvenile) perennial plant cover, the score for nascent vegetation would be 10 (10%). In estimating cover, include the gaps between the leaves as part of the canopy estimate. Imagine a polygon drawn around the very perimeter of the plant canopy in question, and tally the number of linear feet that canopy intercepts the tape measure.

Count understory vegetation separately from overstory vegetation. For example, if a shrub canopy covers the transect from 20-30 ft, and again from 50-60 ft, then the shrub cover is 20% [(10+10)/100]. If an understory of perennial grasses/sedges occurs under that shrub canopy, then record the percent cover of that perennial cover in addition to the shrub cover estimate and record it in the appropriate row on the form. In this regards, it may be possible in mature riparian stands to record a total vegetation cover greater than 100%.

Active Bank Erosion
The previous categories indicate bank susceptibility to erosion. This category assesses recent or ongoing bank erosion processes. Bare soil or bank material does not necessarily indicate active erosion. Look for clues such as vegetation, exposed roots, evidence of bank material deposited at the bank toe, and fresh erosion on bank faces. Here, instead of assigning a percent length to each category, pick the category that best matches the observed extent (percent length) of active bank erosion. Low (0 – 25%), Moderate (25 – 50%), High (50 – 75%), Severe (75 – 100%). Bank restoration treatments that are underperforming or failing may coincide with active bank erosion. Note the active erosion here and document the bank treatment under the "Restoration Treatment Assessment" described below.

Bed Stability
Equally as important as assessing bank stability is channel bed stability. For the sake of brevity, percent lengths are not included in this portion of the assessment. Rather, the field crew selects the dominant bed sediment type (following Table 1) and dominant morphology type (Figure 4) of the sub-reach. They note whether active or recent incision exists. Clues from positions of roots along the bank and presence of migrating headcuts help inform this. Finally, if recent or active incision exists, the field crew estimates the depth of erosion along the sub-reach. Active incision may occur at or as a result of a stream restoration structure failure. Please note the incision or instability here and document the structure under the "Restoration Treatment Assessment" described below.

Restoration Treatment Assessment
This is assessed after restoration projects have been constructed. Here, the field team assesses the quality and integrity of any stream restoration treatments and structures in the channel (e.g., grade control vanes or habitat enhancements) and banks (e.g., erosion control fabric, live stakes, toe wood or root wads). Bank and in-channel treatments encountered are each numbered, identified by type, and then scored. This assessment follows the spirit of the bed stability assessment in that it does not consider percent lengths of each sub-reach. Rather, each structure or treatment encountered is scored as follows: *Good*: Stable and meeting design goals (e.g., bed or bank stability and reduction of erosion), *Moderate*: Could use some minor maintenance, *Poor*: evidence of erosion, plant death, or processes that may soon lead to restoration treatment failure, *Failed*: restoration treatment no longer serving its intended function and/or the structure or treatment is damaged to an extent that is problematic to the stability of the channel. The field crew should have an annotated "as-built" drawing of the reach that identifies what restoration treatments were installed where to aid in the inventory and assessment of these.

General Assessment Notes
Round estimates of percent length of each category to the nearest 10, 20, or 25%. Because this assessment protocol is visually based, precision beyond the nearest 10% is likely inaccurate and unnecessary. If working as a team, each team member should evaluate each category

independently. Results can then be averaged. For a more comprehensive view of channel change over time, bank and channel bed monitoring should also incorporate repeated cross section and longitudinal profile surveys as well a repeated photographs from monumented locations. A good primer on stream surveying methods can be found in Harrelson et al. (1994).

Bank Erosion Hazard Score Calculations

To calculate bank stability scores, data collected on each sub-reach is entered into the "Calculations Spreadsheet" in which one column represents a sub-reach. Categories within each group (e.g., bank composition, bank vegetation) are assigned a value from 1 – 4 with 4 indicting the highest risk of instability. Based on the percent lengths attributed to each group category, a weighted average score is calculated for each bank for each category. These scores are then aggregated as a percent of total score, with higher scores indicating a higher risk of instability. Because this index-based approach is arbitrary (is bank angle equally as important as riparian vegetation coverage?), weights can be assigned to each category to give more or less weight to a particular category in the overall "Composite Bank Erosion Hazard Score". Currently, all categories have a weight of 1 with the exception of "Active Bank Erosion", which has a weight of 2. Bed stability and stream restoration treatment assessments are scored separately from the composite bank erosion hazard score. Each sub-reach with active incision is flagged. Each restoration treatment is assessed and tallied for each category of quality / stability. These can then be inventoried at the project reach level.

Interpretation of Results

The results from this monitoring protocol may be used in a number of ways. They may be used to gather a baseline assessment of the stability of a reach of interest, and to document restoration needs. It can then be used to track the evolution of the channel's stability over time in response to restoration efforts. Repair and maintenance needs may also be identified by this protocol. These assessments cannot at this time be used to estimate the quantity of eroded sediment entering a stream or the rate of bank erosion. However, they can provide objective and transparent evaluations of bank and bed stability that can aid in documenting overall changes and / or improvements to stability as a result of a restoration effort.

In addition to the SSA, we implemented the BEHI assessment of bank stability (Rosgen 2001) to compare the level of effort involved in each method and to compare the results of the SSA with BEHI. This protocol is conducted at a discrete point within a subreach, and is generally implemented on the most severely eroding bank.

RESULTS

Here we present overall results from our baseline geomorphic assessments of the Hall II and Western Mobile study reaches based on cross-section and longitudinal profile surveys and the SSA. We compare our observations and field measurements with the results from the SSA and BEHI protocols. Results from the SSA are presented in Table 2. A stability score of 0-5 is assigned to each sub-reach for each bed and bank stability metric with 5 being very unstable and 0 being very stable. A weighted average of each score is then calculated as discussed in the Methods section for each overall study reach. These scores can be interpreted as indicating relative stability and are meant to be compared among different reaches to assess relative stability as well as within the same reach over time to track trends in stability.

HALL-II

Based on our observations, field measurements (Table 2), and results from the SSA (Table 3), the South Fork of the St. Vrain River within Hall-II site on were generally very wide with steep, moderately stable to unstable banks. Based on pre- and post-flood aerial photography, the current main channel migrated south from its original location where it ran up against the bedrock cliff face on the north end of the floodplain (Figures 3-4). Channel top widths ranged from approximately 60 to 80 feet, maximum depths (thalweg to top of bank) ranged from 3.5 to 4.4 feet, and width-to-depth ratios ranged from 16 to 19. Summary data on channel dimensions is provided in Table 1, below. Plots from field surveys are provided in Appendix C. Bank material tended to be non-cohesive with mostly cobble to gravel sized material with some sand and

Figure 1. South St. Vrain River at Hall-II property looking upstream.

boulders. Though little vegetation had established on these banks, they were mostly stable having found their angle of repose. Along the downstream-most reach (Hall-3), the banks were composed of cohesive clayey-silt material and were vertical and undercut in some places. Evidence of mass-wasting in some locations was evident. As indicated in Table 3, below, the banks of this reach were most unstable. The Hall-1 and Hall-2 reaches were fairly similar in their bank stability metrics.

Based on results from the SSA and our overall observations, very little woody or herbaceous vegetation was observed on banks or in the entire riparian zone because of severe floodplain scour and deposition from the recent floods. Negligible recruitment of woody vegetation was observed as well, though some live mature cottonwood trees were observed near the active river channel. Side or relic channels were observed on either side of the main channel in the floodplain. Based on observations from pre-flood aerial photographs, the main channel has shifted south from its previous location where it ran up against the bedrock bluff located at the north end of this site.

Bed material was primarily cobble to boulder sized with some sand and gravel intermixed, reflecting the relative steepness of these reaches. Average reach slope ranged from approximately 0.5% to 3%. Bed morphology was generally characterized as riffles and glides with some boulder steps and very shallow pools. The bed appeared relatively stable at this site.

The severe bank erosion at the downstream-most reach (Hall-3) did indicate that some net bed incision may have occurred here. Note that the current channel position is drastically different from the pre-flood channel location, therefore this channel cut through floodplain material at some point during the flood to form this current channel. Though the channel may have incised to some degree during the flood, the large amount of sediment in transport from upstream and through this site resulted in little evidence of overall bed degradation.

The composite Bank Stability score for all sub-reaches is 3.0 out of 5.0 and the overall Stream Stability score (including bed stability) is 3.6 out of 5.0, with 5 indicating very unstable conditions. Reach specific scores are provided in Table 2. Relative values of SSA parameters accord well with our overall observations that the banks are generally unstable due to their steepness as well as the lack of bank and riparian vegetation. The bed of the channel appears relatively stable due to very coarse bed material, and this is also reflected in the SSA. Site average BEHI score is 44, which results in a "Very High" instability rating. Rosgen (2001) assigns descriptions to ranges of BEHI scores; however, these must be interpreted by the user given the overall geomorphic context of the study reach. Descriptive BEHI ratings can range from "Very Low" (5-9) to "Extreme" (45-50+). BEHI scores are summarized in Table 3. SSA and BEHI field sheets are provided in Appendix B.

Table 2. Summary of Channel Dimensions

Sub Reach Name	Sub Reach Length	Channel Top Width	Maximum Bank Height	W:D	Slope	Dominant Bed Material
	(ft)	(ft)	(ft)			
Hall - 1	240	83	4.4	19	0.4%	Cobble
Hall - 2	200	59	3.6	16	2.6%	Gravel-Cobble
Hall - 3	200	72	4.4	16	2.8%	Cobble
WM - 1	245	148	9.5	16	0.9%	Cobble
WM - 2	440	112	4.5	25	0.8%	Cobble

Table 3. Stream stability assessment scoring results.

		Reach ID						
		Hall - 1	Hall - 2	Hall - 3	Site Avg.	WM - 1	WM - 2	Site Avg.
Bank Stability	Bank Composition	2.1	1.6	3.7	2.5	2.1	2.2	2.1
	Bank Angle - Degrees	2.0	1.4	3.1	2.2	2.1	1.7	1.9
	Bank Vegetation	2.8	4.9	4.7	4.1	4.9	4.5	4.7
	Riparian Vegetaton	4.0	4.3	4.3	4.2	4.0	2.3	3.1
	Active Bank Erosion	1.2	1.0	1.9	1.4	2.5	1.2	1.8
	Composite Bank Stability Score	2.5	2.9	3.7	3.0	3.6	2.6	3.1
Bed Stab.	Severity of incision	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Bed Material Composition	2.6	2.3	2.3	2.4	2.3	2.3	2.3
	Composite Stream Stability Score	**3.6**				**3.5**		

Table 4. Bank Erosion Hazard Index (BEHI) scoring results.

	Reach ID						
	Hall - 1	Hall - 2	Hall - 3	Site Avg.	WM - 1	WM - 2	Site Avg.
BEHI Score	**39**	**44**	**50**	**44**	**54**	**33**	**44**
BEHI Rating	HIGH	VERY HIGH	EXTREME	**VERY HIGH**	EXTREME	HIGH	**VERY HIGH**

Western Mobile

Two reaches were assessed along the main stem of the St. Vrain River near the Western Mobile property. Based on pre- and post-flood aerial photography, a meander bend migrated several hundred feet downstream cutting into the left bank (Figures 5-6). The channel also avulsed at this site taking a temporary southern route. This avulsion resulted in bank and floodplain scour on river right as well as sediment deposition. It appears that the right bank has been re-constructed at this site and several hundred feet of boulder-sized riprap have been installed. Some of this rip-rap has stabilized the cohesive banks located behind this revetment, but evidence of rip-rap and bank failure was observed over at least 100 feet of bank. It appears that this rip rap was hastily installed. The thin layer and lack of size gradation have allowed high flows to scour the bank material behind this rip rap.

This section of river is very wide, possibly over-widened due to the flood, with top-of-bank widths ranging from approximately 110 to 150 feet and width-to-depth ratios of 16 to 25. Mid-channel bars observed along WM-1 may indicate that the channel is aggrading and beginning to narrow. The banks of WM-1 are very steep and unstable, especially on river left where maximum bank height is about 9.5 feet. The WM-2 reach is a meander bend with more shallow banks on river right and a point bar on river left (max bank height ≈ 4.5 feet). Negligible vegetation exists on the banks and riparian area of WM-1. A mature cottonwood and willow forest exists on river left of WM-2 at the edge of the active point bar. Approximately two year old cottonwood seedlings were observed along the toe of the right bank of the downstream end of WM-1 and upstream end of WM-2 providing some level of stability to these banks. However, no perennial vegetation was observed within the rip rapped portion of this bank, only annual herbs and grasses.

The bed material of these reaches is primarily cobble and gravel-sized material. Given the steep and tall nature of the banks on WM-1, some evidence of incision from the recent flood may exist. However, no active incision was evident on either reach. Bed morphology here is in transition from riffle-run to pool-riffle. Because the sinuosity is not great, true pool-rifle morphology does not yet exist; however, incipient pools and riffles were observed and surveyed

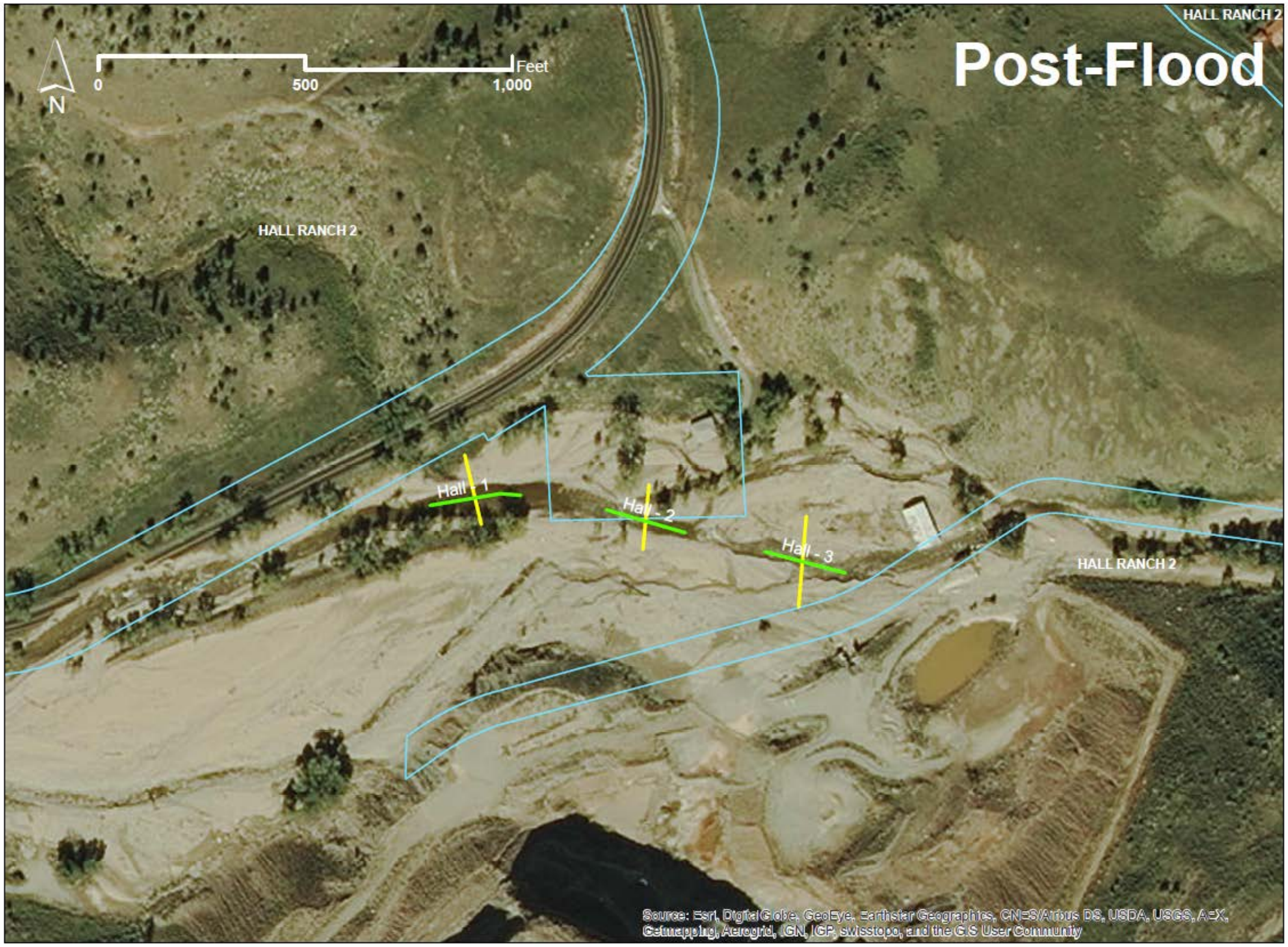
Figure 2. St. Vrain River at Western Mobile, looking downstream.

within the longitudinal profile. Average reach slope ranges from approximately 0.8% to 1%. A large cobble, gravel, and sand mid-channel bar was observed within WM-1. This is a very wide reach and the presence of this bar indicates that aggradation may be occurring here as the reach narrows over time. Base flow is split here.

As indicated by the SSA, lack of bank and riparian vegetation as well as very steep, sandy banks are the leading cause of bank stability along these reaches, with the banks of WM-1 being the most unstable. The composite bank stability score is 3.1 / 5.0 and the overall composite stream stability score is 3.5 / 5.0 indicating a moderately unstable system. The average BEHI score is 44 / 50, or “Very High”. These scores are very similar to those of the Hall-II reaches. Bank stability is the over driver of these high instability scores.

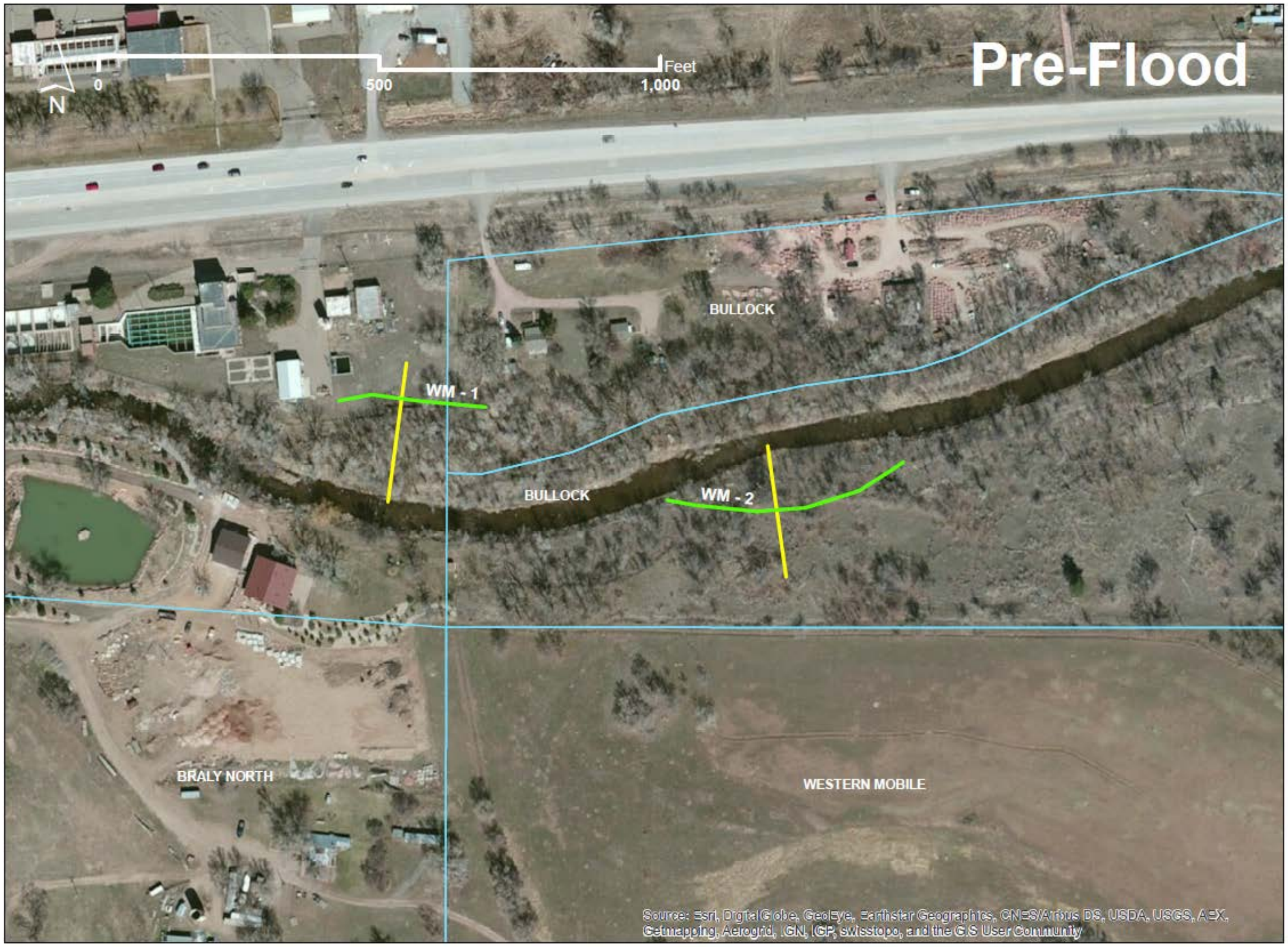
Map Created by Joel Sholtes, AloTerra Restoration Services, October 2015

Figure 3. Pre-Flood aerial photograph of the Hall-II site with longitudinal profiles (green) and cross-section survey transects (yellow).



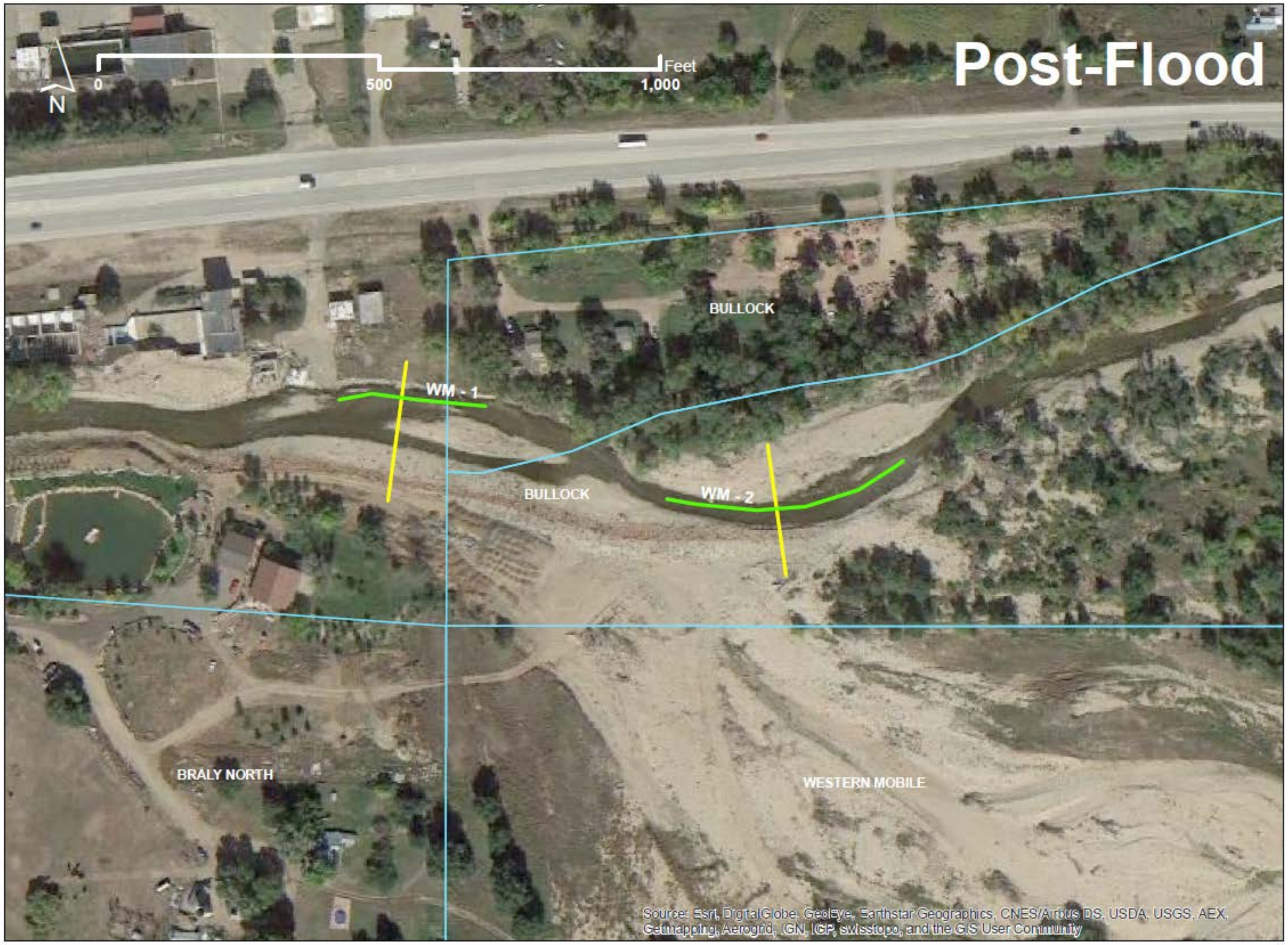
Map Created by Joel Sholtes, AloTerra Restoration Services, October 2015

Figure 4. Post-Flood aerial photograph of the Hall-II site with longitudinal profiles (green) and cross-section survey transects (yellow).



Map Created by Joel Sholtes, AloTerra Restoration Services, October 2015

Figure 5. Pre-Flood aerial photograph of the Western Mobile site with longitudinal profiles (green) and cross-section survey transects (yellow).



Map Created by Joel Sholtes, AloTerra Restoration Services, October 2015

Figure 6. Post-Flood aerial photograph of the Western Mobile site with longitudinal profiles (green) and cross-section survey transects (yellow).

DISCUSSION

The SSA method proved to be relatively rapid, requiring approximately 5 minutes of visual field assessment (walking the sub reach) before filling out field sheets, and approximately 10 minutes to conduct the SSA, for a total of approximately 15 minutes per sub-reach. Its results compared well with our field measurements and our interpretation of our observations of relative channel stability. The strength of the SSA is that it allows one to identify which stability parameters are most problematic on a sub-reach basis. It also allows one to compare relative stability among reaches and within a reach over time.

Because we implemented the BEHI only once per sub-reach at the most unstable bank site, it tended to over-estimate instability compared to the SSA. The BEHI methodology considers only one bank at a point and would have to be implemented several times over the length of a sub-reach to arrive at the same level of integration as the SSA. It also requires bank geometry surveying (bank height and bankfull height measurement). To integrate stability information over a reach of a similar length assessed by the SSA using BEHI, one would conduct the BEHI assessment on three to four cross sections over a 200 feet reach totaling six to eight assessments. This would take approximately one hour to complete.

SSA and BEHI scores correlate well, though because of the general approach of BEHI assessments, which target one bank within a reach, BEHI scores indicated poorer stability overall relative to SSA scores.

Regarding the overall stability of each reach, our observations and field measurements indicate that both channels are relatively stable vertically given the large size of the bed material present and lack of signs of active incision. However, both channels appeared to be over-widened from the flood. Deposits of sediment in the form of a mid-channel bar on WM-1 indicate that the channel may be in an aggradation phase, or accumulating sediment. The presence of this bar might also indicate that the channel is beginning to narrow as it splits base from between a main and side channel.

Results from the SSA indicate that bank stability is the largest concern for overall channel stability at both reaches. Though bed and bank material tended to be coarse (gravel to cobble size), steep bank angles along with lack of mature or other perennial vegetation on banks and within the riparian area resulted in higher SSA scores for these parameters. Bank angles along the left side of WM-1 as well as both sides of the Hall-3 sub-reach were vertical or nearly vertical and actively eroding or mass-wasting. Here, the channel carved into adjacent floodplains or hillslopes during the flood event leaving unstable banks behind. Rip-rap installed along the right bank of the channel through Western Mobile was failing in places leaving the bank exposed to scour during floods.

Restoration actions on these reaches should first identify a stable channel width given potential sediment supply from upstream and focus on bank stability and re-vegetation of the bed and banks. Bank revetment treatments that rely solely on rip-rap will not likely be long-lived and will require ongoing maintenance.

Any geomorphic stability assessment must rely on interpretation of field measurements, observations, and professional judgement as there is no a fully objective methodology for rapidly assessing stability. The SSA protocol relies on quantitative observations that can be made using inexperienced personnel, but interpretation of its results ultimately rely on interpretation from an experienced fluvial geomorphologist.

Future stability assessments will be able to capture ongoing channel adjustment and stability concerns at Hall II and Western Mobile. Further, as we receive long-term results from other sites (Skin Gulch, tributary to Poudre River; St Vrain at Sandstone Ranch), validity and consistency will be further understood. In the interim, it would be helpful to conduct SSA surveys with trained volunteers and/or non-AloTerra staff, to determine how consistent results are across observers at the same site. Should funding be available in future years, we would like to carry out a training and cross-observer validation on an additional BCPOS property or on these same properties. Once we acquire information and feedback from additional observers, we will feel more confident in the validity of the SSA protocol.

References

Bureau of Land Management (2013). Riparian Area Management, Proper Functioning Condition Assessment for Lotic Areas. Technical Reference 1737-15 v.2, 2013. 294p.

Harrelson, C.C., C.L. Rawlins, and J.P. Potyondy, 1994. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61 p.

Pfankuch, D. J. (1975). Stream reach inventory and channel stability evaluation. U.S. Department of Agriculture Forest Service. Region 1. Missoula, Montana. 30p.

Rosgen, D. L. (2001). A practical method of computing streambank erosion rate. In Proceedings of the Seventh Federal Interagency Sedimentation Conference 2(2): 9-15.

Sholtes, J. S. and J. Giordanengo (2014). DRAFT Stream Bank and Bed Stability Assessment Protocol. AloTerra Restoration Services, LLC, Fort Collins, Colorado. 9p.

Thorne, C. R. (1992). Field Assessment Techniques for Bank Erosion Modeling, Final Report. USACOE European Research Office. 6560-EN-09. 103p.

Appendices

Appendix A (attached): SSA protocol and sample field sheets.

Appendix B (attached): SSA Field Sheets and Scoring Table. BEHI Scoring Results.

Appendix C (attached): Site photos, Cross-section and Longitudinal Surveys and Plots. Benchmark GPS locations.

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Stream Bank and Bed Stability Assessment Protocol

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Introduction

Streambank erosion is often part of equilibrium stream processes resulting from lateral migration stream meanders down valley over time. In this setting the coarse material eroded from the banks is generally deposition downstream in point bars resulting in a rough balance between erosion and deposition over time (Knighton 1998). However, disturbance to streams from land use change and the resulting changes in runoff hydrology, channel straightening, and flood impacts can lead to conditions in which banks become unstable and are a net source of sediment to a stream channel, exceeding its natural balance. In fact, sediment from bank erosion under these situations has been cited as one of the leading source of fine sediment to streams in the U.S. (EPA 2009).

This stream bank and bed stability assessment protocol has been developed to rapidly assess factors contributing to channel stability and identify which areas along a stream reach have the greatest amount of active erosion or are at the greatest risk of future erosion. It also considers the stability and effectiveness of channel restoration structures as a post-restoration monitoring class. Each sub-reach (100-200 feet) is evaluated for bed and bank material properties, bank slope and vegetation coverage, as well as evidence of active bed and bank erosion. An aggregated score is calculated for each sub-reach allowing one to identify which sub-reaches pose the greatest concern to channel stability along the reach as well as identify what factors contribute to this. Finally, this protocol can be used for repeated assessments to monitor change over time and compare pre- and post-restoration results in a manner that allows for targeted maintenance treatments necessary to address project goals.

We begin this protocol with background information on channel stability and instability processes. We follow with a description of the protocol, and end with a discussion on interpreting the results.

Background

Many models of channel evolution in response to a disturbance exist. One intuitive model introduced by Schumm et al. (1984) describes the series of stages a channel may go through in response to a disturbance such as channelization, urbanization, or flooding (Figure 1). Beginning with Stage III, post disturbance, channel incision occurs by degradation (incision) of the channel bed and migration of head cuts (break in slope in erodible material) upstream. This increases the heights of the banks, reduces their stability, and can lead to enhanced scour at the toes of the banks. Bank erosion and failure result and the channel widens (Stage IV). As the channel widens, the erosive force of the flow dissipates, deposition of sediment results (aggradation), and a new floodplain begins to form within the incised channel (Stage V). Over a period of time (10 to > 100 years depending on the flow regime, vegetation, and bed and bank material) a new stable channel forms (Stage VI). Bank erosion resulting from channel instability may be observed along Stages III to V.

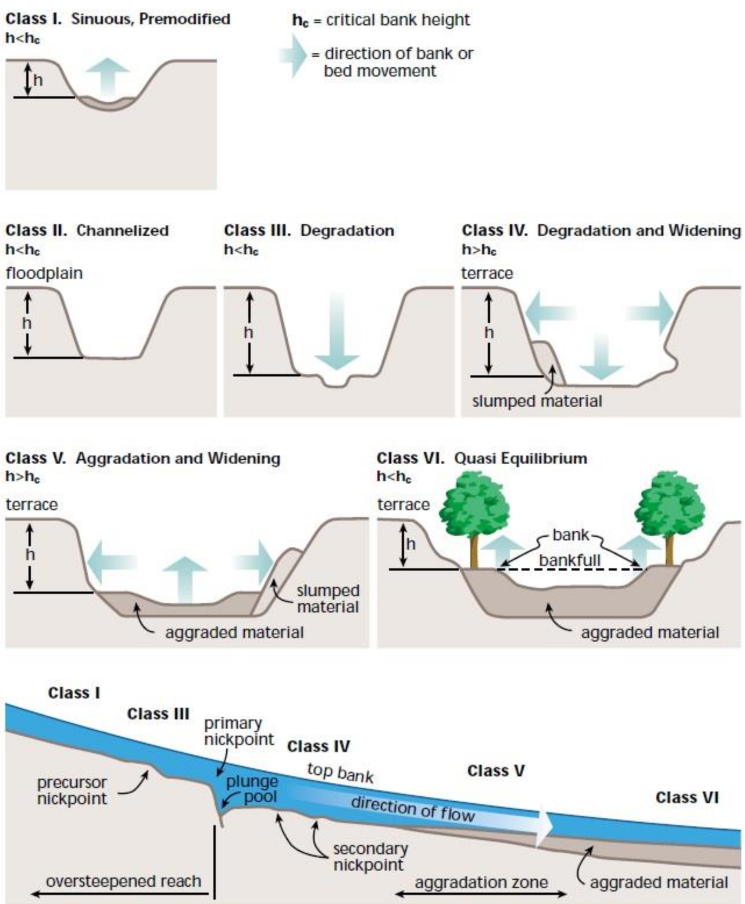

Figure 1. Channel evolution model following a disturbance (FISRWG 1998), modified from Schumm et al. (1984).

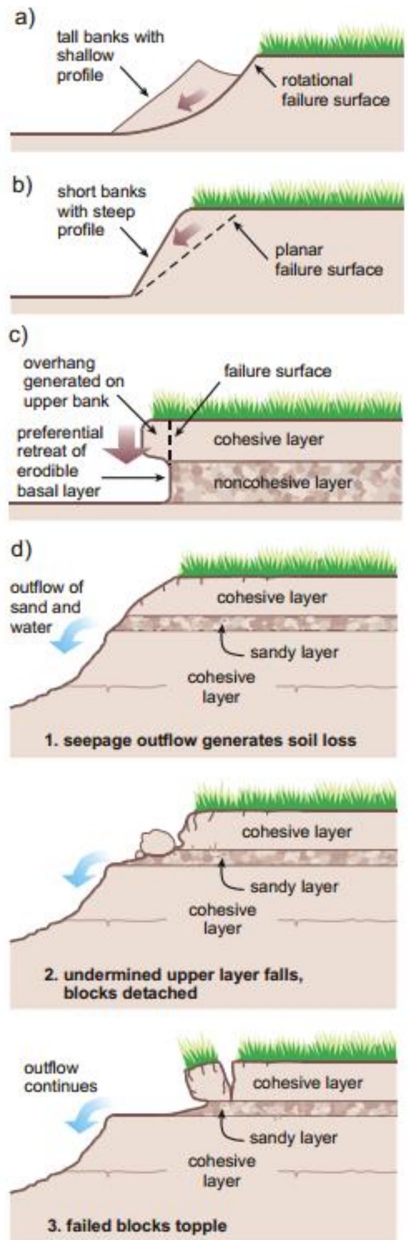

Figure 2. Bank failure mechanisms: a) rotational failure, b) planar failure, c) cantilever failure, d) piping or sapping failure from groundwater. (FISWRG 1998), modified from Hagerty (1991).

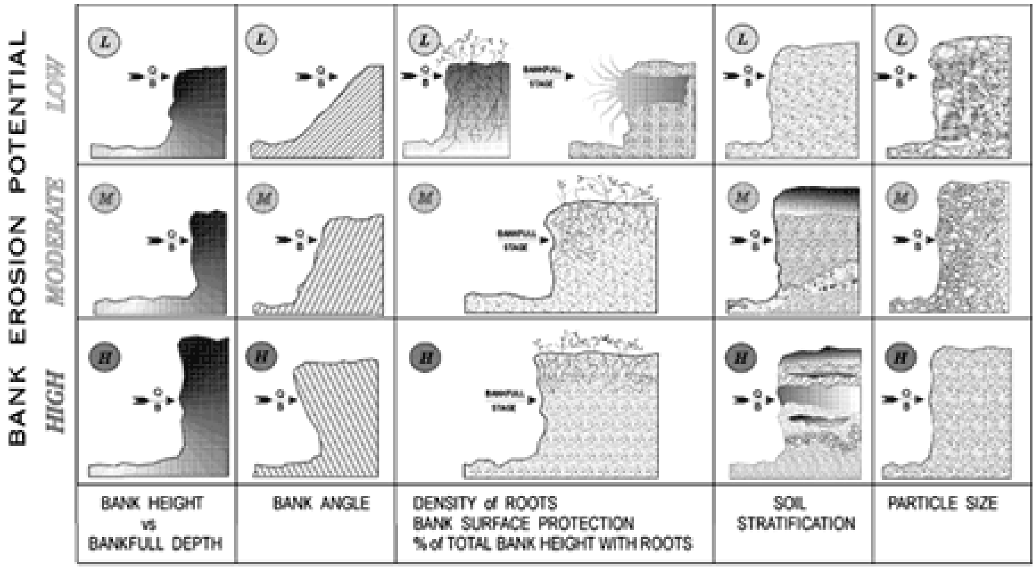

Figure 3. Bank erosion potential diagram as function of various factors. Arrows indicate bankfull height. (Rosgen 2006)

Loss of bank material to the channel occurs by two primary processes that work in tandem: slope instability and erosion. Slope stability is a geotechnical property of banks that involves the type of material comprising the banks, the angle of the banks, pressure from groundwater entering the banks, as well as the amount of roots in the bank. All materials have a natural “angle of repose” below which they are stable. Besides bedrock, cohesive bank materials such as silty and clayey soils have the largest stable angle of repose because of the inter-particle cohesion inherent in this material. However, they are susceptible to mass wasting or the loss of large chucks of bank material when they become geotechnically unstable (Haggerty 1991, Simon et al. 1999) (Figure 2a & b).

Scour at the toe of cohesive banks can lead to undercut banks and bank slumping or mass wasting (Figure 2c). Non-cohesive materials such as sand up through cobble material have lower angles of repose, with sand having the lowest. This means that for a sandy bank to be stable it must have a shallow angle. In deeply incised channels and gullies, the groundwater table may intersect the bank. Pressure in the pore space of bank material from this groundwater can reduce the stability of the bank and assist in bank failure (Figure 2d). Finally, roots from vegetation growing on the bank face and on the floodplain just beyond the bank face greatly assist in increasing the tensile strength of the bank. Dense shallow-rooted vegetation such as grasses can prevent erosion of the bank face, but do not contribute greatly to enhancing tensile strength, while deep-rooted woody vegetation (i.e., willows, cottonwoods, and other shrubs and trees) are most effective at increasing the tensile strength of the bank (Figure 3, middle column).

Bank erosion involves the properties of the bank sediment as well as the hydraulic (flow) conditions along the bank face. Bank material erodibility (susceptibility to erosion) tends to follow the angle of repose trends of different bank materials previously discussed with sand being the most erodible of non-cohesive sediments. The erodibility of cohesive sediments falls between sands and gravels and is a function of the relative percentages of sand, silt, and clay, as well as organic matter. Soils with larger percentages of sands and silts and lower percentages of organic matter tend to be more erodible (Schwab et al. 1981).

Banks may have horizontal layers of different types of material each with different erodibilities (soil stratification, Figure 2, 3).

Flow hydraulics near the bank also play an important role in erosion. Shear stress in flowing water—the friction-like stress working parallel to the bank and responsible for scour— is concentrated along the channel bed and toe of the bank. This can lead to toe scour, and cantilevered (undercut) banks, which are more susceptible to geotechnical failure, as described above (Figure 2c). Meandering channel form concentrates shear stress on the outside of meander bends resulting in a steeper "cutbank", which can be very steep in incised channels, eventually becoming unstable.

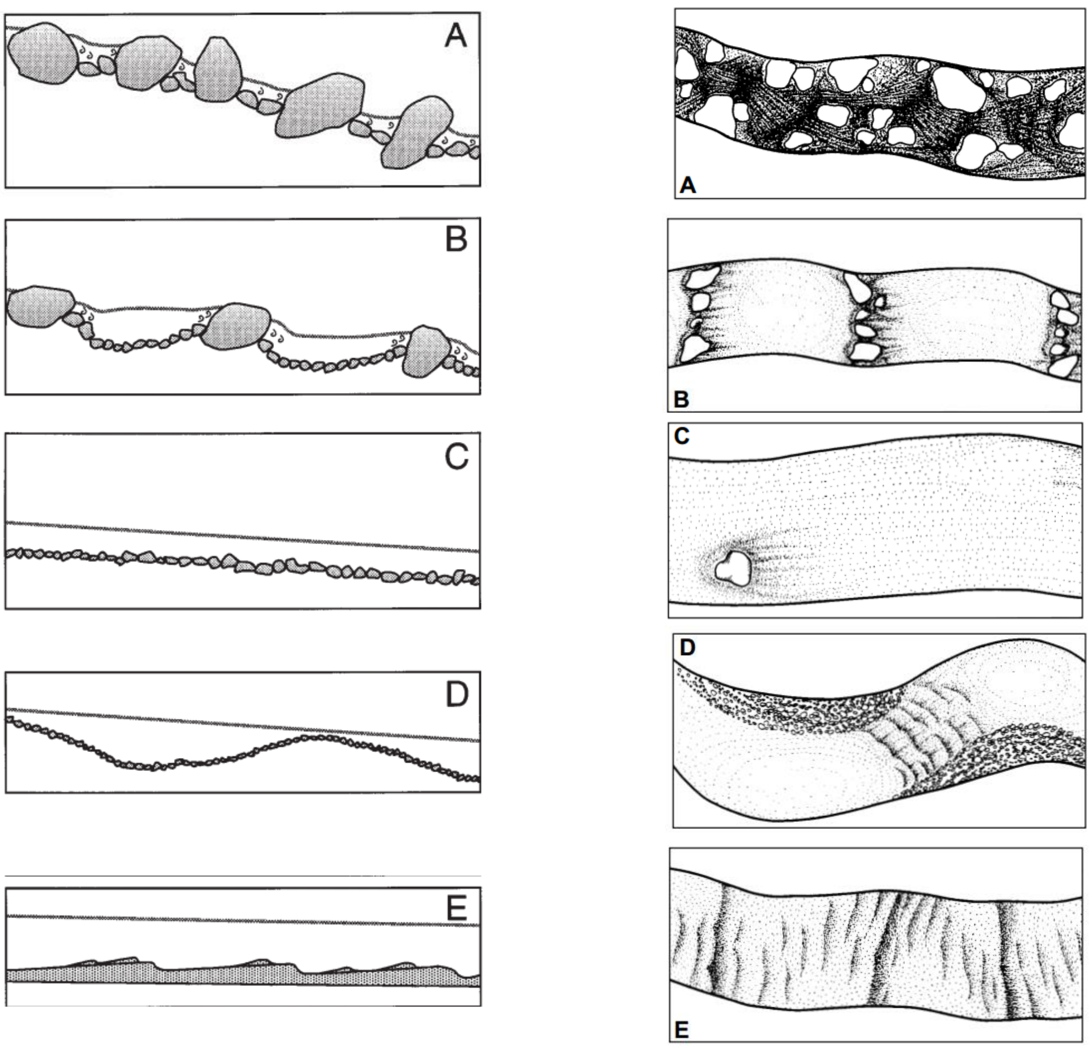

Figure 4. Channel morphologies and bedforms for mountain rivers. Longitudinal profile in left column, and planform view in right. (A) cascade; (B) step pool; (C) plane bed; (D) pool riffle; and (E) dune ripple. (Montgomery and Buffington, 1997). Reprinted under GSA Bulletin's Fair Use Policy.

Channel bed stability also plays an important role in overall stream stability and influences bank stability. Channel incision can lead to steeper banks and more concentrated flow, both of which contribute to bank instability and erosion. Bed material in most perennial natural channels is for the most part non-cohesive, that is, it is composed of sediment deposited by flow from upstream. Channel beds are often a mixture of many grain sizes ranging from purely sand and sand and gravel mixtures, up to boulder and cobble dominated beds (Figure 4). As a rule: the steeper the channel the coarser the bed material. This model excludes gullies and other channels that form in cohesive soils in dry climates.

While finer bed channels may be more susceptible to vertical incision, streams with fine beds tend to have mild slopes, and less vertical relief to erode. Steeper channels with coarser material are also susceptible to incision, especially where large boulders are lacking to provide grade control. Evidence of active incision often comes in the form of headcuts (or knickpoints), which are steps or discontinuities in the slope of the bed. Headcuts migrate upstream as their faces erode until they encounter a vertical grade control such a boulders or bedrock (Figure 1). They serve to reduce channel slope and erosive energy allowing a channel to adjust to the disturbance that initiated this vertical instability. A range of natural mountain stream types is shown in Figure 4, above.

A final consideration of channel stability concerns the stability and quality of installed grade control, habitat enhancement, and bank protection structures, otherwise known as restoration treatments. Hard engineering approaches such as rip-rapped banks and grade control vanes can be undermined or circumvented by erosion processes. Bank bioengineering treatments such as planted erosion control fabric, live stakes, and use of wood installed along the bank toe can fail if subjected to high flows before plant establishment or if installed improperly. These examples of restoration treatment failures are not exhaustive, and it is outside of the scope of this protocol to discuss different stream restoration treatments and their failure mechanisms. However, part of this protocol involves assessing the integrity of these structures as described below.

Assessment Protocol

This stream bank and bed assessment protocol was developed to allow a field crew of one to two people assess the stability of a stream reach rapidly, thoroughly, and in a spatially explicit manner so that stability concerns may be identified and located along a reach. The field team will ideally comprise at least one person with experience in fluvial geomorphology and another with experience in field botany. Factors leading to bank stability (or risk of instability) included in this protocol are: bank and channel material composition, bank angle, bank and riparian vegetation type and percent coverage, evidence of active or recent bank erosion, channel bed composition, bed morphology, and evidence and severity of recent vertical incision.

Figure 5. Example of mapped stability scores

This protocol was designed to allow inter-annual comparison and tracking changes over time, possibly after a restoration effort. It is largely a visual assessment, conducted along a 100 – 200 ft sub-reach within which channel and bank information is aggregated. The length of the sub-reach may vary according to the channel size, but its length should be on the order of 10 to 20 times the bankfull width of the channel (floodplain edge to floodplain edge). Each category of the stability assessment may be evaluated separately to identify specific factors leading to stability issues within a sub-reach or along the entire project reach. These factors are also aggregated to identify unstable sub-reaches within the larger reach. For example, lack of bank and riparian vegetation may be a leading cause of risk of instability along the project reach. Bank instability may only be an issue for select areas within a project reach, and not a pervasive problem. This assessment protocol will aid in identifying each of these.

The general assessment procedure involves laying a measuring tape along a stream bank for the specified length of the sub-reach and characterizing bed and bank properties along this sub-reach. A handheld GPS may be used to mark the starting point of each sub-reach as well as the location of any failed stream restoration structures. Stream stability information may be later incorporated into a GIS database allowing the stability metrics to be mapped (Figure 6). Photos should be taken in the middle of each sub-reach (upstream, downstream, leftbank, right bank), as well as of any noteworthy observations, such as a particularly severe example of erosion or a failure restoration structure. In addition to using the accompanying field sheet to document each sub-reach, notes should be taken of the photo numbers, any waypoints collected on the GPS, as well as one to two sentences of narrative describing the sub-reach.

The following is a description of each assessment category:

Bank Composition

Visually and tactilely (use your hands) assess the relative size of the bank material. Assign percent of sub-reach length to each material category. Note that cohesive banks are composed of soil, which has a certain percentage of silt and clay. Non-cohesive banks lack silt and clay, though can be a mixture of sands, gravel, cobbles, etc. Table 1 contains descriptions and lengths associated with each sediment class.

Table 1. Grain size descriptions

	Cohesive	***Non-Cohesive***			
Type	***Silt / Clay (soil)***	***Sand***	***Gravel***	***Cobble***	***Boulder***
Grain Size	< 0.062 mm	0.063 to 2 mm	2 to 64 mm	64 to 256 mm	256 + mm
Description	Fine texture, cohesive, smooth when rubbed between fingers	Fine sugar to kosher salt sized particles	Peppercorn to egg sized	Baseball to grapefruit sized	Melon sized and larger

Bank Angle

The bank angle categories are as follows: *Mild* (0°-30°), *Moderate* (30°-60°), *Steep* (60°-90°), and *Overhang* (> 90°). Evaluate percent of each sub-reach having each bank angle category.

Vegetation: Bank and Riparian Zone

Start each field day by following a line-intercept procedure (Herrick et al., 2005) over a representative 100-foot section of bank in order to calibrate the observers eyes. Assess percent of bank and stream edge (riparian zone) covered by *bare earth* (soil, rock, and/or organic litter), *nascent vegetation* (annual or biennial grasses or forbs, and juvenile perennial vegetation), *perennial grasses and forbs*, and *shrubs* and *trees*. This may represent the most challenging component of the stability assessment. Use of a vegetation density transect method may assist in estimating the relative percentages of cover within each vegetation category. Avoid looking upstream to assess vegetation coverage, as oblique visual assessments of vegetation cover often lead to gross cover overestimates. Rather, walk the bank while looking down and note the percent cover for that transect (measured distance of the cover for each vegetation category divided by the total transect length). For instance, if a combined 10 feet of a 100 foot transect is comprised a combination of annual forbs and grasses and/or 1-year-old (juvenile) perennial plant cover, the score for nascent vegetation would be 10 (10%). In estimating cover, include the gaps between the leaves as part of the canopy estimate. Imagine a polygon drawn around the very perimeter of the plant canopy in question, and tally the number of linear feet that canopy intercepts the tape measure.

Count understory vegetation separately from overstory vegetation. For example, if a shrub canopy covers the transect from 20-30 ft, and again from 50-60 ft, then the shrub cover is 20% [(10+10)/100]. If an understory of perennial grasses/sedges occurs under that shrub canopy, then record the percent cover of that perennial cover in addition to the shrub cover estimate and record it in the appropriate row on the form. In this regards, it may be possible in mature riparian stands to record a total vegetation cover greater than 100%.

Active Bank Erosion

The previous categories indicate bank susceptibility to erosion. This category assesses recent or ongoing bank erosion processes. Bare soil or bank material does not necessarily indicate active erosion. Look for clues such as vegetation, exposed roots, evidence of bank material deposited at the bank toe, and fresh erosion on bank faces. Here, instead of assigning a percent length to each category, pick the category that best matches the observed extent (percent length) of active bank erosion. Low (0 – 25%), Moderate (25 – 50%), High (50 – 75%), Severe (75 – 100%). Bank restoration treatments that are underperforming or failing may coincide with active bank erosion. Note the active erosion here and document the bank treatment under the "Restoration Treatment Assessment" described below.

Bed Stability

Equally as important as assessing bank stability is channel bed stability. For the sake of brevity, percent lengths are not included in this portion of the assessment. Rather, the field crew selects the dominant bed sediment type (following Table 1) and dominant morphology type (Figure 4) of the sub-reach. They note whether active or recent incision exists. Clues from positions of roots along the bank and presence of migrating headcuts help inform this. Finally, if recent or active incision exists, the field crew estimates the depth of erosion along the sub-reach. Active incision may occur at or as a result of a stream restoration structure failure. Please note the incision or instability here and document the structure under the "Restoration Treatment Assessment" described below.

Restoration Treatment Assessment

Here, the field team assesses the quality and integrity of any stream restoration treatments/structures in the channel (e.g., grade control vanes or habitat enhancements) and banks (e.g., erosion control fabric, live stakes, toe wood or root wads). Bank and in-channel treatments encountered are each numbered, identified by type, and then scored. This assessment follows the spirit of the bed stability assessment in that it does not consider percent lengths of each sub-reach. Rather, each structure or treatment encountered is scored as follows: *Good*: Stable and meeting design goals (e.g., bed or bank stability and reduction of erosion), *Moderate*: Could use some minor maintenance, *Poor*: evidence of erosion, plant death, or processes that may soon lead to restoration treatment failure, *Failed*: restoration treatment no longer serving its intended function and/or the structure/treatment is damaged to an extent that is problematic to the stability of the channel. The field crew should have an annotated "as-built" drawing of the reach that identifies what restoration treatments were installed where to aid in the inventory and assessment of these.

General Assessment Notes

Round estimates of percent length of each category to the nearest 10, 20, or 25%. Because this assessment protocol is visually based, precision beyond the nearest 10% is likely inaccurate and unnecessary. If working as a team, each team member should evaluate each category independently. Results can then be averaged. For a more comprehensive view of channel change over time, bank and channel bed monitoring should also incorporate repeated cross section and longitudinal profile surveys as well a repeated photographs from monumented locations. A good primer on stream surveying methods can be found in Harrelson et al. (1994).

Bank Erosion Hazard Score Calculations

To calculate bank stability scores, data collected on each sub-reach is entered into the "Calculations Spreadsheet" in which one column represents a sub-reach. Categories within each group (e.g., bank composition, bank vegetation) are assigned a value from 1 – 4 with 4 indicting the highest risk of instability. Based on the percent lengths attributed to each group category, a weighted average score is calculated for each bank for each category. These scores are then aggregated as a percent of total score, with higher scores indicating a higher risk of instability. Because this index-based approach is arbitrary (is bank angle equally as important as riparian vegetation coverage?), weights can be assigned to each category to give more or less weight to a particular category in the overall "Composite Bank Erosion Hazard Score". Currently, all categories have a weight of 1 with the exception of "Active Bank Erosion", which has a weight of 2.

Bed stability and stream restoration treatment assessments are scored separately from the composite bank erosion hazard score. Each sub-reach with active incision is flagged. Each restoration treatment is assessed and tallied for each category of quality / stability. These can then be inventoried at the project reach level.

Interpretation of Results

The results from this monitoring protocol may be used in a number of ways. They may be used to gather a baseline assessment of the stability of a reach of interest, and to document restoration needs. It can then be used to track the evolution of the channel's stability over time in response to restoration efforts. Repair and maintenance needs may also be identified by this protocol. These assessments cannot at this time be used to estimate the quantity of eroded sediment entering a stream or the rate of bank erosion. However, they can provide objective and transparent evaluations of bank and bed stability that can aid in documenting overall changes and / or improvements to stability as a result of a restoration effort.

References

EPA, 2009. *National Water Quality Inventory: Report to Congress, 2004*. Pub. # EPA 841-R-08-001. 43p.

FISRWG, 1998. *Stream Corridor Restoration: Principles, Processes, and Practices*. Federal Interagency Stream Restoration Working Group (FISRWG). GPO Item No. 0120-A.

Hagerty, D.J., 1991. *Piping/sapping erosion. I: Basic considerations*. Journal of Hydraulic Engineering, 117(8), 991-1008.

Harrelson, C.C., C.L. Rawlins, and J.P. Potyondy, 1994. *Stream channel reference sites: an illustrated guide to field technique*. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61 p.

Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M. Burkett, and W.G. Whitford, 2005. *Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems. Volume I: Quick Start.* USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico. ISBN 0-9755552-0-0. University of Arizona Press, Tucson, Arizona, USA.

Knighton, D., 1998. *Fluvial forms and processes: A new perspective*. New York: Oxford University Press. 400 p.

Montgomery, D. R., and J.M. Buffington, 1997. *Channel-reach morphology in mountain drainage basins*. Geological Society of America Bulletin, 109(5), 596-611.

Rosgen, D.L., 2006. *Watershed Assessment of River Stability and Sediment Supply (WARSSS)*, Wildland Hydrology Books, Fort Collins, CO, 648 p.

Schumm, S. A., M.D. Harvey, and C.C. Watson, 1984. *Incised channels: Morphology dynamics and control*. Littleton, Colorado, Water Resources Publications, 200 p.

Simon, A., A. Curini, S. Darby, and E. Langendoen, 1999. *Stream-bank mechanics and the role of bank and near-bank processes in incised channels*. In Incised River Channels, Darby S. and Simon A, (eds). Wiley: New York; 123–152.

Schwab, G.O., R.K. Frevert, T.W. Edminster, and K.K. Barnes, 1981. *Soil and Water Conservation.* Third edition. Wiley, New York, 525 p.

Bank - Channel Stability and Riparian Vegetation Field Assessment

Date	**Stream**	**Crew**	
Sub-Reach ID	**Sub-Reach Length**	**Lat.**	**Lon.**
Photos US:	DS:	LB:	RB:

		Right Bank	**Left Bank**
Bank Composition		*Percent of Length*	
Cohesive (Silt/Clay)			
Sand			
Gravel/Cobble			
Boulder/Bedrock			
Bank Angle	***Degrees***		
Mild	0-30		
Moderate	31-60		
Steep	61-90		
Overhang	91+		
Bank Vegetation			
Bare Earth			
Nascent Vegetation			
Perennial Vegetaton			
Shrubs			
Trees			
Riparian Vegetaton			
Bare Earth			
Nascent Vegetation			
Perennial Vegetaton			
Shrubs			
Trees			
Active Bank Erosion			
Low	0 - 25%		
Moderate	26 - 50%		
High	51 - 75%		
Severe	76 - 100%		

Stream Restoration Treatment Inventory

Bank Treatments

	Right Bank	**Left Bank**
Type		
Length		
Quality		
Photos		
Type		
Length		
Quality		
Photos		

Quality: Good: 4, Moderate: 3, Poor: 2, Failed: 1

In-Channel Treatments / Structures

Type

Number

Quality **Good Moderate Poor Failed**

Photos

Type

Number

Quality **Good Moderate Poor Failed**

Photos

Bed Stability

Bed Composition	**Cohesive**	**Sand**	**Gravel**	**Cobble**	**Bedrock/Boulder**
Bed Morphology	**Cascade**	**Step-pool**	**Riffle/Glide**	**Pool/Riffle**	**Dune/Ripple**
Recent/active incision?	**YES**	**NO**			
Severity of incision	**< 1 ft**	**1-2 ft**	**2-3 ft**	**> 3 ft**	

NOTES

Instructions: Enter percent length values into each white box for each sub-reach. The colored boxes will automatically calculated weighted averages within each category as well as the composite bank stability score. Category weights may also be adjusted as the user deems appropriate.

Bank Stability

Weights		SCORE	REACH ID 1 Left Bank	REACH ID 1 Right Bank	REACH ID 2 Left Bank	REACH ID 2 Right Bank	REACH ID 3 Left Bank	REACH ID 3 Right Bank	REACH ID 4 Left Bank	REACH ID 4 Right Bank	Average Scores Left Bank	Average Scores Right Bank
			Percent of Length		*Percent of Length*		*Percent of Length*		*Percent of Length*			
1	**Bank Composition**											
	Cohesive (Silt/Clay)	4										
	Sand	3		25		25		25		25		
	Gravel/Cobble	2	60	75	60	75	60	75	60	75		
	Boulder/Bedrock	1	40		40		40		40			
			1.6	2.3	1.6	2.3	1.6	2.3	1.6	2.3	1.6	2.3
1	**Bank Angle - Degrees**											
	Mild - 0-30	1										
	Moderate - 30-60	2	50	50	50	50	50	50	50	50		
	Steep - 60-90	3	50	50	50	50	50	50	50	50		
	Overhang - > 90	4										
			2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
1	**Bank Vegetation**											
	Bare Earth	5	75	50	75	50	75	50	75	50		
	Nascent Vegetation	4	10	35	10	35	10	35	10	35		
	Perennial Vegetation	3	10	35	10	35	10	35	10	35		
	Shrubs	2	15	15	15	15	15	15	15	15		
	Trees	1										
			4.8	5.3	4.4	3.9	4.4	3.9	4.4	3.9	4.5	4.2
1	**Riparian Vegetaton**											
	Bare Earth	5	40	40	40	40	40	40	40	40		
	Nascent Vegetation	4	10	35	10	35	10	35	10	35		
	Perennial Vegetation	3	50	50	50	50	50	50	50	50		
	Shrubs	2	10	10	10	10	10	10	10	10		
	Trees	1										
			4.1	5.1	3.7	3.7	3.7	3.7	3.7	3.7	3.8	4.1
3	**Active Bank Erosion**											
	Low: 0 - 25%	1										
	Moderate: 25 - 50%	2		1		1		1		1		
	High: 50 - 75%	3										
	Severe: 75 - 100%	4	1		1		1		1			
			4	2	4	2	4	2	4	2	4.0	2.0
	Composite Bank Erosion Hazard Score		83%	70%	81%	61%	81%	61%	81%	61%	81%	63%

Bed Stability

		Reach 1	Reach 2	Reach 3	Reach 4	
Recent/active incision?	(Yes / No)	Yes	No	Yes	Yes	**No. Sub-Reachse w/ Incision:** 3
Severity of incision	> 1 ft	1				
	1 - 2 ft			1		
	2 - 3 ft				1	
	> 3 ft					**Average Incision Severity**
		1	0	2	3	1.5

Stream Restoration Treatment Inventory

Bank Treatments

	Reach 1 Left Bank	Reach 1 Right Bank	Reach 2 Left Bank	Reach 2 Right Bank	Reach 3 Left Bank	Reach 3 Right Bank	Reach 4 Left Bank	Reach 4 Right Bank
Type	PECF	PECF			PECF	PECF	PECF	PECF
Length (ft)	100	100	0	0	100	100	100	100
Quality: (Good: 4, Mod: 3, Poor: 2, Fail: 1)	3	2			3	4	2	3
Type	Live stakes	Live stakes			Live Stakes	Live stakes	Toe Wood	Live stakes
Length	100	100	0	0	100	100	100	50
Quality: (Good: 4, Mod: 3, Poor: 2, Fail: 1)	4	3			4	2	2	3

Bank Treatment Summary

	Left Bank	Right Bank
Overall Length	600	550
Weighted Score	3.0	2.8

Channel Treatments / Structures

	Reach 1	Reach 2	Reach 3	Reach 4
Type	Stone Cross Vanes		Log Vanes	
Number	3		2	
Quality: (Good: 4, Mod: 3, Poor: 2, Fail: 1)	3		3	
Type				
Number				
Quality: (Good: 4, Mod: 3, Poor: 2, Fail: 1)				

Channel Treatment Summary

Overall No. Structures	5
Weighted Score	3.0

Notes on Type Codes (Create your own as needed)

PECF: Planted Erosion Control Fabric

Bank - Channel Stability and Riparian Vegetation Field Assessment

Date 10/16/2015 **Stream** South St. Vrain - Hall 2 **Crew** Joel Sholtes & John Giordanengo

Sub-Reach ID HALL-1 **Sub-Reach Length** 200 **Northing** **Easting**

Photos **US:** **DS:** **LB:** **RB:**

	Left Bank		Right Bank	
Bank Composition	*% Length*	*% C/B*	*% Length*	*% C/B*
Cohesive (Silt/Clay)				
Sand / Fine Gravel	5		50	
Gravel/Cobble	70		45	
Boulder/Bedrock/Other	25		5	

Bank Angle	***Degrees***	Left Bank	Right Bank
Mild	0-30		
Moderate	31-60	100	100
Steep	61-90		
Overhang	91+		

Bank Vegetation	Left Bank	Maturity	Right Bank	Maturity
Bare Earth, Rock, Litter	93			
Nascent Vegetation	7		2	1
Perennial Herb. Vegetaton			1	1
Shrubs (Mature)			10	3
Trees (Mature)			40	4

Maturity: (**1** = 1st yr; **2** = 1-5 yrs; **3** = mature; **4** = old growth)

Riparian Vegetation	Left Bank	Maturity	Right Bank	Maturity
Bare Earth, Rock, Litter	78		15	
Nascent Vegetation	2		1	
Perennial Herb. Vegetaton	10	3	70	3
Shrubs (Mature)	5	2	10	2
Trees (Mature)	5	3	40	3

Active Bank Erosion (% of Face)		Left Bank	Right Bank
Low	0 - 25%	100	85
Moderate	26 - 50%		
High	51 - 75%		15
Severe	76 - 100%		

Stream Restoration Treatment Inventory

Bank Treatments

	Right Bank	Left Bank
Type		
Length		
Quality		
Photos		
Type		
Length		
Quality		
Photos		

Quality: *(**1** = Failed; **2** = Poor; **3** = Moderate; **4** = Good)*

In-Channel Treatments / Structures

Type	
Number	
Quality	**Good Moderate Poor Failed**
Photos	
Type	
Number	
Quality	**Good Moderate Poor Failed**
Photos	

Notes on Structures:

Bed Stability

Bed Composition (%)	**Cohesive**	**Sand**	5	**Gravel**	45	**Cbl/Bldr**	50	**Bedrock**
Bed Morphology	**Cascade**	**Step-pool**		**Riff/Gld**		**Pool/Riff**		**Dune/Ripp**
Recent/active incision?	**YES**	**NO**		Aggradation?		**YES**		**NO**
Severity of incision	**< 1 ft**	**1-2 ft**		**2-3 ft**	**> 3 ft**			

REACH NOTES: Recently dead trees counted as living as roots are still providing stability. River right riparian veg includes top of a levee. Riff/glide transitions into pool at d/s end, then another riffle d/s of this reach. Banks are non-cohesive, narrow bench on right floodplain then cohesive levee with grass and some trees. Relatively stable, possibly over-widened.

Bank - Channel Stability and Riparian Vegetation Field Assessment

Date 10/16/2015 **Stream** South St. Vrain - Hall2 **Crew** Joel Sholtes & John Giordanengo

Sub-Reach ID HALL-2 **Sub-Reach Length** 200 **Northing** **Easting**

Photos **US:** **DS:** **LB:** **RB:**

	Left Bank		Right Bank	
Bank Composition	*% Length*	*% C/B*	*% Length*	*% C/B*
Cohesive (Silt/Clay)				
Sand / Fine Gravel	20	50	20	50
Gravel/Cobble	20		20	
Boulder/Bedrock/Other	60		60	
Bank Angle *Degrees*				
Mild 0-30	80		40	
Moderate 31-60	20		60	
Steep 61-90				
Overhang 91+				
Bank Vegetation				
Bare Earth, Rock, Litter	97	**Maturity**	98	**Maturity**
Nascent Vegetation	1		2	1
Perennial Herb. Vegetaton				
Shrubs (Mature)				
Trees (Mature)	2			3

Maturity: (**1** = 1st yr; **2** = 1-5 yrs; **3** = mature; **4** = old growth)

	Left Bank		Right Bank	
Riparian Vegetation				
Bare Earth, Rock, Litter	66	**Maturity**	94	**Maturity**
Nascent Vegetation	3		1	
Perennial Herb. Vegetaton	15			
Shrubs (Mature)	1	3		3
Trees (Mature)	15	3	5	3
Active Bank Erosion (% of Face)				
Low 0 - 25%	100		100	
Moderate 26 - 50%				
High 51 - 75%				
Severe 76 - 100%				

Stream Restoration Treatment Inventory

Bank Treatments

	Right Bank	Left Bank
Type		
Length		
Quality		
Photos		
Type		
Length		
Quality		
Photos		

Quality: *(**1** = Failed; **2** = Poor; **3** = Moderate; **4** = Good)*

In-Channel Treatments / Structures

Type	
Number	
Quality	**Good Moderate Poor Failed**
Photos	
Type	
Number	
Quality	**Good Moderate Poor Failed**
Photos	

Notes on Structures:

Bed Stability

Bed Composition (%)	**Cohesive**		**Sand**	10	**Gravel**	10	**Cbl/Bldr**	80	**Bedrock**
Bed Morphology	**Cascade**		**Step-pool**		**Riff/Gld**		**Pool/Riff**		**Dune/Ripp**
Recent/active incision?	**YES**		**NO**		Aggradation?		**YES**		**NO**
Severity of incision	**< 1 ft**		**1-2 ft**		**2-3 ft**	**> 3 ft**			

REACH NOTES: Channed visibily widened from flood. Dry side channels in floodplain on either side of natural / artifical levees. Relatively steeper reach with more boulder material in bed than other reaches. Very wide FP and XS does not cover entire FP. Potential artifical levee on LB. Boulder steps. FP scoured / aggraded from flood and very little vegetation.

Bank - Channel Stability and Riparian Vegetation Field Assessment

Date 10/16/2015 **Stream** South St. Vrain - Hall 2 **Crew** Joel Sholtes & John Giordanengo

Sub-Reach ID HALL-3 **Sub-Reach Length** 200 **Northing** **Easting**

Photos **US:** **DS:** **LB:** **RB:**

	Left Bank		Right Bank	
Bank Composition	*% Length*	*% C/B*	*% Length*	*% C/B*
Cohesive (Silt/Clay)	80		90	
Sand / Fine Gravel	10		3	
Gravel/Cobble	8		5	
Boulder/Bedrock/Other	2		2	

Bank Angle	***Degrees***	Left Bank	Right Bank
Mild	0-30		
Moderate	31-60		30
Steep	61-90	60	70
Overhang	91+	40	

Bank Vegetation	Left Bank	**Maturity**	Right Bank	**Maturity**
Bare Earth, Rock, Litter	92		93	
Nascent Vegetation	8		5	1
Perennial Herb. Vegetaton			2	2
Shrubs (Mature)				
Trees (Mature)				3

<u>**Maturity:**</u> (**1** = 1st yr; **2** = 1-5 yrs; **3** = mature; **4** = old growth)

Riparian Vegetation	Left Bank	**Maturity**	Right Bank	**Maturity**
Bare Earth, Rock, Litter	89		80	
Nascent Vegetation	10		15	1
Perennial Herb. Vegetaton			5	2
Shrubs (Mature)	1			2
Trees (Mature)				

Active Bank Erosion (% of Face)		Left Bank	Right Bank
Low	0 - 25%	50	80
Moderate	26 - 50%		
High	51 - 75%	25	
Severe	76 - 100%	25	20

Stream Restoration Treatment Inventory

<u>Bank Treatments</u>

	Right Bank	Left Bank
Type		
Length		
Quality		
Photos		
Type		
Length		
Quality		
Photos		

<u>Quality:</u> *(**1** = Failed; **2** = Poor; **3** = Moderate; **4** = Good)*

<u>In-Channel Treatments / Structures</u>

Type
Number
Quality **Good Moderate Poor Failed**
Photos

Type
Number
Quality **Good Moderate Poor Failed**
Photos

Notes on Structures:

Bed Stability

Bed Composition (%)	**Cohesive**	**Sand**	5	**Gravel**	15	**Cbl/Bldr**	80	**Bedrock**
Bed Morphology	**Cascade**	**Step-pool**		**Riff/Gld**		**Pool/Riff**		**Dune/Ripp**
Recent/active incision?	**YES**	**NO**		Aggradation?		**YES**		**NO**
Severity of incision	**< 1 ft**	**1-2 ft**		**2-3 ft**	**> 3 ft**			

REACH NOTES: Channel widened from flood. Chohesive banks undermined in places along bank toe. Mid-channel cobble.gravelbar.
Stratified bank aiding in bank undermining / failure. Groundwater leaking out of bank face on this hard pain.
Some boulders. Bank failure in places on LB. Mass-wasting. Floodplain high and dry on LB.

Bank - Channel Stability and Riparian Vegetation Field Assessment

Date 10/16/2015 **Stream** St. Vrain - Western Mobile **Crew** Joel Sholtes & John Giordanengo

Sub-Reach ID WM-1 **Sub-Reach Length** 200 **Northing** **Easting**

Photos **US:** **DS:** **LB:** **RB:**

	Left Bank		Right Bank	
Bank Composition	*% Length*	*% C/B*	*% Length*	*% C/B*
Cohesive (Silt/Clay)				
Sand / Fine Gravel	100	40	10	
Gravel/Cobble				
Boulder/Bedrock/Other			90	

Bank Angle	***Degrees***	Left Bank	Right Bank
Mild	0-30		90
Moderate	31-60		10
Steep	61-90	100	
Overhang	91+		

Bank Vegetation	Left Bank	**Maturity**	Right Bank	**Maturity**
Bare Earth, Rock, Litter	90		80	
Nascent Vegetation	10		20	
Perennial Herb. Vegetaton				
Shrubs (Mature)				
Trees (Mature)				

Maturity: (**1** = 1st yr; **2** = 1-5 yrs; **3** = mature; **4** = old growth)

Riparian Vegetation	Left Bank	**Maturity**	Right Bank	**Maturity**
Bare Earth, Rock, Litter	15		85	
Nascent Vegetation			15	
Perennial Herb. Vegetaton	80	3		
Shrubs (Mature)				
Trees (Mature)	5	4		

Active Bank Erosion (% of Face)		Left Bank	Right Bank
Low	0 - 25%		90
Moderate	26 - 50%		10
High	51 - 75%	10	
Severe	76 - 100%	90	

Stream Restoration Treatment Inventory

Bank Treatments

	Right Bank	Left Bank
Type	RipRap	
Length	200	
Quality	3	
Photos		
Type		
Length		
Quality		
Photos		

Quality: *(**1** = Failed; **2** = Poor; **3** = Moderate; **4** = Good)*

In-Channel Treatments / Structures

Type	
Number	
Quality	**Good Moderate Poor Failed**
Photos	
Type	
Number	
Quality	**Good Moderate Poor Failed**
Photos	

Notes on Structures:

Bed Stability

Bed Composition (%)	**Cohesive**	**Sand**	10	**Gravel**	10	**Cbl/Bldr**	80	**Bedrock**	
Bed Morphology	**Cascade**	**Step-pool**		**Riff/Gld**		**Pool/Riff**		**Dune/Ripp**	
Recent/active incision?	**YES**	**NO**		Aggradation?		**YES**		**NO**	
Severity of incision	**< 1 ft**	**1-2 ft**		**2-3 ft**	**> 3 ft**				

REACH NOTES:

Channel is over-widened from the flood. Vertical banks crumbling on river left. Sandy, gravel floodplain bench on river right. Riprap placed on RB is failing in places. No gradation (not engineered). Poor vegetation on both banks. Just downstream of old water treatment plant. Some aggradation evident in form of mid-channel bar, that splits low flow.

Bank - Channel Stability and Riparian Vegetation Field Assessment

Date 10/16/2015 **Stream** St. Vrain - Western Mobile **Crew** Joel Sholtes & John Giordanengo

Sub-Reach ID WM-2 **Sub-Reach Length** 435 **Northing** **Easting**

Photos **US:** **DS:** **LB:** **RB:**

	Left Bank		Right Bank	
Bank Composition	*% Length*	*% C/B*	*% Length*	*% C/B*
Cohesive (Silt/Clay)			5	2
Sand / Fine Gravel	40		5	
Gravel/Cobble	50		80	
Boulder/Bedrock/Other	10		10	

Bank Angle	***Degrees***	Left Bank	Right Bank
Mild	0-30	90	
Moderate	31-60	10	80
Steep	61-90		20
Overhang	91+		

Bank Vegetation	Left Bank		Right Bank	
Bare Earth, Rock, Litter	90	**Maturity**	89	**Maturity**
Nascent Vegetation	10		10	
Perennial Herb. Vegetaton			1	
Shrubs (Mature)				
Trees (Mature)				

Maturity: (**1** = 1st yr; **2** = 1-5 yrs; **3** = mature; **4** = old growth)

Riparian Vegetation	Left Bank		Right Bank	
Bare Earth, Rock, Litter	20	**Maturity**		**Maturity**
Nascent Vegetation	5		40	
Perennial Herb. Vegetaton	20		60	
Shrubs (Mature)	5	3		
Trees (Mature)	100	4		

Active Bank Erosion (% of Face)		Left Bank	Right Bank
Low	0 - 25%	100	85
Moderate	26 - 50%		
High	51 - 75%		15
Severe	76 - 100%		

Stream Restoration Treatment Inventory

Bank Treatments

	Right Bank	Left Bank
Type	RipRap	
Length	300	
Quality	3	
Photos		
Type		
Length		
Quality		
Photos		

Quality: (**1** = Failed; **2** = Poor; **3** = Moderate; **4** = Good)

In-Channel Treatments / Structures

Type	
Number	
Quality	**Good Moderate Poor Failed**
Photos	
Type	
Number	
Quality	**Good Moderate Poor Failed**
Photos	

Notes on Structures:

Bed Stability

Bed Composition (%)	**Cohesive**	**Sand**	5	**Gravel**	15	**Cbl/Bldr**	80	**Bedrock**	
Bed Morphology	**Cascade**	**Step-pool**		**Riff/Gld**		**Pool/Riff**		**Dune/Ripp**	
Recent/active incision?	**YES**	**NO**		Aggradation?		**YES**		**NO**	
Severity of incision	**< 1 ft**	**1-2 ft**		**2-3 ft**	**> 3 ft**				

REACH NOTES: Reach is along a cutbank on the right bank. Riprap on RB is failing along ~50 ft at location of max bend shear stress.
Left bank is a point bar composed of cobble, gravel, and sand. Good tree cover on LB, none on RB, which is high and dry.
Surveyed from toe of riffle to toe of riffle.

Instructions: Enter percent length values into each white box for each sub-reach. The colored boxes will automatically calculated weighted averages within each category as well as the composite bank stability score. Category weights may also be adjusted as the user deems appropriate.

Bank Stability

Weights		SCORE	REACH ID Hall-1 Left Bank	Hall-1 Right Bank	REACH ID Hall-2 Left Bank	Hall-2 Right Bank	REACH ID Hall-3 Left Bank	Hall-3 Right Bank	Average Scores Left Bank	Average Scores Right Bank
			Percent of Length		*Percent of Length*		*Percent of Length*			
1	**Bank Composition**									
	Cohesive (Silt/Clay)	4					80	90		
	Sand	3	5	50	20	20	10	3		
	Gravel/Cobble	2	70	45	20	20	8	5		
	Boulder/Bedrock	1	25	5	60	60	2	2		
			1.8	2.5	1.6	1.6	3.7	3.8	2.4	2.6
1	**Bank Angle - Degrees**									
	Mild - 0-30	1			80	40				
	Moderate - 30-60	2	100	100	20	60		30		
	Steep - 60-90	3					60	70		
	Overhang - > 90	4					40			
			2.0	2.0	1.2	1.6	3.4	2.7	2.2	2.1
2	**Bank Vegetation**									
	Bare Earth	5	93		97	98	92	93		
	Nascent Vegetation	4	7	2	1	2	8	5		
	Perennial Vegetation	3		1				2		
	Shrubs	2		10						
	Trees	1		40	2					
			4.9	0.7	4.9	4.9	4.6	4.7	4.8	3.4
1	**Riparian Vegetaton**									
	Bare Earth	5	78	15	66	94	89	80		
	Nascent Vegetation	4	2	1	3	1	10	15		
	Perennial Vegetation	3	10	70	15			5		
	Shrubs	2	5	10	1		1			
	Trees	1	5	40	15	5				
			4.4	3.5	3.9	4.8	4.5	4.2	4.3	4.1
3	**Active Bank Erosion**									
	Low: 0 - 25%	1	100	85	100	100	50	80		
	Moderate: 25 - 50%	2								
	High: 50 - 75%	3		15			25			
	Severe: 75 - 100%	4					25	20		
			1	1.3	1	1	2.25	1.6	1.4	1.3
	Composite Bank Stability Score		3.0	1.9	2.8	3.0	3.9	3.6	3.2	2.8

Bed Stability

		Hall-1	Hall-2	Hall-3	
Recent/active incision?	(Yes / No)	No	No	No	**No. Sub-Reachse w/ Incision:** 0
Severity of incision	> 1 ft (1)				
	1 - 2 ft (2)				
	2 - 3 ft (3)				
	> 3 ft (4)				
		0	0	0	**Average Incision Severity:** 0
Bed Material Composition					
Cohesive	5	0	0	0	
Sand	4	5	10	5	
Gravel	3	45	10	15	
Cbl/Bldr	2	50	80	80	
Bedrock	1	0	0	0	
		2.6	2.3	2.3	**Average Bed Material Size:** 2.4

Composite Stream Stability Score

3.6

Stream Restoration Treatment Inventory

Bank Treatments	Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank
Type						
Length (ft)						
Quality: (Good: 4, Mod: 3, Poor: 2, Fail: 1)						
Type						
Length						
Quality: (Good: 4, Mod: 3, Poor: 2, Fail: 1)						

Bank Treatment Summary

Left Bank	Right Bank	
0	0	**Overall Length**
		Weighted Score

Channel Treatments / Structures			
Type			
Number			
Quality: (Good: 4, Mod: 3, Poor: 2, Fail: 1)			
Type			
Number			
Quality: (Good: 4, Mod: 3, Poor: 2, Fail: 1)			

Channel Treatment Summary

0	**Overall No. Structures**
	Weighted Score

Notes on Type Codes (Create your own as needed)

Instructions: Enter percent length values into each white box for each sub-reach. The colored boxes will automatically calculated weighted averages within each category as well as the composite bank stability score. Category weights may also be adjusted as the user deems appropriate.

Bank Stability

Weights		SCORE	REACH ID WM - 1 Left Bank	REACH ID WM - 1 Right Bank	REACH ID WM - 2 Left Bank	REACH ID WM - 2 Right Bank	Average Scores Left Bank	Average Scores Right Bank
			Percent of Length		*Percent of Length*			
1	**Bank Composition**							
	Cohesive (Silt/Clay)	4				5		
	Sand	3	100	10	40	5		
	Gravel/Cobble	2			50	80		
	Boulder/Bedrock	1		90	10	10		
			3.0	1.2	2.3	2.1	2.7	1.6
1	**Bank Angle - Degrees**							
	Mild - 0-30	1		90	90			
	Moderate - 30-60	2		10	10	80		
	Steep - 60-90	3	100			20		
	Overhang - > 90	4						
			3.0	1.1	1.1	2.2	2.1	1.7
2	**Bank Vegetation**							
	Bare Earth	5	90	80	90	89		
	Nascent Vegetation	4	10	20	10	10		
	Perennial Vegetation	3				1		
	Shrubs	2						
	Trees	1						
			4.9	4.8	4.5	4.5	4.7	4.6
1	**Riparian Vegetaton**							
	Bare Earth	5	15	85	20			
	Nascent Vegetation	4		15	5	40		
	Perennial Vegetation	3	80		20	60		
	Shrubs	2			5			
	Trees	1	5		100			
			3.2	4.9	2.7	1.8	3.0	3.3
3	**Active Bank Erosion**							
	Low: 0 - 25%	1		90	100	85		
	Moderate: 25 - 50%	2		10				
	High: 50 - 75%	3	10			15		
	Severe: 75 - 100%	4	90					
			3.9	1.1	1	1.3	2.5	1.2
	Composite Bank Stability Score		4.4	2.9	2.6	2.7	3.5	2.8

Bed Stability

			WM - 1	WM - 2	Average
Recent/active incision?	(Yes / No)		No	No	0
Severity of incision	> 1 ft (1)				
	1 - 2 ft (2)				
	2 - 3 ft (3)				
	> 3 ft (4)				
			0	0	0
Bed Material Composition					
Cohesive		5	0	0	
Sand		4	10	5	
Gravel		3	10	15	
Cbl/Bldr		2	80	80	
Bedrock		1	0	0	**Average Bed Material Size**
			2.3	2.3	2.3

Composite Stream Stability Score

3.5

Stream Restoration Treatment Inventory

Bank Treatments	Left Bank	Right Bank	Left Bank	Right Bank
Type				
Length (ft)				
Quality: (Good: 4, Mod: 3, Poor: 2, Fail: 1)				
Type				
Length				
Quality: (Good: 4, Mod: 3, Poor: 2, Fail: 1)				

Bank Treatment Summary

Left Bank	Right Bank	
0	0	**Overall Length**
		Weighted Score

Channel Treatments / Structures		
Type		
Number		
Quality: (Good: 4, Mod: 3, Poor: 2, Fail: 1)		
Type		
Number		
Quality: (Good: 4, Mod: 3, Poor: 2, Fail: 1)		

Channel Treatment Summary

0	**Overall No. Structures**
	Weighted Score

Notes on Type Codes (Create your own as needed)

Appendix C. Field Photographs

Western Mobile Reach 1. Clockwise from top left: upstream, downstream, left bank, right bank.

Western Mobile Reach 2. Clockwise from top left: upstream, downstream, left bank, right bank.