Final Report

Coal Creek Confluence Reach Assessment

Gunnison County, Colorado

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

November 18, 2012

AlpineEco

EcoMetrics
Stream & Riparian Monitoring, Assessment & Restoration

Table of Contents

List of Figures

List of Tables

List of Appendices

1.0 Introduction

The study area for this project includes the reach of Coal Creek just downstream from the Town of Crested Butte from it's confluence with the Slate River, upstream to the western extent of the Crested Butte Land Trust (CBLT) property (**Figure 1**). This reach is also referred to as "Segment 1" or the "Confluence Parcel."

1.1 Purpose of this Study

Aquatic and riparian resources on the Confluence Reach of Coal Creek are highly valued by both Crested Butte Land Trust (CBLT) and the Coal Creek Watershed Coalition (CCWC), making this property a high priority for preservation. There is a perception that the reach is in poor health and in need of treatment to restore proper natural ecological functioning. In a recent watershed-wide reconnaissance Alexander and Brown (2009) identified the reach as impaired, and in need of stream and riparian restoration. This study is aimed to follow up on that recommendation by further evaluating the need for restoration by identifying specific problems and assessing the degree of impairment. This level of detailed diagnosis is necessary to ensure that any planned restoration treatments are appropriately designed to address documented problems and to make an informed decision about the need for action based on the potential improvement that could be achieved.

1.2 Assessment Strategy

Alexander and Brown (2009) suggest that the reach is unstable due to riparian vegetation impacts. Specifically, they report, "In this segment the riparian vegetation, primary willows, is removed and major erosion is occurring due to overgrazing of the riparian zone by cattle... This is causing Coal Creek to widen, braid and increasing (sic.) the sediment load entering the stream which is covering stream bed habitat." Our strategy for assessing the reach is therefore aimed at evaluating the degree of reported stream instability and increased sediment load. Riparian vegetation condition is undeniably a critical component to stream stability and habitat condition on streams of this type, and since they suggest that degraded vegetation is the root cause of the perceived problems, our methods also include a quantitative assessment of the condition of riparian vegetation on the reach.

Our study utilizes the US Environmental Protection Agency (EPA) Watershed Assessment of River Stability and Sediment Supply (WARSSS) protocol for predicting stream stability and sediment load (Rosgen 2006). According to this method, the stability of a stream is a major determinant of its condition and a prerequisite for optimal functioning. "Stream stability is morphologically defined as the ability of the stream to maintain, over time, its dimension, pattern, and profile in such a manner that it is neither aggrading nor degrading and is able to transport without adverse consequence the flows and detritus of its watershed" (Rosgen 1996).

The first two phases of WARSSS, namely the Reconnaissance Level Assessment (RLA) and Rapid Resource Inventory of Sediment and Stability Consequences (RRISSC) were completed to provide site context and potential and to specifically identify anthropogenic stressors and land use impacts that affect stability, including riparian degradation as well as any other impacts that had not yet been recognized.

The bulk of the work in this study is an application of the Prediction Level Assessment (PLA) of WARSSS including a quantitative assessment of riparian condition. PLA is essentially a set of diagnostic tools (some quantitative and some qualitative) that aid the evaluator in making informed predictions about the stability and sediment supply from the reach based on field data from detailed hydrologic, geomorphic, and riparian surveys. These surveys were set up and monumented on site so that they can be repeated as part of an ongoing monitoring strategy that can be used to validate or refute the predictions.

Thus, if decision-makers are satisfied with the level of certainty in these predictions, then specific restoration treatments can be made immediately to address identified problems and monitoring can be directed at evaluating restoration or stabilization success. In general, though, riparian and stream restoration treatments tend to be both expensive and risky in nature so it is important to be quite certain about the need to take on these activities before designing specific treatments and implementing them. Our assessment strategy therefore includes specific monitoring activities that will significantly reduce uncertainty about any of the predictions made in this report if the methods are followed for a period of several seasons to actually observe trends of channel and riparian vegetation response.

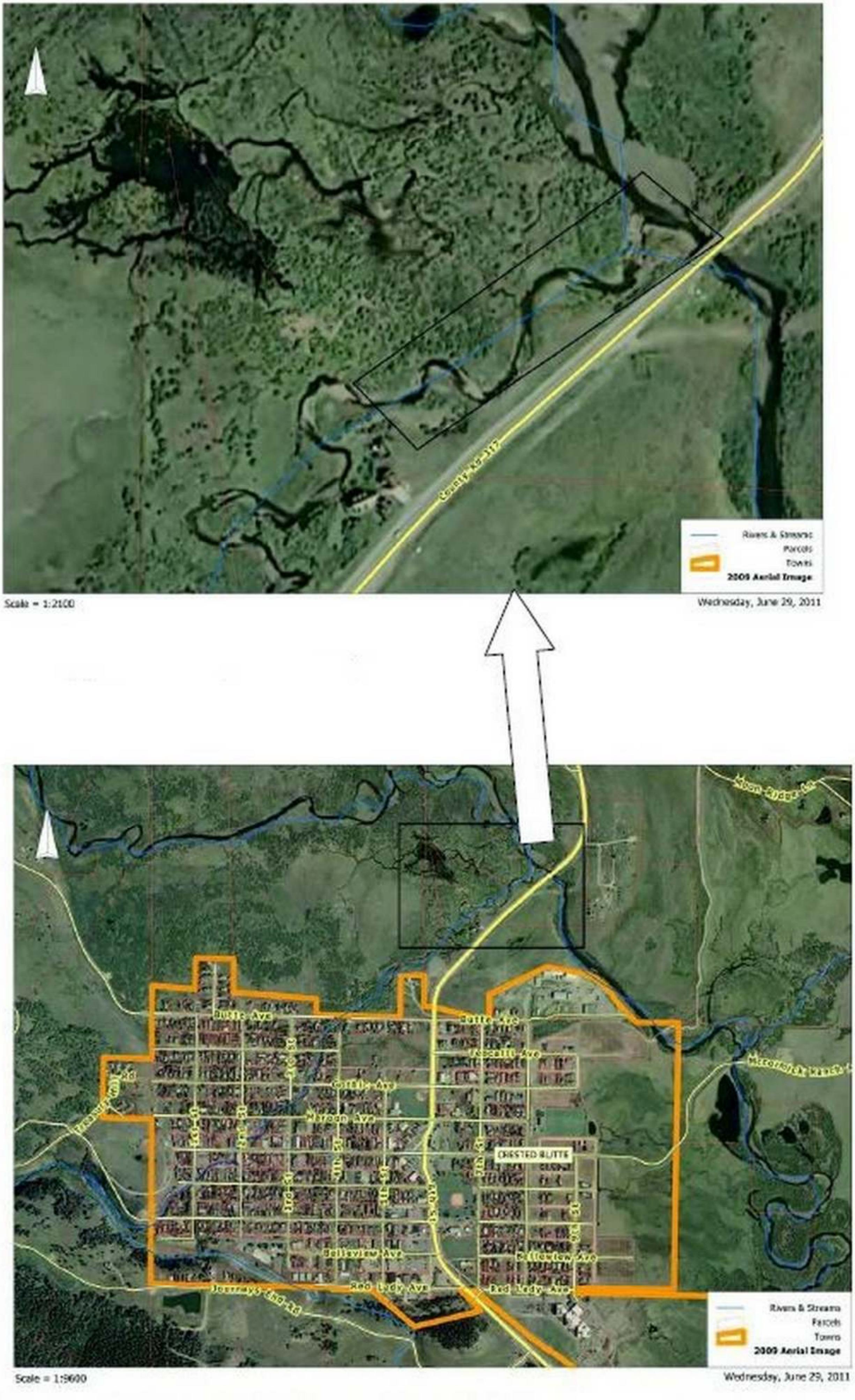


Figure 1 - Crested Butte area with site shown in black box. Source: CCWC

2.0 Methods

This study is an application of all four phases of WARSSS including a broad watershed-wide reconnaissance using (RLA phase), rapid qualitative assessment of the reach based on indicators of instability and human impacts (RRISSC phase), and a detailed quantitative assessment based on parameters measured in the field (PLA phase). The fourth phase (monitoring) was also begun, and the field data we collected may also serve as the beginning of time-trend monitoring of the reach. A detailed description of the WARSSS process and specific methodology for each of the phases are described in Rosgen (2006). The steps outlined below describe how the phases of WARSSS were used to provide the data needed to make predictive assessments of the stability and riparian condition of the Confluence Reach of Coal Creek.

Fieldwork for this project was performed in August 2012 by Mark Beardsley and Jessica Doran of EcoMetrics and Andy Herb of AlpineEco.

2.1 Watershed Overview

The watershed-wide reconnaissance level assessment (RLA) is the broadest level of assessment in WARSSS. Our assessment at this level began by reviewing a recent watershed-wide assessment of riparian and aquatic habitat condition provided by Alexander and Brown (2009). Using this report as a guide, we then made a broad remote reconnaissance using Google Earth and Bing aerial imagery to identify the character of the upper Coal Creek watershed and to identify significant land use patterns that could affect sediment supply or stream stability on the Confluence Reach of Coal Creek. Significant findings were field-checked during a site visit in August 2012.

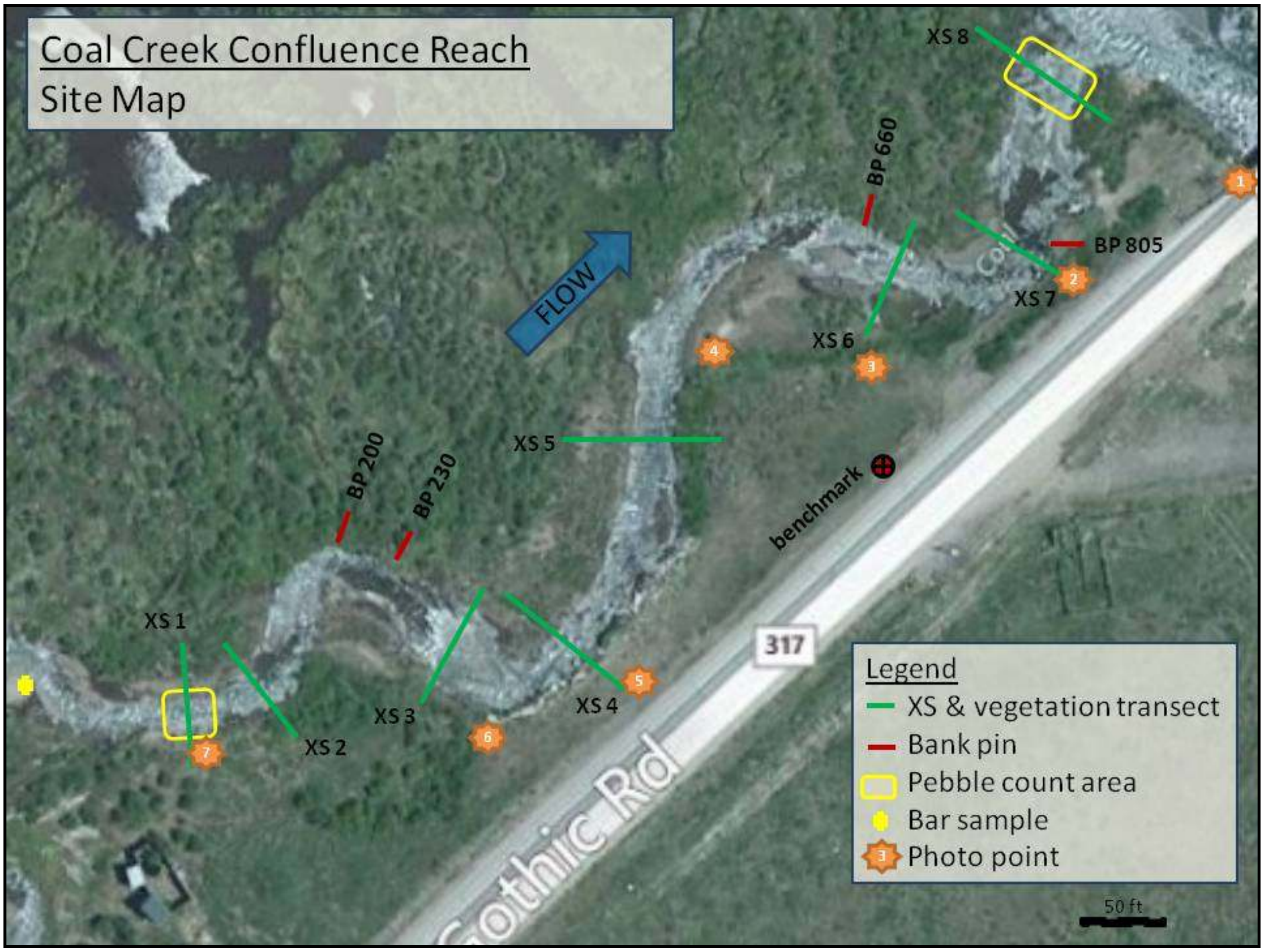
2.2 Rapid Qualitative Assessment

Worksheets for each of the RRISSC variables were completed based on rapidly observable indicators during a field visit to the site in August.

2.3 Physical Surveys

Field data were collected in August 2012. **Figure 2** shows the location of surveys and data collection points.

Figure 2: Coal Creek Confluence Reach



2.3.1 Channel Dimension

Eight 100-foot (ft) long physical cross-section (XS) surveys were made, and the end points were monumented so that they can be repeated in the future. Five XS are on riffles, and three are on bends where lateral scour pools would be expected. XS were surveyed by setting up tapes from the left bank end pin (0 ft) to the right bank end pin (100 ft) to record station. Elevation was measured with a survey rod and laser level. Points were measured at a frequency to capture all significant grade breaks that define the shape of the channel, banks, and floodplain. All surveys were tied to a capped pin benchmark which was assigned a relative elevation of 100 ft. A photo was taken of each XS from upstream.

2.3.2 Channel Profile

A longitudinal profile survey was completed over the entire length of the reach. Stationing was measured as distance along the right bank of the channel using a measuring wheel. The survey captured elevations for streambed on the thalweg, water surface, bankfull indicators, and left and right bank using a laser level and rod.

2.3.3 Channel Pattern

Basic plan form measurements of sinuosity, meander lengths, belt width, amplitude, and the radius of curvature of meander bends were made using the most recent aerial imagery available on Google Earth (from 2012).

2.3.4 Channel Materials

Pebble counts were made to quantify the size distribution of channel materials on the riffles at XS 1 and XS 8 by sampling regular intervals across the complete bankfull width of the streambed and banks on as many complete transects as it took to obtain a statistically valid sample size.

2.3.5 Point Bar Sample

A volumetric sample of point bar material was taken from the downstream third of the uppermost point bar on the reach at an elevation half the distance between the thalweg and bankfull. The sample included all of the material excavated from a 1-ft diameter plot to a depth 0.6 feet (twice the length of the intermediate axis of the largest particle observed on the surface). The sample was divided into fractions by size class using sieves with pore sizes of 2, 4, 8, 16, 32, and 64 millimeter (mm), and the size distribution was calculated as the weight of each fraction.

2.3.6 Vegetation

Classification and XS Survey: Vegetation in the study area was classified into six plant associations, including two that are willow-dominated. Associations were considered willow-dominated (*Salix* spp.) if the cover of willows was 30 percent or greater. Associations identified usually include small areas of other associations, but if those areas were less than approximately 200 square feet, they were included with the dominant association. All plant nomenclature follows the National Wetland Plant List (NWPL) (Lichvar and Kartesz 2009). If a species is not listed in the NWPL, the nomenclature from the PLANTS Database (NRCS 2012) is used. A complete list of plant species observed is included in **Appendix 2**.

Cross-section surveys were done along each of the eight 100-ft long XS used for the stream assessment. Data collected at these cross-sections were collected using the line-intercept method (BLM 1999) which included recording both the plant associations present, as well as willow canopy cover. When recording canopy cover, gaps in a canopy smaller than 0.5 foot were ignored. If gaps greater than 0.5 foot were present, the canopy was split into separate canopies. Height class was also recorded for all willows, using the following four classes (a through d):

- Class a: 0 to 1 foot
- Class b: 1 to 3 feet
- Class c: 3 to 5 feet
- Class d: 5 feet or taller

All transect data were recorded in increments no smaller than 0.5 foot. All cross-sections were set so that the surveys sampled only riparian areas, excluding upland areas as much as possible.

Green Line Survey: In addition to classifying the vegetation in the study area, greenline and cross-section surveys were conducted. Greenline surveys were made along both banks between XS-1 and XS-8 using protocol described in Winward (2000). This entailed recording the distance of each plant association present along the water's edge throughout the reach, including rocks or logs if they were large enough to preclude the presence of bank-side vegetation. Distance was recorded using steps and not actually measured.

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).

2.5 Bankfull Discharge Estimation

No historic flow records or regional curve data are published for this watershed, so bankfull discharge estimation was made using identification of field indicators for bankfull elevation and calculation of discharge from hydraulic relationships based on XS area and velocity on the uppermost straight, stable cross section (XS-1). Several methods were used to calculate velocity from channel roughness and slope including friction factor equations, the Darcy-Weisbach equation, and several different equations for calculating Manning's N. The most appropriate of these results were used to estimate bankfull discharge on the reach.

2.6 Identification of Reference Condition

Since there are no off-site documented stable reference reaches to serve an appropriate analog for this reach, a best estimate for the potential stable reference channel condition was made by documenting indicators of stability on presumably unimpacted segments within the study reach.

2.7 Identification of Stability Indices

The following indicators of stream stability were observed and classified for individual segments along the reach according to PLA guidelines:

- Stream size and Strahler stream order
- Flow regime
- Riparian vegetation condition
- Meander patterns
- Deposition patterns
- Channel blockage
- Width/depth ratio condition
- Pfankuch channel stability assessment
- Degree of channel incision
- Degree of lateral confinement

2.8 Prediction of Bank Erosion Volume

Bank Erosion Hazard Index (BEHI) and Near-Bank Stress (NBS) values were calculated for each potentially erodible bank segment on the reach while in the field, and each segment was identified numerically. For each bank segment scored, the mean bank height and bank segment length was recorded, and the segment was identified on a site map.

Total bank erosion was calculated using the empirical model described in Rosgen (2006) for Colorado streams to predict annual bank lateral accretion from observed BEHI and NBS values. Sediment volume was calculated for each segment from lateral accretion rate, mean bank height, and segment length. Sediment volume is converted to mass using a standard conversion rate of 1.3 tons per cubic yard (cy).

2.9 Sediment Competence

WARSSS PLA procedures describe two methods for evaluating bed stability from sediment competence using dimensionless and dimensional shear stress calculations. We evaluated sediment competence following these protocols on all five riffle XS on the study reach. For these equations, the PLA procedure recommends using a volumetric point bar sample as a surrogate for actual bedload at bankfull, which is helpful since no actual bankfull sediment sampling is available for the reach. Calculations for critical dimensionless shear stress and the determination of width-depth ratio (W/D) required to entrain the largest particles observed in the bar sample follow the protocol in Rosgen (2006) and empirical data from Colorado streams published therein, and a prediction of stability is made by comparing predicted stable W/D to actual W/D on each riffle XS. The determination of critical dimensional shear stress was also made using Rosgen's (2006) empirical relationship for Colorado streams. For this assessment, we can assess stability by comparing predicted stable shear stress to actual shear stress calculated on each riffle XS.

2.10 Stream Channel Succession

The successional status of channel type evolution was assessed across the reach and recorded by segment.

2.11 PLA Stability Predictions

The data from all of the above parameters were compiled using PLA worksheets to make a prediction of channel lateral stability, vertical stability, enlargement, and sediment supply. In this study, the reach was divided into individual segments to assess stability, and individual assessments were made to cover each of the following according to PLA. As part of this step and following the complete PLA predictions phase, we also repeated the rapid assessment protocols used by Alexander and Brown (2009) in their initial assessment of the reach, namely the *EPA Rapid Bioassessment Protocols* for physical habitat (RBP III) in Chapter 5 of (Barbour et. al. 1999) and the Bureau of Land Management (BLM) Assessment of *Proper Functioning Condition* (PFC) for lotic habitats as described in (Prichard et. al 1998). Both of these protocols rely on subjective interpretations of general questions so it is important to identify the individuals that make the evaluations. The RBP III physical habitat assessment was made by Mark Beardsley of EcoMetrics, and the team of evaluators for the PFC assessment included Mark Beardsley and Jessica Doran of EcoMetrics and Andy Herb of AlpineEco.

3.0 Results

3.1 Watershed Overview

The confluence reach of Coal Creek is at the terminus of the watershed where Coal Creek enters the Slate River. At this point, the creek runs northeast, perpendicular to the Slate River, across the broad Slate River floodplain. The confluence reach is the lower third of the length of Coal Creek that is in this alignment on the Slate River floodplain. Upstream from the Slate River floodplain, Coal Creek is contained within a narrow artificial channel that carries creek flows diagonally through the Town of Crested Butte from just above a bridge on Whiterock Avenue at the west end of town to just below a Bridge on Butte Avenue on the north side of town. Above Crested Butte, Coal Creek is confined within a tight, V-shaped valley (**Figure 3**).

Figure 3: Aerial View of the Coal Creek Watershed

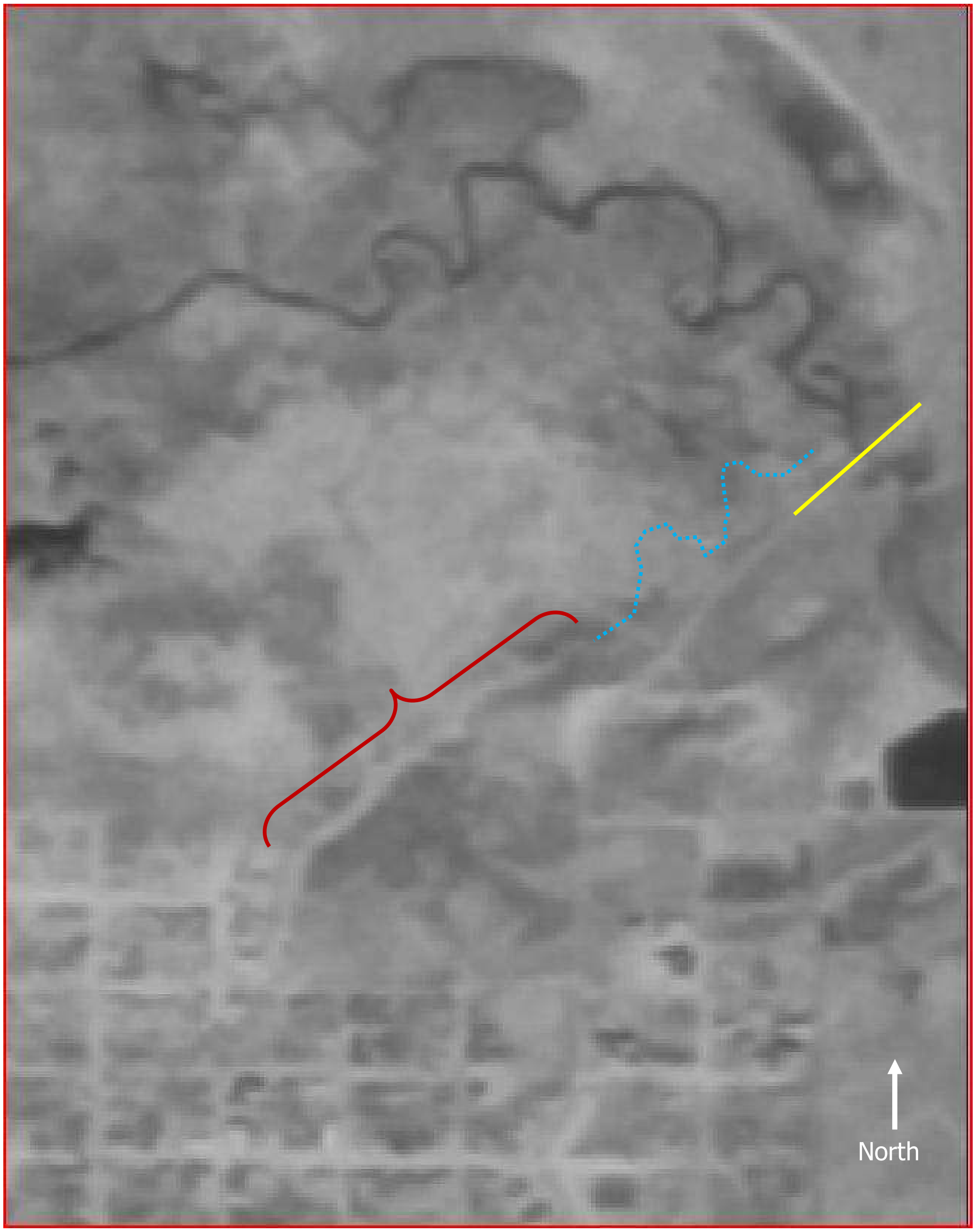
The approximate alignment of Coal Creek is outlined by the blue dashed line. The Confluence Reach is at the lowest end of Coal Creek, towards the foreground. The photo illustrates the overall pattern through the watershed with Coal Creek emerging from the mountains in a tight V-shaped valley to where it makes a sharp left turn into an artificial channel through Crested Butte and then ultimately across the broad Slate River floodplain to the confluence.

As the Creek comes out of the tight valley and into the artificial channel at Crested Butte, it makes a curious tight turn to the left (north). This unusual turn, and the length of artificial channel through town raise suspicion about whether the present alignment of the Coal Creek is natural. It seems possible, or even probable, that Coal Creek was historically realigned when the town was being developed, and that it used to flow more directly through the alluvial fan where the town now sits as a braided system to join the Slate River further downstream. Signs of a braided channel downstream of town, east of the school provide some evidence of this hypothesis (**Figure 4**), and further evidence of this exists in the relatively straight (channelized?) alignment of Coal Creek on historical aerials where it enters the Slate River floodplain below town (**Figure 5**). If it is the case that Coal Creek was realigned through town, then the confluence reach, where it is now, is relatively recent.

Figure 4: Current Aerial of Crested Butte Area

This current image of the Crested Butte area shows the Confluence Parcel in the yellow box and evidence of historic river features in the red box.

Figure 5: Historic Aerial Photo of the Confluence Reach



This cropped image from a 1978 historic aerial photo shows evidence that Coal Creek may have been artificially straightened and/or channelized at that time (identified by the red bracket). The approximate alignment of Coal Creek through the Confluence Reach is shown by the blue dashed line. The lower portion of this alignment may have been altered to accommodate the realignment of the Gothic Road and construction of the Gothic Bridge prior to 1978 (yellow line).

In any event, the oldest aerials available (from 1955) show Coal Creek in roughly its present alignment, and any major realignment would have had to have taken place at the time the town was founded, so the confluence reach has been evolving with its present floodplain for at least 120 years, if not for its entire geologic history. More recently, realignment of Gothic Road and construction of the Gothic Road Bridge sometime between 1955 and 1975 required a local shift in the alignments of both the Slate River and Coal Creek. Because of this, the lowest two meander bends on the confluence reach are part of a relatively new channel configuration about 35 to 50 years old. Road fill and streambank hardening associated with the Gothic Road affects about 20 percent of the reach, effectively truncating the floodplain area upon which the channel can meander and limiting the establishment appropriate riparian vegetation.

There are several other major human influences on Coal Creek in addition to past artificial channel realignments. Alexander and Brown (2009) provide an excellent overview of the watershed condition and impacts. Most important among the geomorphological impacts they describe in the upper Coal Creek Watershed are the artificially channelized condition of the river through Crested Butte, confinement from the construction of the adjacent railroad and Kebler Pass Road, mining impacts, and segments of significant riparian degradation. Direct impacts from Gothic Road and Gothic Road Bridge, including the abandoned bridge abutments just downstream of the current bridge, are also potentially significant (see the *Draft Upper Slate River Geomorphic Assessment Report* (AlpineEco and EcoMetrics 2012) for more information on the Gothic Road Bridge and its effects).

Alexander and Brown (2009) also describe alterations to hydrology including augmentation from a trans-basin diversion through Lake Irwin and depletions to feed the town water supply and for irrigation. The hydrologic effects of the impervious surface area of roads and urban development in Crested Butte are also noteworthy stressors. The magnitude of these changes is probably small compared to bankfull discharge, however. Furthermore, the timing of these impacts often do not coincide with snowmelt peak flows. While these hydrologic changes may be quite important ecological stressors during low flow, from a geomorphic perspective the degree of impact is quite low.

3.2 Rapid Qualitative Assessment

RRISSC assessment was made to identify potential sediment and stream instability concerns related to hillslope, hydrologic, and channel processes, and to obtain a rapid assessment of overall condition of the Confluence Reach. RRISSC variable ratings are designed to indicate the level of risk for inordinate sediment supply or stream instability using a scoring system of 1 (very low risk), 2(low), 3 (moderate), 4 (high), and 5 (very high). A summary of scores for the specific variables in each of these categories is provided as **Table 1** (RRISSC summary), and the results are summarized below.

Hillslope and hydrologic processes score low in RRISSC, and the overall rating of 4 (high) is a result of impacts that affect channel processes. Most important is the direct channel impact of the alignment of the Gothic Road adjacent to the channel. This impact alone is significant enough to drive both the direct channel impacts and degradation variables to the 5 (very high) risk category. Road fill impacts also play into an increased streambank erosion risk. The streambank erosion variable scores 3 (moderate), and the primary contributing factors are the presence of two very tight meander bends with high, poorly vegetated banks adjacent to road fill areas. Aggradation risk is 4 (high), largely due to an assumed over-wide channel condition on portions of the reach and the observation of obvious excess deposition and extensive mid-channel bar formation.

Table 1: Summary of RRISSC Scores Compiled Prior to the PLA Assessment

WARSSS RRISSC rating scores for the Confluence Reach of Coal Creek

Variable		**RRISSC rating**	
Hillslope Processes			
1	Mass erosion risk	**1**	very low
2	Sediment from roads	**1**	very low
3	Surface erosion	**1**	very low
Hydrologic Processes			
4	Streamflow change	**2**	low
Channel Processes			
5	Streambank erosion	**3**	moderate
6	In-channel mining	**1**	very low
7	Direct impacts	**5**	very high
8	Channel enlargement	**3**	moderate
9	Aggradation	**4**	high
10	Channel evolution	**1**	very low
11	Degradation	**5**	veryhigh
Overall Rating			
Overall RRISSC score		**4**	high

3.3 Physical Surveys

3.3.1 Channel Dimension

Plots of channel XS surveys, photos and critical bankfull channel dimension data are shown in **Appendix 1, Figures A1-A8**. **Table A1** is summary of critical channel dimension data for riffles. **Table A2** is a summary of critical channel dimension data for pools.

3.3.2 Channel Profile

Results of the longitudinal profile survey are displayed in **Appendix 1, Figure A9**. Channel slope, a measure of stream gradient, is 0.66 percent over the reach, meaning that water elevation at bankfull stage drops an average of 0.66 ft per 100 ft of stream length.

3.3.3 Channel Pattern

Sinuosity, the ratio of stream length to the distance directly down-valley, is 1.4. Data for meander length, belt width, amplitude, radius of curvature (R_c), and R_c /W are given in **Appendix 1, Table A3**.

3.3.4 Channel Materials

Pebble count surveys at XS-1 and XS-8 are plotted in **Appendix 1, Figures A10-A11**. It is noteworthy that the channel materials are much smaller on XS-8 than they are on XS-1. For instance, D_{50} (the median particle size making up the bed material) on XS-1 is 45 mm, and D_{50} on XS-8 is 14 mm. The distribution of materials on XS-1 appears to be consistent throughout most of the reach, except near the extreme lower end at XS-8 where Coal Creek enters the Slate River.

3.3.5 Point Bar Sample

Results from the point bar materials sample are plotted in **Appendix 1, Figure A12**. This survey is intended to serve as a surrogate for bedload sediment at bankfull. The largest particle sizes in the sample had intermediate axis length of 79mm, measured directly.

3.3.6 Vegetation

Classification and XS Survey: Vegetation in the study area was classified into six different plant associations (**Photos 17 through 21 in Appendix 4**):

- **Sedge**—dominated by various species of sedge (*Carex* spp.), namely leafy tussock sedge (*Carex aquatilis*) and Northwest Territory sedge (*Carex utriculata*). Other common plants observed in this community include tufted hairgrass (*Deschampsia caespitosa*), bluejoint (*Calamagrostis canadensis*), Arctic rush (*Juncus arcticus*), largeleaf avens (*Geum macrophyllum*), and daggerleaf rush (*Juncus ensifolius*). This association is mostly found in the wettest portions of the riparian corridor.

- **Willow/Sedge**—dominated by willow (*Salix* spp.) and sedges. The willows observed include Drummond's willow (*Salix drummondiana*), park willow (*S. monticola*), Idaho willow (*S. wolfii*), tealeaf willow (*S. planifolia*), and narrowleaf willow (*S. exigua*). The most common sedges observed are leafy tussock sedge and Northwest Territory sedge. Other common species present are those found in the sedge community. This association is found in very wet portions of the riparian corridor.

- **Willow/Other**—dominated by willow with a variable understory. The most common willows are Drummond's and park. The most common understory plants include black bent (*Agrostis gigantea*), tufted hairgrass, Arctic rush, and oxeye daisy (*Leucanthemum vulgare*), with red clover (*Trifolium pratense*) and alsike clover (*Trifolium hybridum*) common in some locations. This association is found in more mesic (neither wet nor dry) portions of the riparian community that were somewhat recently disturbed (old point bars or sediment deposits) and appears to be an evolution of the mixed graminoid associations.

- **Mixed Graminoid**—dominated by various grasses and grass-likes, with some forbs present. The most common plants in this community are black bent and leafy tussock sedge. Oxeye daisy, field horsetail (*Equisetum arvense*), and alsike clover are common in some locations. This associations is found in recently disturbed areas, namely on point bars and other sediment deposits along the channel edge.

- **Cinquefoil**—dominated by golden hardhack (aka cinquefoil) (*Dasiphora fruticosa*) with a diverse understory of forbs and graminoids. The most common understory plants include Arctic rush, common yarrow, and oxeye daisy. Others present in most areas are Virginia strawberry (*Fragaria virginiana*), Parry's oatgrass (*Danthonia parryi*), clustered field sedge (*Carex praegracilis*), pincushion beardtounge (*Penstemon procerus*), and various herbaceous cinquefoils (*Potentilla* spp.). This association is found in the drier portions of the riparian corridor.

- **Upland**—somewhat sparsely vegetated and dominated by mostly slender wildrye (*Elymus trachycaulus*) and common dandelion (*Taraxacum officinale*), with coaltown sagebrush (*Artemisia cana*), hairy false golden aster (*Heterotheca vilosa*), and showy goldeneye (*Heliomeris multiflora*). This association is found in the driest portions of the study area—generally outside the riparian corridor.

A summary of the associations observed on the eight XS is provided in **Table 2**. Data sheets for the eight XS surveys are in **Appendix 2** along with a complete list of plant species observed in the study area. Photographs of the XS are in **Appendix 3 (Photos 1 through 16)**.

Table 2: Results of Vegetation XS Survey

Cross-Section	Plant Associations on Transects (percent of transect)					
	Sedge	Willow/Sedge	Willow/Other	Mixed Graminoid	Cinquefoil	Upland
XS-1	0	37	10	12	17	0
XS-2	11	2	35	4.5	18	0
XS-3	0	15	12	12	12	0
XS-4	0	0	51	0	20	7
XS-5	0	16	18	4.5	36	0
XS-6	0	38	37	0	0	0
XS-7	0	18	13	16	0	10.5
XS-8	0	17	38	0	0	0
Average for all Transects	**1.4**	**17.9**	**26.8**	**6.1**	**12.9**	**2.2**

The most common association observed along the transects was willow/other, occurring on 26.8 percent of the transects. The least common associations recorded were sedge (1.4 percent) and upland (2.2 percent). The lack of the sedge association is mainly because none of the transects were placed within the large sedge area near the middle of the reach between XS-5 and XS-6 (see **Figure 2**). This area was captured by the greenline surveys (see below). The lack of the upland plant association on the transects was intentional since the survey was designed to record riparian communities only.

In addition to recording the plant associations, willow cover was also recorded on each of the eight XS. Willows were recorded by height class as discussed earlier in the

Methods section. Table 3 provides a summary of the willow canopy cover recorded on each transect. See the data sheets in **Appendix 2** for more information.

Table 3: Results of Willow Cover XS Survey

Cross-Section	Height Classes Recorded on Transects (percent of transect)				
	0 to 1 foot	1 to 3 feet	3 to 5 feet	5+ feet	Total Cover (%)
XS-1	0	4	21	2	27
XS-2	0	13	5	2	20
XS-3	0	5	4	5	14
XS-4	0	18	0	0	18
XS-5	0	7	6.5	16	29.5
XS-6	0	30	7	0	37
XS-7	0	7	0	10	17
XS-8	0	12	33.5	0	45.5
Average for all Transects	**0.0**	**12.0**	**9.6**	**4.4**	**26.0**

The most common willow height classes recorded on the transects is 1 to 3 feet (almost half of all willow cover was in this class) and 3 to 5 feet (nearly a third of all willow cover). This is likely a result of the removal of grazing by CBLT and US Fish and Wildlife Service in 2010 (CBLT 2012). According to Alexander and Brown (2009), riparian vegetation, primarily willows, was removed from the site by grazing activity. If the willows were heavily browsed until a fencing exclosure was installed in summer 2010, but left with roots intact, the lack of cattle on the site for the last two growing seasons would have allowed the willows to rebound. Growth of 1 to 3 feet in that time span would be reasonable.

No willows were recorded in the 0 to 1 foot height class. It may appear that the lack of willows 0 to 1 foot tall indicates that there is no willow regeneration taking place, but I believe this is a result of the site being overall well-vegetated with no substantial areas of new disturbance that would allow for new willows to become established. Some willow seedlings in the 0 to 1 foot height class were observed on sediment deposits in and along the channel, but these were not captured on the XS surveys.

Greenline Survey: The results of the greenline survey are presented in **Table 4**. The results show that the sedge association is the most common bankside vegetation in the study area (43.2 percent on the left bank and 27.8 percent on the right bank). Given that this association is typical of very wet sites, it follows that it is found along the channel where overbank flooding, beaver activity, and capillary action keep it wet throughout most of the growing season.

The willow/other and mixed graminoid associations are relatively common along both banks. These are associations that are found in more recently disturbed areas along the channel, mainly on sediment deposits. The mixed graminoid association dominates the most recent vegetated deposits and appears to convert to willow/other over time.

Table 4: Greenline Vegetation Survey Results

Bank	Plant Associations and Other Cover Types								
	Sedge	Willow/Sedge	Willow/Other	Mixed Graminoid	Cinquefoil	Upland	Log	Rock	Total
Right Bank									
Steps	108	43	83	32	46	0	8	68	**388**
% of Greenline	27.8	11.1	21.4	8.2	11.9	0	2.1	17.5	**100**
Left Bank									
Steps	165	59	39	89	30	0	0	0	**382**
% of Greenline	43.2	15.4	10.2	23.3	7.9	0	0	0	**100**

Summary: Generally, the vegetation in the riparian community along this reach of Coal Creek is in good condition. It is diverse and there are no signs of stressors such as insect infestations, disease, or modified hydrologic conditions. There is ample beaver activity, which is especially important for wetting the floodplain, dispersing willows, and generally creating a more heterogeneous environment. Most of the recent sediment deposits in and along the channel are revegetating with perennial species (mainly the mixed graminoid association) and similar areas that are several years older have been colonized by willows, comprising the willow/other association.

Grazing was discussed as a major impact in the 2009 assessment of this reach (Alexander and Brown 2009), but little evidence of severe grazing impacts were observed during our field surveys. It is likely that the 2009 assessment was done immediately after (or during) an intense grazing episode and that the cattle had trampled and browsed much of the vegetation along the channel. However, based on the presence of healthy plant associations in the study area in 2012, it is likely that the vegetative structure of willows and other key plants (mainly roots) was left intact and once grazing was removed the site was able to recover. This is consistent with the dominance of willows in the 1 to 3 feet height class.

Some small portions of the study area have seen some recent changes, including several large sediment deposits and two cut-banks along the toe of the Gothic Road embankment that have been revetted with rocks and logs, and planted with willows. These areas have clearly been recently eroded and generally lack appropriate riparian vegetation. Most of the willow plantings were not successful or were lost to erosion or beavers after planting, and the establishment of riparian vegetation may be physically precluded from these areas due to the height of the banks above the stream.

3.4 Stream Classification

Coal Creek emerges from a narrow, V-shaped valley (Type I) to where it comes into the Town of Crested Butte. The reach through Crested Butte is highly modified, but prior to disturbance, the Creek was probably a braided system flowing across a large alluvial fan landform (Valley Type III). From there it flows laterally across the wide alluvial valley of the Slate River (Valley Type VII), which is the valley setting for the Confluence Reach. The Confluence Reach classifies as a C4 stream type. Classification data for the reach are summarized in **Table 5**.

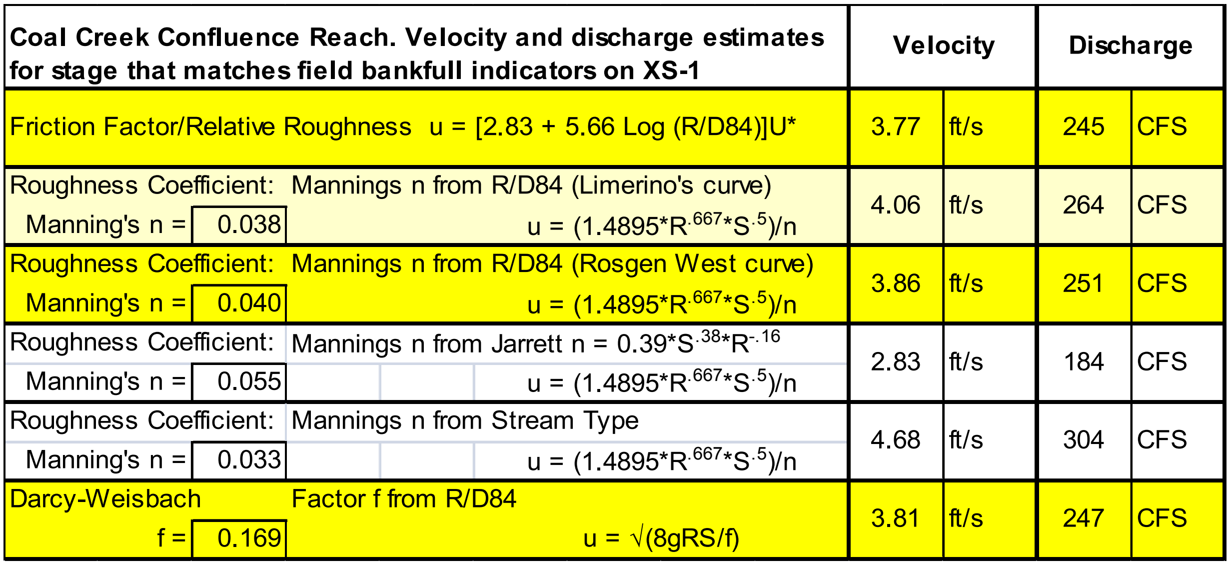
Table 5: Stream Classification Data

Valley Type	Valley	VIII
Bankfull Width	W	30-65 ft
Mean Depth	d	1.2-1.9 ft
Bankfull XS Area	A	57-78 ft^2
Width/Depth Ratio	W/d	16-54
Max depth	d_{max}	2.1-3.5 ft
Width Floodprone	W_{fpa}	>>100 ft
Entrenchment Ratio	ER	>2.2
Channel Materials	D_{50}	14-45 mm
Water Surface Slope	S	0.66%
Sinuosity	K	1.4
Stream Type		C4

3.5 Bankfull Discharge Estimation

Bankfull discharge is estimated to be approximately 250 cubic feet per second (CFS). This value was obtained by calculating velocity on XS-1 using a variety of hydraulic equations that relate hydraulic radius, bankfull slope, roughness, and cross-sectional area of the channel. This is possible because very clear field-identifiable indicators of bankfull stage are present along the reach. Results are summarized in **Table 6**.

Table 6: Results for Calculation of Bankfull Discharge on XS-1



Coal Creek Confluence Reach. Velocity and discharge estimates for stage that matches field bankfull indicators on XS-1	Velocity		Discharge	
Friction Factor/Relative Roughness u = [2.83 + 5.66 Log (R/D84)]U*	3.77	ft/s	245	CFS
Roughness Coefficient: Mannings n from R/D84 (Limerino's curve) Manning's n = 0.038 u = $(1.4895*R^{.667}*S^{.5})/n$	4.06	ft/s	264	CFS
Roughness Coefficient: Mannings n from R/D84 (Rosgen West curve) Manning's n = 0.040 u = $(1.4895*R^{.667}*S^{.5})/n$	3.86	ft/s	251	CFS
Roughness Coefficient: Mannings n from Jarrett n = $0.39*S^{.38}*R^{-.16}$ Manning's n = 0.055 u = $(1.4895*R^{.667}*S^{.5})/n$	2.83	ft/s	184	CFS
Roughness Coefficient: Mannings n from Stream Type Manning's n = 0.033 u = $(1.4895*R^{.667}*S^{.5})/n$	4.68	ft/s	304	CFS
Darcy-Weisbach Factor f from R/D84 f = 0.169 u = √(8gRS/f)	3.81	ft/s	247	CFS

Rows highlighted in bright yellow indicate methods that provided similar estimates of bankfull discharge. The row highlighted in light yellow differs only slightly.

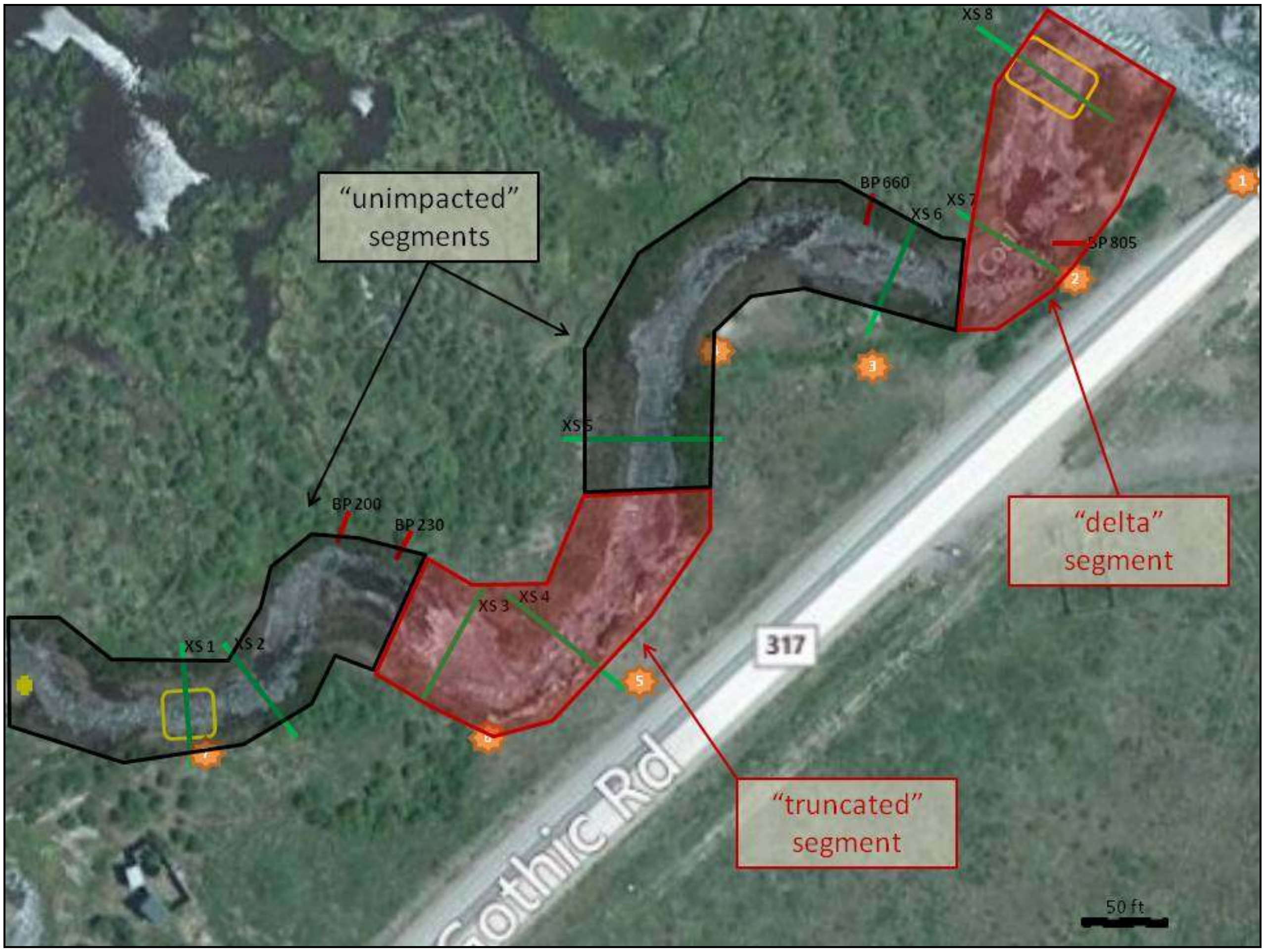
Results from the three most reliable equations for this stream type are in excellent agreement (Friction factor, Manning's N derived from R/D_{84} using "Rosgen's West" curve, and the Darcy Weisbach method). The method that derives Manning's N from "Limerino's " curve also produces an estimated bankfull discharge rate that is very close to these (264 CFS versus about 250 CFS). The Jarrett method is not a good estimate of velocity for low-gradient streams, and the derivation of Manning's N directly from stream type is also often very unreliable, so it is justified to eliminate results from these equations from consideration for the estimate of bankfull velocity and discharge on this reach.

3.6 Identification of Reference Condition

We know of no other reaches similar to the Confluence Reach on Coal Creek or elsewhere in the watershed that have been monitored to document stability and that could serve as a suitable reference analog. In fact, few other reaches of Coal Creek even exist that are similar to the Confluence Reach in terms of valley and stream type. The only other portion of Coal Creek with similar geologic context is the section just upstream from the Confluence Reach, downstream from Crested Butte. Looking at time series of this reach and comparing it to the Confluence Reach, there is no indication that this reach is any more stable than the Confluence Reach. In fact it appears that the upstream reach has been subject to even more direct channel impact and channel adjustment. Aerials as recent as the 1980s show fairly clearly that Coal Creek was channelized and subject to vegetation impacts for some distance downstream from Crested Butte (see **Figure 4**).

Since there are no other analogous systems that have well-documented stability to serve as a reference, the best indication of potential stable reference condition is made by inferences about stream stability on-site. There is no evidence to suggest that the C4 stream type seen on the reach is not a stable form, and that any instability seen here in the form of excess deposition, rapid lateral accretion, or incision is due to localized direct channel impacts related to the Gothic Road and Bridge. For this reason, we defined three separate assessment areas within the reach as shown in **Figure 6**.

Figure 6: Segments of the Confluence Reach



The segment from about station 230 to 480 we named the "truncated segment" since its meander pattern is abruptly truncated by fill at the Gothic Road. The "delta segment" runs from about station 700 to the bottom of the reach at the Slate River near station 945. This segment shows signs that it is probably a backwater when the Slate River becomes impounded during high flows behind the Gothic Road Bridge. The delta segment is also truncated by road fill, and it actually appears this whole segment was relocated to its present position when the Gothic Road was realigned in the 1960s or 70s.

Finally, the "unimpacted segments" run from the top of the reach down to about station 230 and from about station 480 to 700. These are stream segments that are not directly impacted by the road or the bridge, and they may serve as a reference of the potentially stable condition. An analysis of the data and stability assessments throughout the rest of the report provide a compelling case that the "unimpacted segments" on this reach are a good reference for stable channel morphology. Based on this assumption, a set of reference data for stable channel morphology was derived from these segments and summarized in **Table 7**.

Table 7: Reference Data for Stable Channel Morphology

Coal Creek, Confluence Reach **Potential Stable Channel Reference Data**		
Stream Type		C4
Bankfull Width	W	30-42 ft
Mean Depth	d	1.5-1.9 ft
Bankfull XS Area	A	57-64 ft^2
Width/Depth Ratio	W/d	16-28
Max depth	d_{max}	2.8-3.5 ft
Width Floodprone	W_{fpa}	>>100 ft
Entrenchment Ratio	ER	>2.2
Channel Materials	D_{50}	45 mm
Water Surface Slope	S	0.66%
Sinuosity	K	1.4

All data derived from the unimpacted segments on the Confluence Reach.

3.7 Identification of Stream Stability Indices

Coal Creek on this reach is a 3rd order stream with bankfull width ranging from 30 to 65 feet. Results for the rest of the PLA stability indices are summarized in **Table 8**.

Table 8: Results for the Stream Stability Indicators of the PLA Analysis

Stability indicator	unimpacted segments	truncated segment	delta segment
Riparian vegetation	High stability vegetation (dense shrub/grass mix with carex) on 90% of segment, with one patch of weak grass/forb mix on the right bank at XS-1 on a high relic gravel bar.	Same high stability vegetation on the left side of the segment. The right bank is adjacent to upland or road fill that supports only the weakest grass/forb mix.	Same high stability vegetation on the left side of the segment. The right bank is adjacent to upland or road fill that supports only the weakest grass/forb mix.
Meander patterns	M3 - Irregular meanders	M4 - Truncated meanders	M4 - Truncated meanders
Deposition patterns	B2 - Point bars with few mid-channel bars	B3 - Numerous mid-channel bars B5 - Diagonal bars	B3 - Numerous mid-channel bars B4 - Side bars B5 - Diagonal bars
Debris/ blockage	D2 - LWD and other natural debris is small and infrequent, D8 - Frequent beaver dams	D2, D8 - Same as unimpacted segment, D10 - Human impacts, road fill and hardened bank	D2, D8 - Same as unimpacted segment, D10 - Human impacts, road fill and hardened bank, Gothic Road Bridge
W/D ratio state	High/increasing stability W/D : W/D_{REF} $\leq$ 1.0 and not incised	Unstable W/D : W/D_{REF} = 1.9	Unstable W/D : W/D_{REF} = 1.5
Pfankuch	71 - Good = Very stable for C4	80 - Good = stable for C4	102 - Fair = moderately unstable for C4
Degree of incision	Stable BHR = 1.0 - 1.1	Stable BHR = 1.1	Moderately incised BHR = 1.4
Degree of confinement	Unconfined MWR/MWR_{REF} = 1.0	Unconfined MWR/MWR_{REF} = 1.0	Unconfined MWR/MWR_{REF} = 1.0

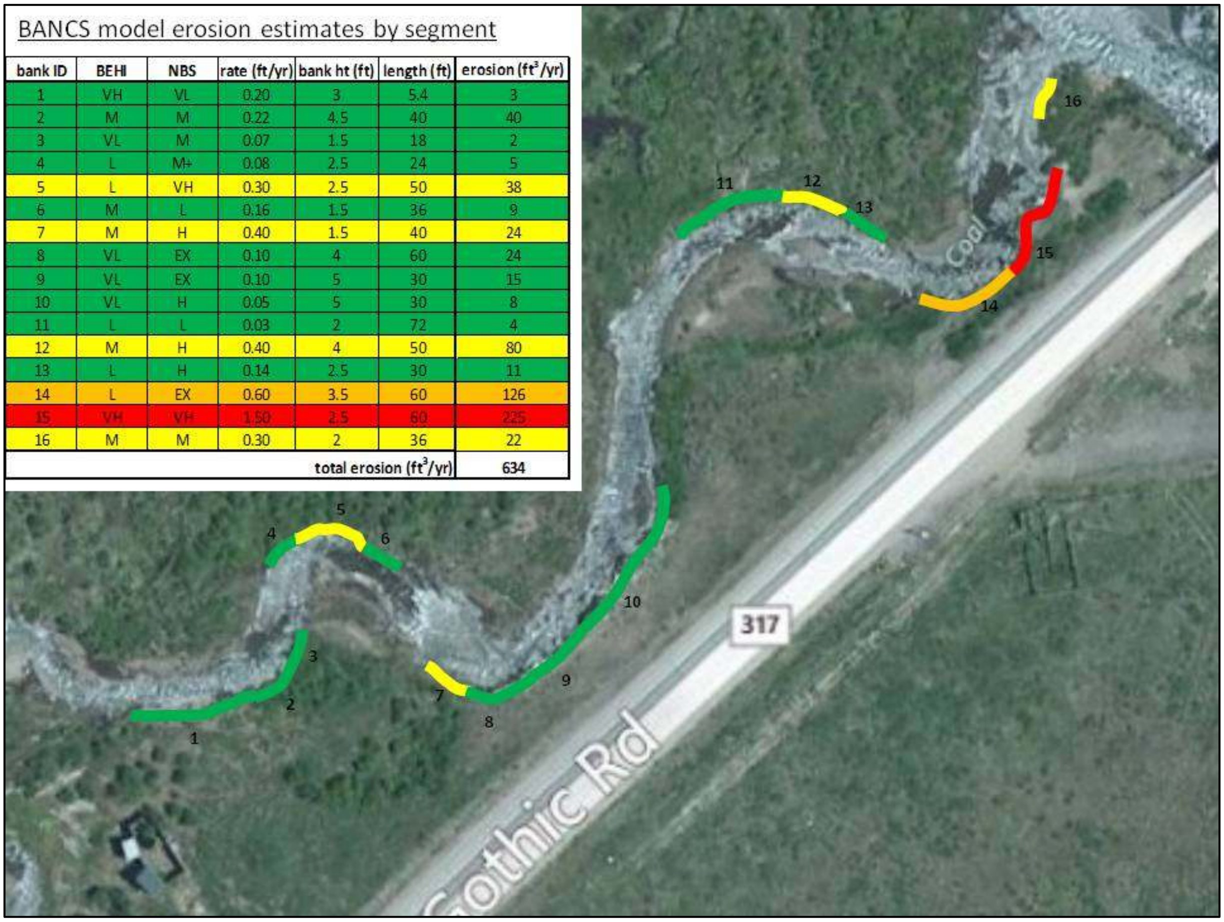
The assessment was made individually for each of the three segment types on the reach.

3.8 Prediction of Bank Erosion Volume

Streambank and channel parameters were measured along the entire length of the reach to calculate BEHI and NBS, and these values were used to predict annual bank erosion rates and to calculate a predicted annual volume of sediment produced from bank erosion on the reach. **Figure 7** shows the location of all the bank segments for which significant erosion is predicted. The table within the figure summarizes the results of the BANCS model and the computation of estimated annual sediment volume produced by bank erosion.

Over the entire reach, an estimated 634 cubic feet (ft^3) or about 30 tons of sediment is produced annually from bank erosion. Roughly two-thirds of this total, 373 ft^3 (about 20 tons) comes from the short delta segment. The other presumably unstable truncated segment shows relatively little predicted bank erosion because the primary susceptible bank is extensively armored with concrete and boulders.. In contrast, only a portion of the eroding bank on the delta segment is armored, and the armoring on this bank is simply a layer of loosely stacked rock and concrete pieces that may fail.

Figure 7: Results from Streambank Erosion Estimates Using the BANCS Model



BANCS model erosion estimates by segment

bank ID	BEHI	NBS	rate (ft/yr)	bank ht (ft)	length (ft)	erosion (ft^3/yr)
1	VH	VL	0.20	3	5.4	3
2	M	M	0.22	4.5	40	40
3	VL	M	0.07	1.5	18	2
4	L	M+	0.08	2.5	24	5
5	L	VH	0.30	2.5	50	38
6	M	L	0.16	1.5	36	9
7	M	H	0.40	1.5	40	24
8	VL	EX	0.10	4	60	24
9	VL	EX	0.10	5	30	15
10	VL	H	0.05	5	30	8
11	L	L	0.03	2	72	4
12	M	H	0.40	4	50	80
13	L	H	0.14	2.5	30	11
14	L	EX	0.60	3.5	60	126
15	VH	VH	1.50	2.5	60	225
16	M	M	0.30	2	36	22
					total erosion (ft^3/yr)	634

The location of individual bank segments is identifies on the site map and color coded to indicate the relative magnitude of erosion. The table summarizes all of the BANCS model data.

3.9 Sediment Competence

The results of stability assessments made from both of the methods defined in WARSSS PLA (dimensionless shear stress calculations and dimensional shear stress calculations) are summarized for each of the riffle XS in **Table 9**.

Table 9: Results of Sediment Entrainment Calculations for the Five Riffle XS

Coal Creek, Confluence Reach Channel stability predictions based on sediment entrainment					
Predictions from critical dimensionless shear stress (T*c)	**XS-1**	**XS-3**	**XS-5**	**XS-6**	**XS-8**
Calculated W/D required to move the largest observed bedload sediment particles at S=0.66%	27	27	27	27	N/A
Actual measured W/D	28	54	16	27	N/A
% difference	4%	100%	-41%	0%	N/A
Stability prediction	**STABLE**	**Excess deposition**	**Excess scour**	**STABLE**	**N/A**
Predictions from critical dimensional shear stress (Tc) (lb/ft^2)	**XS-1**	**XS-3**	**XS-5**	**XS-6**	**XS-8**
Calculated Tc required to move the largest observed bedload particles at S=0.66%	0.41	0.41	0.41	0.41	0.41
Actual calculated shear stress Tc (lb/ft^2)	0.59	0.48	0.73	0.59	0.49
% difference	44%	17%	78%	44%	20%
Stability prediction	**Excess scour**	**Excess scour**	**Excess scour**	**Excess scour**	**Excess scour**

The upper portion of the table shows results from the critical dimensionless shear stress equations, and the lower portion shows results that used dimensional shear stress. Note that none of the dimensionless shear stress calculations were valid on XS-8 because the bed material was so much smaller than bedload sediment. It is likely that sediment transport and deposition is highly impacted on this XS by impoundment of the Slate River at high flows.

Unfortunately, the results are somewhat ambiguous, since the methods result in contradictory predictions of stability. The predictions made using critical dimensionless shear stress (T*c) indicate stability (and perhaps some excess scour) on the XS within our identified unimpacted reference segments, and excess deposition on the higher W/D impacted segments. The critical dimensional shear stress calculations, on the other hand, predict excess scour on all of the XS.

It is worth pointing out that there is no supporting evidence for any excess scour or degradation along the reach. In contrast, there is very clear field evidence of stability on the unimpacted segments along with clear signs of excess deposition on both the truncated segment and the delta segment (see **Table 8**).

3.10 Stream Channel Succession

All of the segments along the reach are the C4 stream type. The only identifiable successional process is potential channel widening on XS-3 and XS-8 in the truncated and delta segments which could be viewed as the initial stages in a C4→D4 channel type succession. This process is identified as $C4 \rightarrow C4_{WIDE}$. The segment at XS-5 has an unusually low W/D ratio compared to the rest of the reach, and this might be understood as progression along the C→E channel type succession which is commonly understood as an indication of increasing stability.

3.11 PLA Stability Predictions

At this stage, all of the available data from the observations, measurements, and models in previous steps in the PLA process are compiled using analytical worksheets to make comprehensive predictions about lateral stability, vertical stability, the potential for channel enlargement, and overall sediment production. We also repeated the PFC and RBP Physical Habitat surveys made by Alexander and Brown (2009) using the additional data brought to light in this study.

Lateral stability predictions: PLA uses a scoring procedure to evaluate five primary parameters in the analysis of and prediction of lateral stability. The conditions and corresponding scores for each parameter are summarized in **Table 10**. According to PLA guidelines, the prediction of lateral stability can be made directly from the total points from each of the five parameters as follows: <8 (stable), 8-12 (moderately unstable), 13-21 (unstable), >21 (highly unstable). By these criteria, the unimpacted segment is predicted to be laterally stable, and both the truncated and delta segments are predicted to be laterally unstable.

Table 10: Parameters Used to Predict Lateral Stability

Coal Creek Confluence Reach Lateral Stability Analysis

Segment	Lateral Stability Assessment Parameters										Total points	Prediction
	W/d / W/d_{ref}		Deposition pattern		Meander pattern		Dominant BEHI/NBS		Confinement MWR / MWR_{ref}			
	points	condition	points	condition	points	condition	points	condition	points	condition		
unimpacted segments	2	< 1.2	1	B2	1	M3	2	L/H	1	1.00 - 0.80	7	**Stable**
truncated segment	8	> 1.6	3	B3	2	M4	4	L/EX	1	1.00 - 0.80	18	**Unstable**
delta segment	6	1.4 - 1.6	3	B3, B4, B5	2	M4	6	H/VH	1	1.00 - 0.80	18	**Unstable**

Vertical stability predictions: The PLA procedure for predicting vertical stability requires the evaluator to score each of nine parameters as either an indicator of stability, aggradation (excess deposition) or degradation (excess scour). If bankfull sediment and hydrology data are available, a tenth parameter for modeled sediment capacity may be added to the analysis, but neither of these types of data are available on this site.

The parameters are listed in order of relative importance, and the evaluator makes a final prediction of vertical stability based on the distribution of indicators among the different parameters with those near the top of the list receiving greater weight. Because this analysis requires a somewhat subjective compilation of many different types of data and different levels of confidence about each, we included some evaluation of the degree of confidence for each indicator on the list. A summary of the scoring table is provided in **Table 11**.

Table 11: Parameters Used to Predict Overall Vertical Stability

Coal Creek Confluence Reach Vertical Stability Analysis				
Vertical assessment parameters		Unimpacted segments	Truncated segment	Delta segment
Critical Dimensionless Shear Stress	condition	$W/D:W/D^*$ ≤ 1.0	$W/D:W/D^*$ $= 1.5$	$W/D:W/D^*$ $= 1.9$
	prediction	Stable (high)	Aggrad. (mod)	Aggrad. (mod)
Critical shear stress	condition	Excess shear stress	Sufficient shear stress	Sufficient shear stress
	prediction	Degrad. (?) (low)	Degrad. (?) (low)	Degrad. (?) (low)
Degree of Incision	condition	BHR< 1.1	BHR< 1.1	BHR> 1.1
	prediction	Stable (high)	Stable (high)	Degrad. (mod)
W/D Ratio State	condition	$W/D:W/D_{REF}$ $= 1.0$	$W/D:W/D_{REF}$ $= 1.5$	$W/D:W/D_{REF}$ $= 2.0$
	prediction	Stable (high)	Aggrad. (mod)	Aggrad. (high)
Successional State	condition	$C \rightarrow C$, $C \rightarrow E$ (?)	$(C \rightarrow C_{wide})$	$(C \rightarrow C_{wide})$
	prediction	Stable (high)	Aggrad. (low)	Aggrad. (low)
Deposition Patterns	condition	B2	B3	B3, B4, B5
	prediction	Stable (high)	Aggrad. (high)	Aggrad. (high)
Meander Patterns	condition	M3	M4	M4
	prediction	Stable (high)	Stable (high)	Stable (high)
Entrenchment Ratio	condition	>> 2.2	>> 2.3	>> 2.4
	prediction	Stable (high)	Stable (high)	Stable (high)
Confinement	condition	MWR / MWR_{REF} > 0.8	MWR / MWR_{REF} > 0.8	MWR / MWR_{REF} > 0.8
	prediction	Stable (high)	Stable (high)	Stable (high)
Overall vertical stability prediction		Stable	Moderate instability excess deposition	Moderate instability excess deposition

A summary of parameter conditions and associated indications for vertical stability, aggradation, and degradation for determination of an overall prediction of vertical stability on the segments of the Confluence Reach. For each parameter, we describe the relevant condition (observation) obtained from the results of surveys, the appropriate stability indication from PLA guidelines, and a qualitative evaluation of the degree of confidence for the indicator (high, moderate, or low). The bottom row of the table is the derived prediction of vertical stability for each segment. (?) indicates values that are highly questionable.

The unimpacted segments are predicted to be vertically stable. That is, there is no indication that the channel is at risk for either aggradation (raising bed elevation) or degradation (incision or lowering of the bed relative to the floodplain). Both the truncated and delta segments are predicted to be moderately unstable with an excess deposition that could place the segments at risk for aggradation. The mechanism for this, as indicated by the parameter scores, is a loss of stream power and shear stress due to excessive channel widening and increasing W/D to the point that the channel can no longer transport the sediments provided by the watershed. The result of this process is excess deposition, which is evident on both segments.

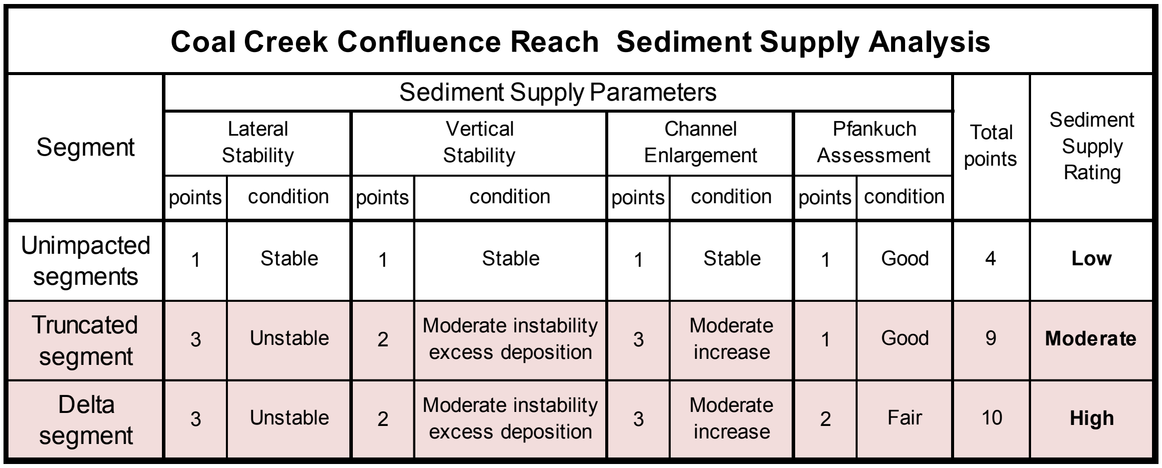
Potential for channel enlargement: The prediction for channel enlargement is made directly by applying numerical scores to each of the previous stability predictions (lateral and vertical) combined with a score for channel successional stage. According to PLA guidelines, the prediction of channel enlargement can be made directly from the total points from each of the three parameters as follows: 6 (stable), 7-12 (slight increase), 13-18 (moderate increase), >18 (extensive). The results of these scoring procedures are summarized in **Table 12**. By these criteria, the unimpacted segment is predicted to be stable (not enlarging), and both the truncated and delta segments are predicted to be at risk for moderate increase in size due to enlargement.

Table 12: Parameters Used to Predict Channel Enlargement

Coal Creek Confluence Reach Potential for Enlargement Analysis								
Segment	Enlargement Assessment Parameters						Total points	Prediction
	Lateral Stability		Vertical Stability		Successional stage			
	points	condition	points	condition	points	condition		
Unimpacted segments	2	Stable	2	Stable	2	Stable ($C \rightarrow C$)	6	**Stable**
Truncated segment	6	Unstable	4	Moderate instability excess deposition	4	($C \rightarrow C_{WIDE}$)	14	**Moderate increase**
Delta segment	6	Unstable	4	Moderate instability excess deposition	4	($C \rightarrow C_{WIDE}$)	14	**Moderate increase**

Overall sediment production: PLA also includes a prediction for the relative amount of sediment contributed by the study segments as a way to prioritize restoration efforts in watersheds that have systemic sediment problems. These predictions, once again, are based on a scoring system that applies scores to the previous stability and enlargement predictions, but also adds an additional parameter score for the Pfankuch stability index (see *Section 3.7 Identification of Stream Stability Indices*). A summary of the scoring for the sediment production prediction procedure is provided in **Table 13**. The procedure yields a prediction of low sediment production by the unimpacted segments, moderate sediment production by the truncated segment, and high sediment production from the delta segment.

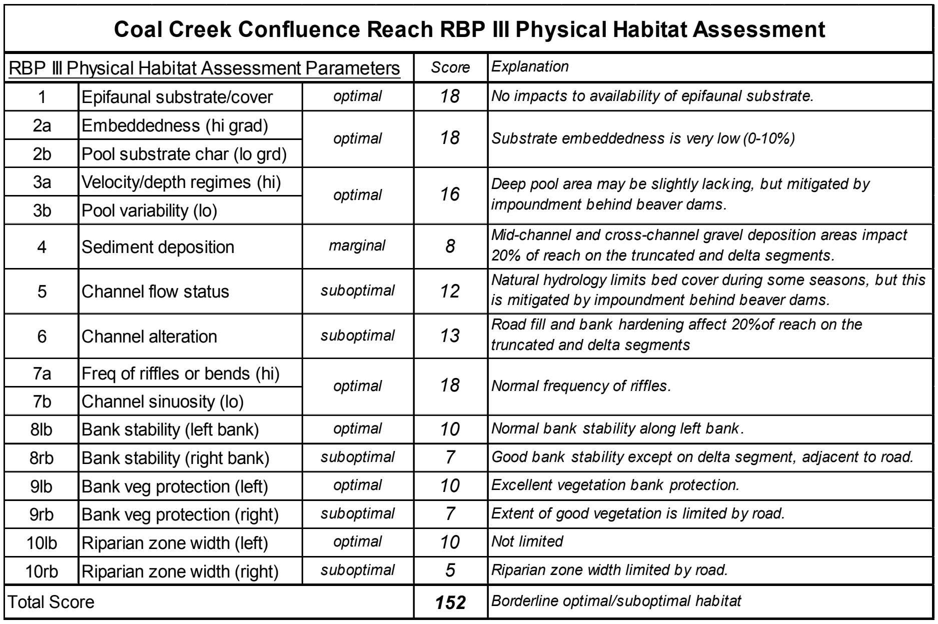
Table 13: Parameters Used to Predict Sediment Production



Coal Creek Confluence Reach Sediment Supply Analysis										
Segment	Sediment Supply Parameters								Total points	Sediment Supply Rating
	Lateral Stability		Vertical Stability		Channel Enlargement		Pfankuch Assessment			
	points	condition	points	condition	points	condition	points	condition		
Unimpacted segments	1	Stable	1	Stable	1	Stable	1	Good	4	**Low**
Truncated segment	3	Unstable	2	Moderate instability excess deposition	3	Moderate increase	1	Good	9	**Moderate**
Delta segment	3	Unstable	2	Moderate instability excess deposition	3	Moderate increase	2	Fair	10	**High**

<u>RBP III Physical Habitat Assessment</u>: The EPA RBP III Physical Habitat Assessment is a protocol through which an evaluator makes a subjective assessment of stream habitat condition by making judgments about 10 different habitat parameters according to general guidelines. The assessment method rates 80 to 100 percent as optimal, 60 to 75 percent as sub-optimal, 40 to 55 percent as marginal, and 0 to 50 percent as poor. Results of our assessment of the Confluence Reach are summarized in **Table 14**. The reach was scored a total of 152/200 (76 percent) which equates to an evaluation on the borderline of optimal and sub-optimal habitat condition.

Table 14: RBP III Physical Habitat Assessment Results



Coal Creek Confluence Reach RBP III Physical Habitat Assessment				
RBP III Physical Habitat Assessment Parameters			*Score*	*Explanation*
1	Epifaunal substrate/cover	*optimal*	*18*	*No impacts to availability of epifaunal substrate.*
2a	Embeddedness (hi grad)	*optimal*	*18*	*Substrate embeddedness is very low (0-10%)*
2b	Pool substrate char (lo grd)			
3a	Velocity/depth regimes (hi)	*optimal*	*16*	*Deep pool area may be slightly lacking, but mitigated by impoundment behind beaver dams.*
3b	Pool variability (lo)			
4	Sediment deposition	*marginal*	*8*	*Mid-channel and cross-channel gravel deposition areas impact 20% of reach on the truncated and delta segments.*
5	Channel flow status	*suboptimal*	*12*	*Natural hydrology limits bed cover during some seasons, but this is mitigated by impoundment behind beaver dams.*
6	Channel alteration	*suboptimal*	*13*	*Road fill and bank hardening affect 20%of reach on the truncated and delta segments*
7a	Freq of riffles or bends (hi)	*optimal*	*18*	*Normal frequency of riffles.*
7b	Channel sinuosity (lo)			
8lb	Bank stability (left bank)	*optimal*	*10*	*Normal bank stability along left bank.*
8rb	Bank stability (right bank)	*suboptimal*	*7*	*Good bank stability except on delta segment, adjacent to road.*
9lb	Bank veg protection (left)	*optimal*	*10*	*Excellent vegetation bank protection.*
9rb	Bank veg protection (right)	*suboptimal*	*7*	*Extent of good vegetation is limited by road.*
10lb	Riparian zone width (left)	*optimal*	*10*	*Not limited*
10rb	Riparian zone width (right)	*suboptimal*	*5*	*Riparian zone width limited by road.*
Total Score			***152***	*Borderline optimal/suboptimal habitat*

Scores and explanations for each of the RBPIII parameters are provided, as well as the final RBPIII score of 152/200 which indicates borderline optimal/sub-optimal condition.

Proper Functioning Condition Assessment: The PFC assessment for lotic habitats is a subjective methodology meant to provide a rapid assessment of stream and riparian habitat conditions. It is a simple checklist that evaluators can use in the field to answer 17 specific questions related to habitat condition. We repeated the PFC assessment for the segments on this reach, answering the questions following PLA analysis, and the results are summarized in **Table 15**.

Table 15: PFC Assessment Results

Coal Creek Confluence Reach PFC Assessment			
Unimpacted segments	Truncated segment	Delta segment	PFC Assessment Parameters
			HYDROLOGY
YES	YES	YES	1) Floodplain above bankfull is inundated in "relatively frequent" events
YES. Beaver dams on all the reaches show seasonal cycles of destruction and reconstruction, but are presently actively maintained.			2) Where beaver dams are present they are active and stable
YES	Increased width/depth ratio.		3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)
YES	YES	YES	4) Riparian-wetland area is widening or has achieved potential extent
YES. Upstream impacts to riparian-wetland condition are minimal.			5) Upland watershed is not contributing to riparian-wetland degradation
			VEGETATION
YES	YES	YES	6) There is diverse age-class distribution of riparian-wetland vegetation (recruitment for maintenance/recovery)
YES	YES	YES	7) There is diverse composition of riparian-wetland vegetation (for maintenance/recovery)
YES	YES	YES	8) Species present indicate maintenance of riparian-wetland soil moisture characteristics
YES	YES	YES	9) Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high-streamflow events
YES	YES	YES	10) Riparian-wetland plants exhibit high vigor
YES	YES	YES	11) Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows
YES	YES	YES	12) Plant communities are an adequate source of coarse and/or large woody material (for maintenance/recovery)
			EROSION/DEPOSITION
YES	YES	YES	13) Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody material) are adequate to dissipate energy
YES	YES	YES	14) Point bars are revegetating with riparian-wetland vegetation
YES	Meanders are trucated at road fill.		15) Lateral stream movement is associated with natural sinuosity
YES	Excess deposition is apparent. Increased risk of aggradation.		16) System is vertically stable
YES	Excess deposition , increased risk of aggradation and channel enlargement.		17) Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)
			Summary Determination
PFC	Functional-At Risk	Functional-At Risk	Functional Rating:
N/A	Not apparent	Not apparent	Trend for Functional—At Risk:
NO	YES	YES	Are factors contributing to unacceptable conditions outside the control of the manager?
N/A	Road Encroachment	Road Encroachment Bridge impacts	If yes, what are those factors?

The results are a consensus among the three evaluators about the relative quality of habitat based on the answers we provided to questions. The unimpacted segments were evaluated as at "Proper Functioning Condition". Both the truncated and delta segments were determined to be " Functional-At Risk" with a trend that is "not apparent." All the evaluators agreed that there were no systemic problems with any of the hydrologic or vegetation parameters on any of the reaches. Significant impacts to vegetation are limited to bank segments that are against the Gothic Road.

The parameters which yielded an "at risk" evaluation were all in the "erosion/deposition" category and related to impacts from the Gothic Road and Bridge. The assessment of "not apparent trend" is related to the uncertainty about the habitat ramifications of any adjustments that the channel makes in response to these stressors. We all agreed that the condition of riparian vegetation may be improving on the reach but that riparian vegetation is already in good condition and not a contributing factor in the risk to proper functioning.

3.12 Channel Survey Photographs

Photos from monumented photopoints are provided in **Appendix 4**.

4.0 Discussion

This study is a detailed assessment that follows up on previous work (Alexander and Brown 2009) that suggested that the Confluence Reach of Coal Creek is in need of restoration to improve impaired functional condition related to instability caused by riparian vegetation impacts.

Our results generally concur with Alexander and Brown (2009) that there are stability concerns on the reach; but whereas they suggest that instability is a systemic concern resulting from vegetation impacts, our study indicates that the cause of instability is more likely a result of direct geomorphic impacts related to the Gothic Road and Bridge. Given the direct, acute nature of these stressors, instability concerns may be pin-pointed to two specific segments on the reach, namely the truncated and delta segments. The rest of the reach, by all indications, appears to be stable and in good condition.

When we repeated the assessment methodologies that Alexander and Brown originally did in 2009, applying the results of our study, we actually came up with fairly similar results. Their RBP score was 128/180 (71 percent), indicating condition of the reach to be borderline between optimal and sub-optimal. The score we derived is 152/200 (76 percent) which also indicates reach condition borderline between optimal and sub-optimal. A similar pattern exists when looking at the PFC assessment. Their assessment looked at the reach in its entirety and resulted in categorization of "functional-at risk." Our application of the assessment was at a finer scale, so we were able to identify specific segments that are "functional-at-risk" and other segments that are "functional." They concluded that there is a downward trend in the condition of the reach, probably due to the grazing impacts they observed, but our assessment is inconclusive about the direction of trend.

While we tend to agree with Alexander and Brown's (2009) assessment of overall reach condition, the results of our more detailed study point to a different explanation of the cause of the problems that do exist. Alexander and Brown (2009) suggest that the stream is over-wide, braided, and suffering from an increased sediment load, and that these problems are a direct result of overgrazing. Our study did not reveal these reported conditions except, perhaps, on the delta segment which is overwide but not braided, but we do not believe that these conditions were caused by overgrazing. Furthermore, our results do not indicate an increased sediment load on this reach. Rather, we suggest that the two potentially unstable segments are suffering from an inability to transport the sediment that is delivered to it from the feeding watershed. The problem, therefore, is more a result of acute stream morphology issues and not of increased sediment load or overgrazing.

Our assessment of the riparian condition is that the reach is in overall excellent vegetative health. In general, our results indicate that some degree of systemic, or reach-wide vegetation impairment from overgrazing may have been present on the site in the recent past, but that these impacts are largely improved following the removal of grazing. Specifically, we identified a trend in increasing willow cover with a prevalence of willows in the 1 to 3 ft size class that are likely present due to release from grazing pressure that had formerly repressed these plants. A relatively high abundance of cinquefoil community may also be evidence of past grazing pressure. There is no indication, however, that riparian vegetation had been degraded to the point that it could have directly caused channel instability through decreased root density and depth.

Truly significant riparian vegetation impairment was identified only on the right bank of the geomorphically impacted segments. This is due to the fact that the right bank is immediately adjacent to road fill at these locations, and the height of these banks relative to the stream is such that hydrology to maintain riparian wetland vegetation does not exist. They are simply too "high and dry." Recent failures to establish vegetation on these sites is further evidence that the locations are hydrologically or geomorphically incapable of supporting a riparian community. We suggest that the geomorphic condition (road fill) is the cause of the observed lack of riparian vegetation and instability at these segments rather than vice-versa.

This bodes well for restoration opportunity since there do not appear to be major systemic problems that would have to be addressed. The significant identified problems can be ameliorated by localized "spot treatments" on the acutely impaired segments.

On the truncated segment, sediment deposition on the extremely sharp 105-degree bend where the stream hits the hardened road embankment has created an enormous mid-channel bar. In addition to being a strong indication of the lack of sediment transport ability and a risk of aggradation at this location, this bar decreases channel capacity and directs erosive forces towards the banks which increases erosion and the the risk of channel enlargement and avulsion. It is likely that the channel will eventually cut a new path around the deposit to the left.

There are significant functional consequences of this instability related to stream habitat. For instance, in its present configuration, this bend no longer maintains a lateral scour pool. On the rest of the reach and the reach immediately upstream, lateral scour pools tend to 5 to 7 feet deep, but the "pool" on this bend presently has maximum depth of 3.4 ft at bankfull. The existing rip-rap bank also offers no possibility for the development of undercuts in the way that banks with strong riparian vegetation do, so overhead cover is limited on the segment.

To ameliorate these deficiencies, we recommend realigning the channel to smooth out the bend that runs adjacent to the road, essentially moving the channel about 30 to 40 ft north to create a buffer between the stream and the road (**Figure 8**). The reconstructed channel can be appropriately sized and shaped using reference data measured on the unimpacted segments of the reach, and temporarily stabilized using bioengineering techniques. The natural channel design should also include a plan to re-create natural lateral scour pool morphology based on the existing reference data. The new buffer area between the stream and the road could be constructed as a floodplain area set to the appropriate bankfull floodplain elevation so that it would support riparian vegetation that has a strong binding root mass. Naturally, the construction of this new floodplain would require extensive revegetation, but most of the vegetation for this purpose could be obtained by transplanting material obtained by excavating the new channel. These treatments would also effectively reduce the risk of erosion undercutting the Gothic Road.

Figure 8: Recommended Restoration Treatments for the Truncated Reach

Our recommendations for restoration on the truncated segment include realignment of the channel to move it away from the road. An approximate new channel alignment is outlined in red. The channel would be sized and shaped based on natural channel design parameters as measured on stable segments in this study, and would include the development of lateral scour pools at appropriate locations along bends (identified in blue). The green area shows where a riparian floodplain buffer could be constructed between the stream and the road.

A similar treatment is recommended for the delta segment, involving a realignment of the channel and construction of a riparian floodplain buffer between the stream and the road (**Figure 9**). In this case, the treatments could effectively mitigate bank erosion on the reach. All of the significantly eroding banks or banks at risk of significant erosion are located on this segment. The causal factors leading to erosion of these banks could be ameliorated by the construction of a floodplain with appropriate bank height and strong-rooted riparian vegetation. As in the case of the truncated reach, these banks could be strengthened with bioengineering techniques to offer stability while replanted vegetation is taking hold. Sediment transport may continue to be a problem, however, even if appropriate stream morphology is reconstructed, particularly towards the lower end of the delta segment unless the issue of bridge constriction on the Slate River is mitigated. If the Slate River continues forming a backwater in this area during high flow periods, then excess deposition will continue here. For this reason, channel restoration on this segment may be at higher risk of eventual failure over the long-term.

In addition to the restoration of functional potential, this work also addresses protection of the Gothic Road which is threatened by active erosion at the toe of the road fill.

Figure 9: Recommended Restoration Treatments for the Delta Reach

Our recommendations for restoration on the delta segment are similar to the truncated reach. Approximate location of a realigned channel is outlined in red. Again, the channel would be sized and shaped based on natural channel design parameters as measured on stable segments in this study, and would include the development of lateral scour pools at appropriate locations along bends (identified in blue). The green area shows where a riparian floodplain buffer could be constructed between the stream and the road. This photo shows the condition of the reach during high flow, and the presence of a backwater effect on the Slate River is apparent upstream of the Gothic Bridge.

These restoration recommendations are based on the results of our detailed assessment and the assumption that CCWC and CBLT are interested in restoring the optimal functioning of the reach. It is worth considering both of these foundations while making the decision about if, when, and how to move forward with restoration. First of all, there is uncertainty in any assessment or forecast of stream stability, no matter how detailed. For this reason, we set up all of the surveys in this study so that they can be repeated on an annual basis to document actual trends in channel and vegetation condition. Monitoring the reach for several seasons to document trends from these surveys will provide a means of determining the accuracy of our assessment. For instance, our predictions about the excess deposition, potential for channel enlargement, and channel widening can be assessed by repeating cross section surveys to see how the channel is shifting. Similarly, bank erosion rates can be directly measured over time to validate the estimated rates we used to fulfill our assessment. Every prediction in this report has a direct means for validation via seasonal monitoring. Thus, the CCWC and CBLT may wish to monitor the reach for at least one season prior to committing to a restoration action. This would also allow for the accumulation of validated baseline data that could be used in the future to document benefits, or "environmental lift", provided by the restoration in a quantifiable way. That is, monitoring trends will provide the "before" data in a "before-after" monitoring assessment of project effectiveness. We highly recommend this monitoring-based approach so that CCWC and CBLT can document success to stakeholders and begin accumulating data that will inform decisions about other potential projects in the watershed.

It is also worth making a practical assessment of the benefits that would be accrued by taking on a restoration project here. Our assessment indicates that this short reach, overall, is in reasonably decent functional condition. Sure, the recommended restoration actions will improve conditions for the reasons described above, but the overall amount of benefit or environmental lift should be compared in a cost-benefit way with other opportunities in the watershed. We know of no other imminently practical restoration opportunities being considered by CCWC or CBLT on Coal Creek, so this may not be a terribly important step in the watershed planning process or prioritization of projects. Either way, it is important to understand the nature and degree of improvement that can be expected from restoration activity in order to set objectives and success criteria for the project.

If the treatments we recommend are effectively implemented, we would expect an expansion of riparian floodplain area, or buffer, on the right side of the channel, along with measurable increases of 15 to 20 percent in desirable vegetation communities such as willow and sedge along the right bank greenline and on relevant transects. We would also expect to see stable channel condition without excess deposition throughout the reach, except perhaps within the active delta of the Slate River. Reach-wide sediment produced from bank erosion would also be expected to decrease by about 40 percent from the present annual rate of about 30 tons per year to an expected reference rate of about 18 tons per year by treating the impaired banks that especially susceptible to erosion.

In-stream habitat would also be expected to improve, particularly with respect to pool area, pool depth, and overhead cover from undercut banks and overhanging vegetation. Quantitative predictions of increase in these functions is a bit more difficult to determine, however. Hydrology for Coal Creek is nearly 100 percent snowmelt driven. Channel-forming and maintenance occurs at high flows on the order of 250 cfs during spring runoff, but most of the habitat features are limited by low flow periods. For most of the season, Coal Creek contains 5 to 15 cfs or less, which means that most of the bed area is exposed during large parts of the year. We wish to point out that this is not an indication of channel instability or enlargement, but rather a reflection of the widely variable hydrograph. The amount of significantly deep pool area and overhead cover on the reach is a function of channel morphology at low flow, and restoration of appropriate channel morphology on the reach would certainly improve both of these factors. For instance, lateral scour pools and undercut banks could be constructed and maintained by the channel if it were realigned away from road fill and hard stabilization structures. The reason that these habitat functions are difficult to quantify, though, lies in the uncertainty related to beaver activity.

Beaver activity is a very important habitat-forming process on this reach. Beaver ponds create deep pool area and overhead cover on the reach somewhat independent of the high-flow channel morphology. Beavers build dams to deal with flow conditions that exist at low flow in summer, and most dams are probably wiped out each spring during runoff. These animals live in bank dens on side channels that are flooded during high flow, and it appears that they build dams to keep these side channel areas flooded during the other 9 to 11 months during which the stream has low flow. The dams also act to create additional deep water ponded areas within the channel. As a result, the reach has much greater amounts of summer, fall, and winter deep pool area and cover than it would if beavers were not present. Even though the recommended restoration treatments would definitely increase the potential for these habitat features from a purely morphological perspective (*e.g.* if beavers were to be, for some reason, not present in the future), any overall amount of increase is difficult to predict since these factors tend to be driven as much by seasonal beaver activity as they are by channel morphology. The importance of beavers must certainly be recognized by any proposed restoration action. Thus, the treatment recommendations we make in this report are consistent with the habitation of beavers on the reach, and may even encourage the health and expansion of the beaver population by adding additional habitat and food source along the right bank, and by moving the channel away from the road. Also, none of the treatments would impact existing side-channel beaver dens.

5.0 Summary

The Confluence Reach of Coal Creek is in generally good condition overall, but it has specific segments with clearly identified stability concerns related to the proximity of Gothic Road and to the formation of a delta where Coal Creek enters an area of the Slate River that forms a backwater behind an artificial constriction related to the Gothic Bridge. Outside of these impacted segments, the riparian vegetation appears to be good and improving, and both channel morphology and stability are rated good. Thus, these unimpacted segments may serve as a reference for the potential stable, functional condition.

Documented impairment on the two impacted segments offers a good restoration opportunity, and recommended restoration activities involve realignment of the channel at these two locations. This would also involve sizing and shaping the realigned channel based on natural channel design using parameters measured in this study, constructing riparian floodplain buffer areas between the stream and the road, revegetating these new floodplain areas, and temporarily stabilizing the new channel segments with bioengineering techniques so that they are stable during the time while new vegetation becomes established.

All of the factors in this assessment including predicted regions of instability, vegetation trends, and quantified erosion rates can be validated by monitoring the reach according to the protocol and surveys we employed in this study. Monitoring the reach by repeating these surveys to establish trends over several seasons is recommended as a way to validate this assessment, to evaluate the need for restoration and to quantify the amount of expected benefit and environmental lift that could be obtained, and ultimately, to provide a baseline for quantitatively evaluation of project effectiveness.

6.0 Literature Cited

Alexander and Brown, 2009. *Assessement (sic.) of Riparian and Aquatic Habitat with (sic.) the Coal Creek Watershed, Gunnison County, Colorado*. Prepared for Coal Creek Watershed Coalition.

AlpineEco and EcoMetrics. 2012. *Draft Upper Slate River Geomorphic Assessment*. Prepared for Coal Creek Watershed Coalition. September 25.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling.1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish*, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C. (especially Chapter 5. Habitat Assessment and Physicochemical Parameters.)

Beardsley, 2011. *D_B: A proposed new stream type class for the Rosgen classification system to account for stream channels controlled by beaver activity*. The Greenline, Vol. 22, No. 3, Fall 2011. Colorado Riparian Association. Available online at: http://colorado-riparian.org/stream-classification-beavers/

Bureau of Land Management (BLM). 1999. *Sampling Vegetation Attributes*. Interagency Technical Reference No. 1734-4. Revised.

Crested Butte Land Trust (CBLT). 2012. Personal communication between Ms. Danielle Beamer (CBLT) and Mr. Andy Herb (AlpineEco) regarding the removal of grazing from the Coal Creek Confluence Parcel. November 16.

Lichvar, Robert W. and Kartesz, John T. 2009. North American Digital Flora: National Wetland Plant List, version 2.4.0 (https://wetland_plants.usace.army.mil). U.S. Army Corps of Engineers, Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH, and BONAP, Chapel Hill, NC.

Natural Resources Conservation Service (NRCS). 2012. Plants Database, Website: http://plants.usda.gov/plants/index.html. Accessed in September.

Prichard, D., J. Anderson, C. Correll, J. Fogg, K. Gebhardt, R. Krapf, S. Leonard, B. Mitchell and J. Staats. 1998. *Riparian Area Management: A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas*. U.S. Bureau of Land Management, U.S. Forest Service and Natural Resource Conservation Service. Technical Reference 1737-15.

Rosgen, D. 1996. *Applied River Morphology*. Wildland Hydrology. Pagosa Springs, CO.

Rosgen, D.L. 2006. Wate*rshed Assessment of River Stability and Sediment Supply (WARSSS)*. Wildland Hydrology Press. Fort Collins, CO. A detailed website is also available for information about the WARSSS methodology at http://www.epa.gov/warsss/index.htm.

Winward, A.H. 2000. *Monitoring the Vegetation Resources in Riparian Areas*. General Technical Report RMRS-GTR-47. Rocky Mountain Research Station. USDA Forest Service.

Appendix 1
Channel Survey Results

Appendix 1: Channel Surveys

Figures A1-A8 show the results of XS surveys. On the plots, black points and lines show the survey of the ground surface. The blue line shows the elevation of bankfull flow as determined by bankfull indicators. On riffle XS, bankfull elevation was adjusted to show the modeled elevation for approximately 250 CFS. Dashed red lines show the elevation of the lowest bank. This is the elevation that water has to reach before it can flow onto the floodplain. The vertical scale for riffle XS plots is 5 ft and the scale for pool XS plots is 10 ft. The photo on each XS page shows the XS viewed from upstream at the time of the survey.

Important bankfull dimension data are listed in the columns on the upper left of each page. In this study "riffles" are defined as straight segments of the channel between meander bends. These are locations where flow is more regular and there is less turbulence related to channel curvature, so simple hydrologic modeling is more valid. "Pools" are locations along meander bends. These are regions of the channel where there is a high degree of turbulence and non-parallel velocity vectors at bankfull flow. For this reason, simple hydrologic modeling is not valid. The increased lateral scour at these locations normally makes these areas deeper, forming pools.

The data for riffles includes the following.

- Width: the wetted width of the channel at bankfull discharge
- Depth: the mean depth at bankfull
- Maximum depth is the depth at the thalweg, or deepest portion of the XS
- W/D (width/depth ratio): the width divided by mean depth at bankfull
- BHR (bank height ratio): the ratio of the distance from thalweg elevation to the elevation of the lowest bank to maximum depth
- D_{max}/D: the ratio of maximum depth to mean depth

The data for pools is the same, but no hydraulic parameters are reported.

Figure A1

Coal Creek Confluence Reach 2012

XS ID:	XS-1	Facet type:	Riffle
Station:	0	Segment:	Unimpacted
Area (ft$_2$)	63	W/D	28
Width (ft)	42	BHR	1.0
Depth (ft)	1.5	D_{max}/D	1.9
Max. depth	2.8	V (ft/s)	3.9
		T (lb/ft^2)	0.59

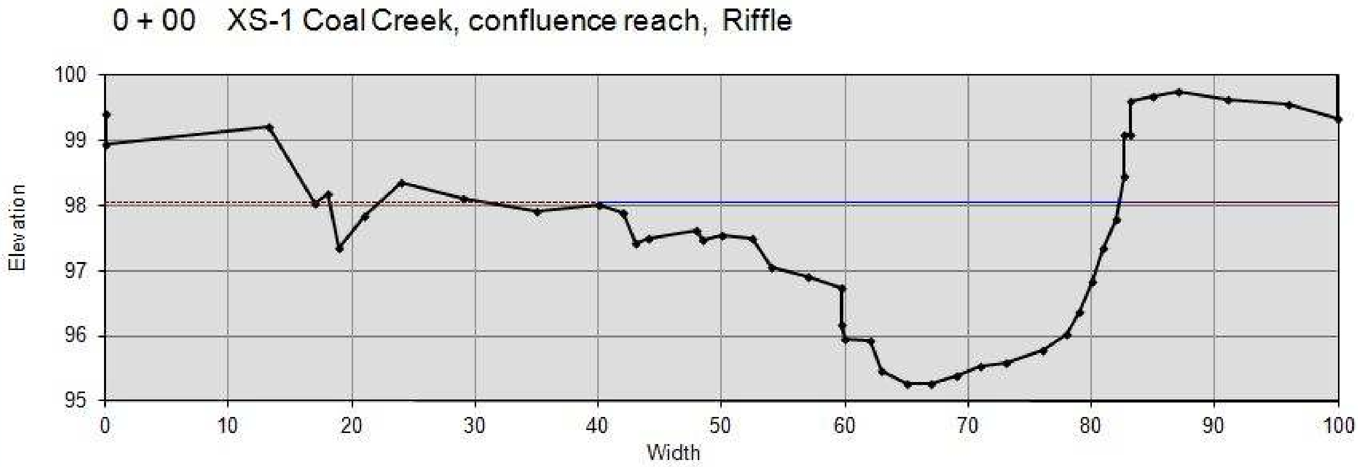


Figure A2

Coal Creek Confluence Reach 2012

XS ID:	XS-2	Facet type:	Pool
Station:	61	Segment:	Unimpacted
Area (ft$_2$)	150	W/D	15
Width (ft)	47	BHR	1.0
Depth (ft)	3.2	D_{max}/D	2.1
Max. depth	6.8		

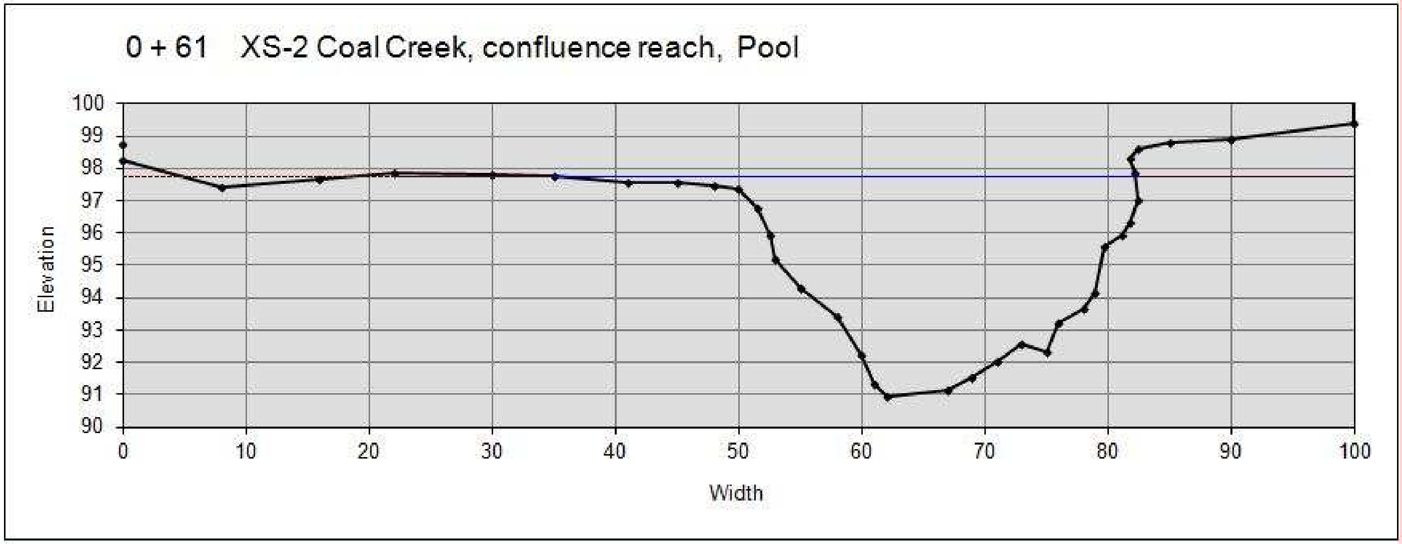


Figure A3

Coal Creek Confluence Reach 2012

XS ID:	XS-3	Facet type:	Riffle
Station:	245	Segment:	Truncated
Area (ft_2)	78	W/D	54
Width (ft)	65	BHR	1.1
Depth (ft)	1.2	D_{max}/D	2.9
Max. depth	2.9	V (ft/s)	3.2
		T (lb/ft^2)	0.48

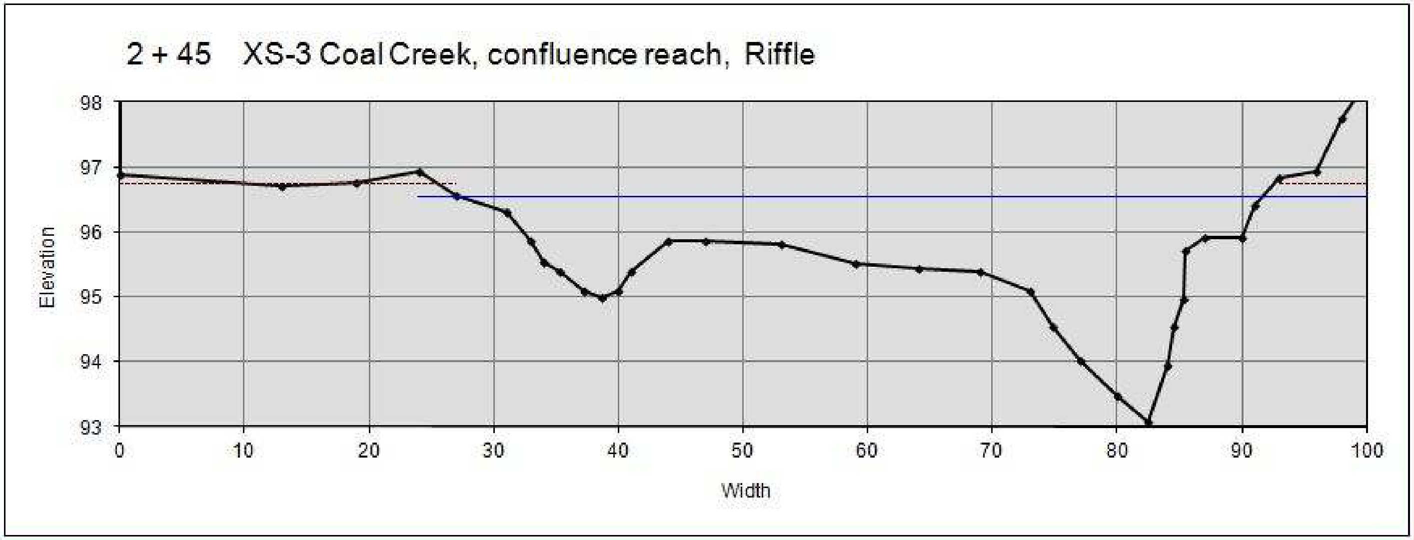


Figure A4

Coal Creek Confluence Reach 2012

XS ID:	XS-4	Facet type:	Pool
Station:	345	Segment:	Truncated
Area (ft_2)	63	W/D	15
Width (ft)	30	BHR	1.0
Depth (ft)	2.0	D_{max}/D	1.7
Max. depth	3.4		

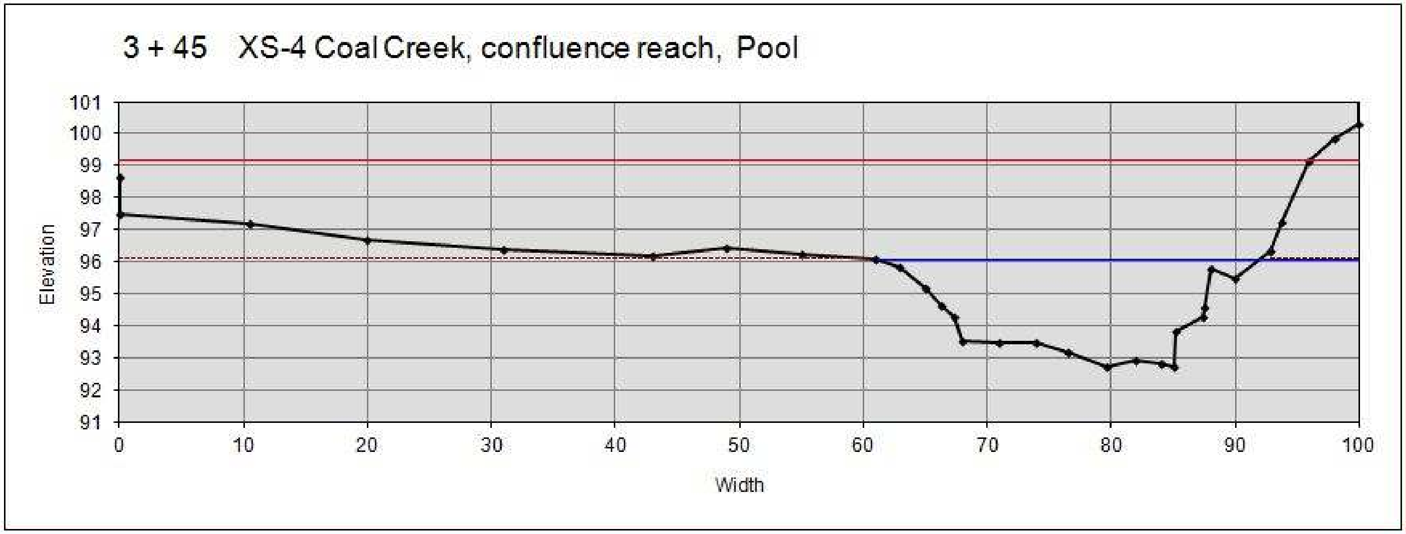

3 + 45 XS-4 Coal Creek, confluence reach, Pool

Figure A5

Coal Creek Confluence Reach 2012

XS ID:	XS-5	Facet type:	Riffle
Station:	500	Segment:	Unimpacted
Area (ft$_2$)	57	W/D	16
Width (ft)	30	BHR	1.2
Depth (ft)	1.9	D$_{max}$/D	1.5
Max. depth	2.8	V (ft/s)	4.4
		T (lb/ft^2)	0.73

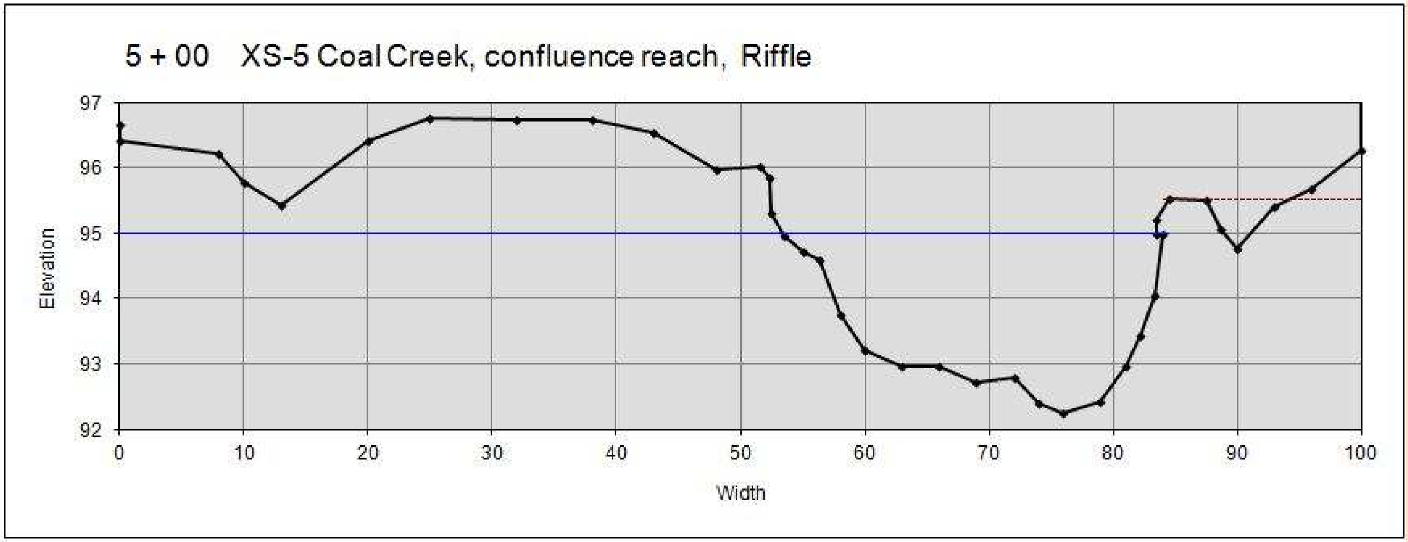


Figure A6

Coal Creek Confluence Reach 2012

XS ID:	XS-6	Facet type:	Riffle
Station:	680	Segment:	Unimpacted
Area (ft_2)	64	W/D	27
Width (ft)	41	BHR	1.0
Depth (ft)	1.6	D_{max}/D	2.2
Max. depth	3.5	V (ft/s)	3.8
		T (lb/ft^2)	0.59

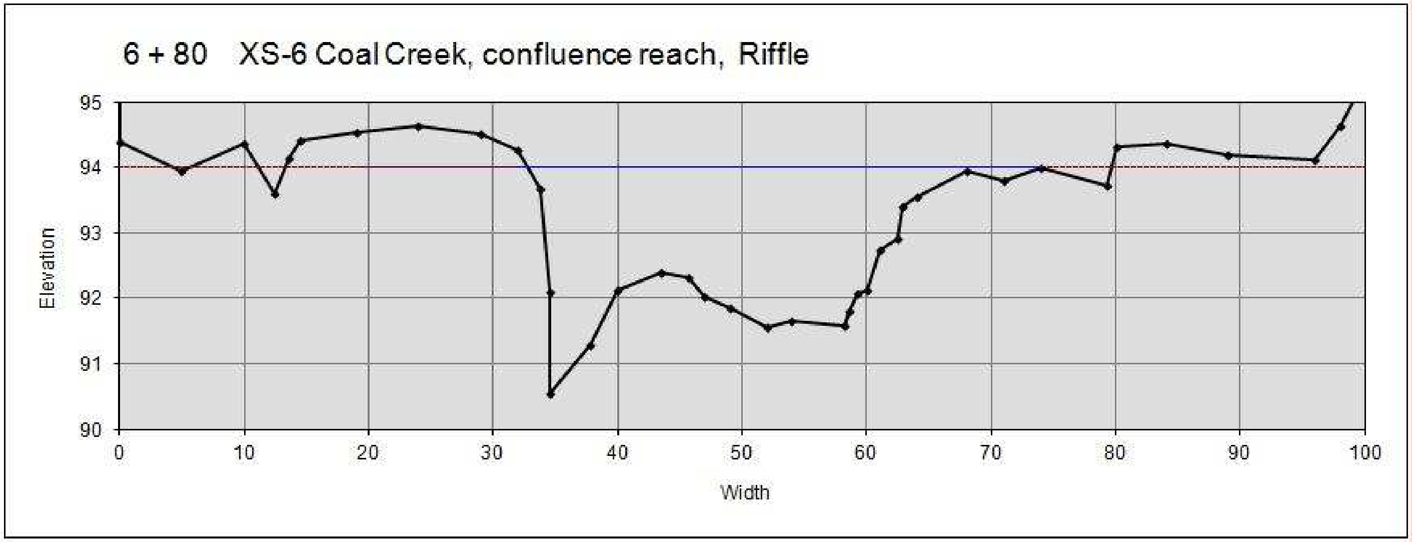
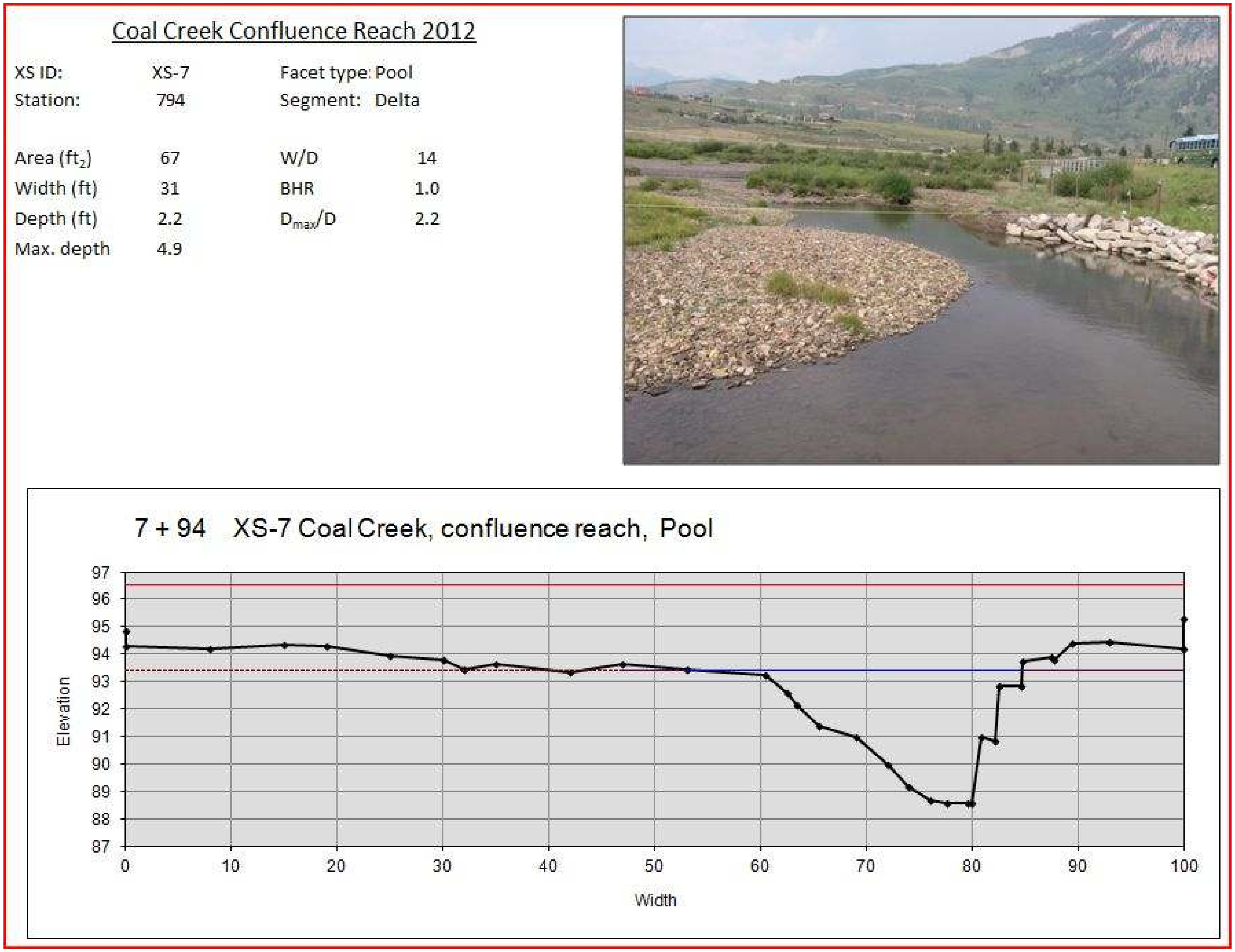


Figure A7



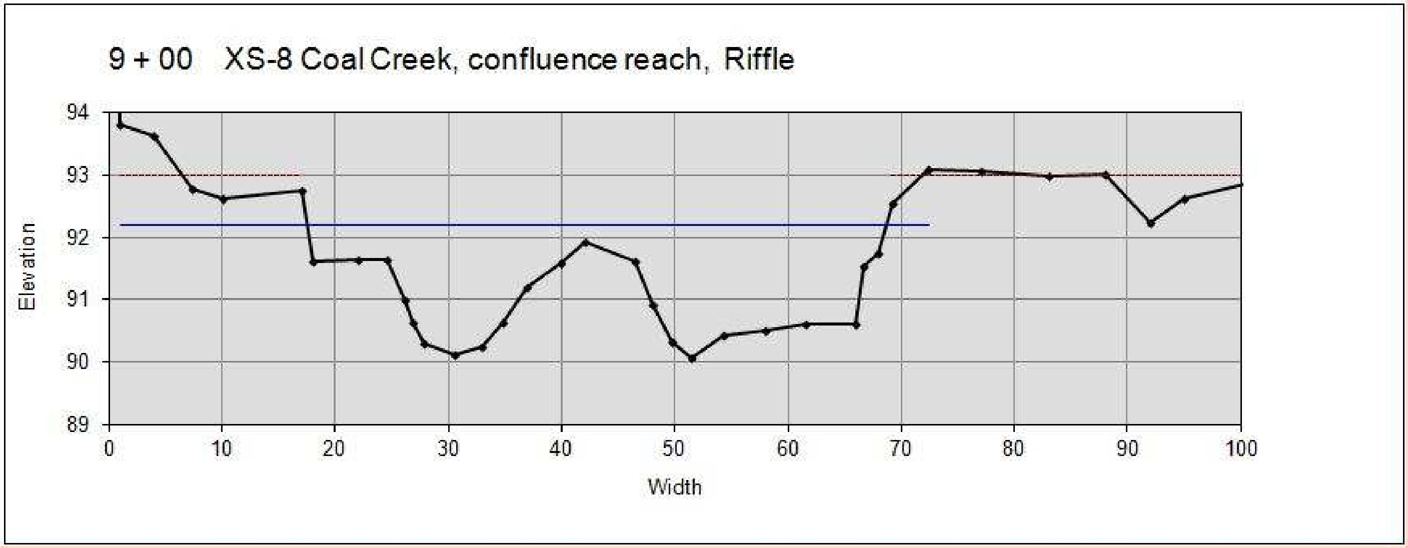
Coal Creek Confluence Reach 2012

XS ID:	XS-7	Facet type:	Pool
Station:	794	Segment:	Delta
Area (ft$_2$)	67	W/D	14
Width (ft)	31	BHR	1.0
Depth (ft)	2.2	D_{max}/D	2.2
Max. depth	4.9		

Figure A8

Coal Creek Confluence Reach 2012

XS ID:	XS-8	Facet type:	Riffle
Station:	900	Segment:	Delta
Area (ft_2)	63	W/D	41
Width (ft)	51	BHR	1.4
Depth (ft)	1.2	D_{max}/D	1.8
Max. depth	2.1	V (ft/s)	3.9
		T (lb/ft^2)	0.49



Appendix 1:
Channel Survey Results

Table A1

Coal Creek Confluence Reach - Riffle dimension summary

Station	XS ID	Segment	Area (ft^2)	W/D	Width (ft)	d (ft)	d_{max} (ft)	d_{max}/d	V (ft/s)	$\mathcal{T}$ (lb/ft^2)	BHR	Scour/ deposition prediction
0	XS-1	unimpacted segment	63	28.0	42.0	1.5	2.8	1.9	3.9	0.59	1.0	stable
245	XS-3	truncated segment	78	54.0	65.0	1.2	3.5	2.9	3.2	0.48	1.1	deposition
500	XS-5	unimpacted segment	57	16.0	30.0	1.9	2.8	1.5	4.4	0.73	1.2	stable
680	XS-6	unimpacted segment	64	27.0	41.0	1.6	3.5	2.2	3.8	0.59	1.0	stable
794	XS-8	delta segment	63	41.0	51.0	1.2	2.1	1.8	3.9	0.49	1.4	deposition

Table A2

Coal Creek Confluence Reach - Pool dimension summary

Station	XS ID	Segment	Area (ft^2)	W/D	Width (ft)	d (ft)	d_{max} (ft)	d_{max}/d
61	XS-2	unimpacted segment	150	15.0	47.0	3.2	6.8	2.1
345	XS-4	truncated segment	63	15.0	30.0	2.0	3.4	1.7
680	XS-7	delta segment	67	14.0	31.0	2.2	4.9	2.2

Table A3

Channel pattern : Coal Creek, confluence

Parameter		min	mean	max
measures	Meander length (ft)	220	**290**	373
	Radius of curvature (ft)	34	**40**	48
	Belt width (ft)	130	**150**	185
ratios	ML/Width Ratio	5.2	**6.9**	8.9
	Rc/Width Ratio	0.8	**1.0**	1.1
	Meander Width Ratio	3.1	**3.6**	4.4

The longitudinal profile shows the elevation of the channel bed (brown), water surface (light blue), bankfull indicators (blue), left bank (red) and right bank (green) down the length of the channel from top to bottom. The dashed blue line is a linear regression through the bankfull indicator points that indicates a hypothetical water surface at the incipient point of flooding. Channel slope calculated from these data is 0.72 percent. The sharp drops in water surface seen at station 170 and 610 are where water drops off of the back side of a beaver dam. The drop at station 830 is a cross-channel deposition bar.

Segments where both banks are higher than bankfull indicate dissociation from the floodplain by incision, but no segments of this reach are incised.

Figure A9

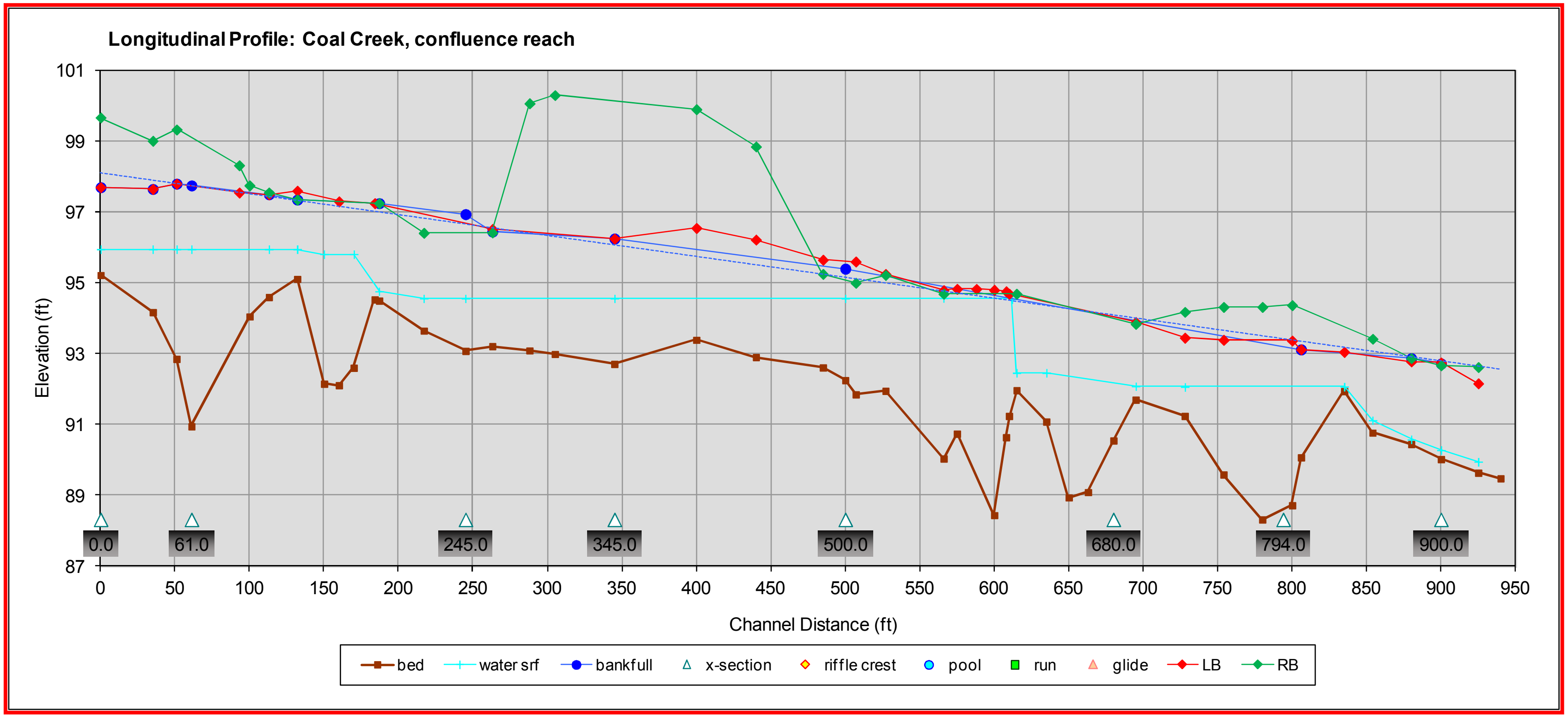
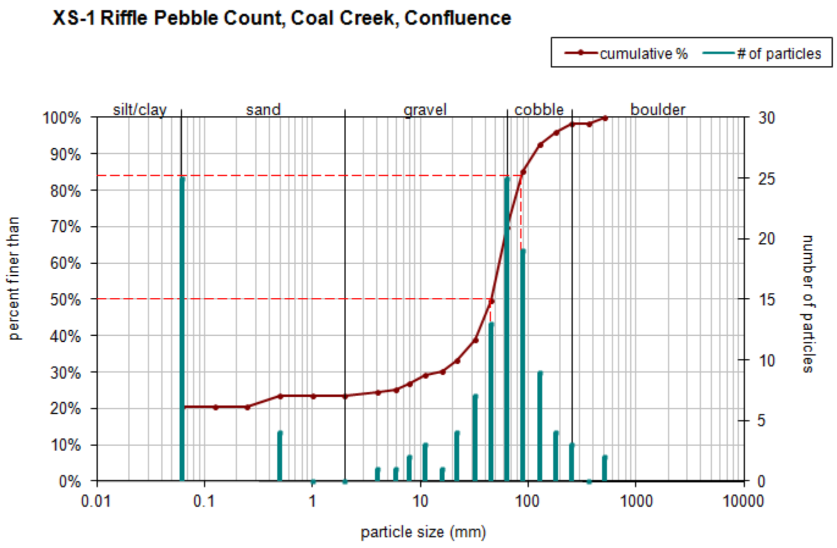


Figure A10

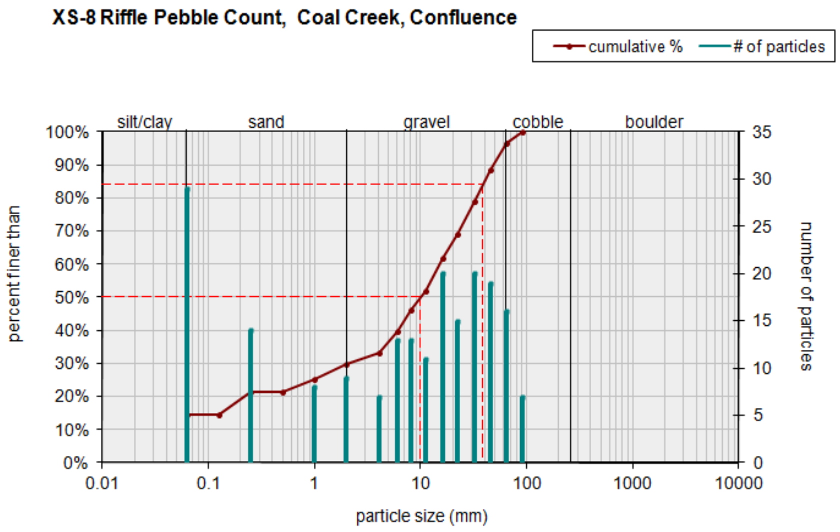


Size (mm)	
D16	0.062
D35	25
D50	45
D65	59
D84	87
D95	160

Size Distribution	
mean	2.3
dispersion	363.9
skewness	-0.73

Type	
silt/clay	20%
sand	3%
gravel	46%
cobble	28%
boulder	2%

Figure A11

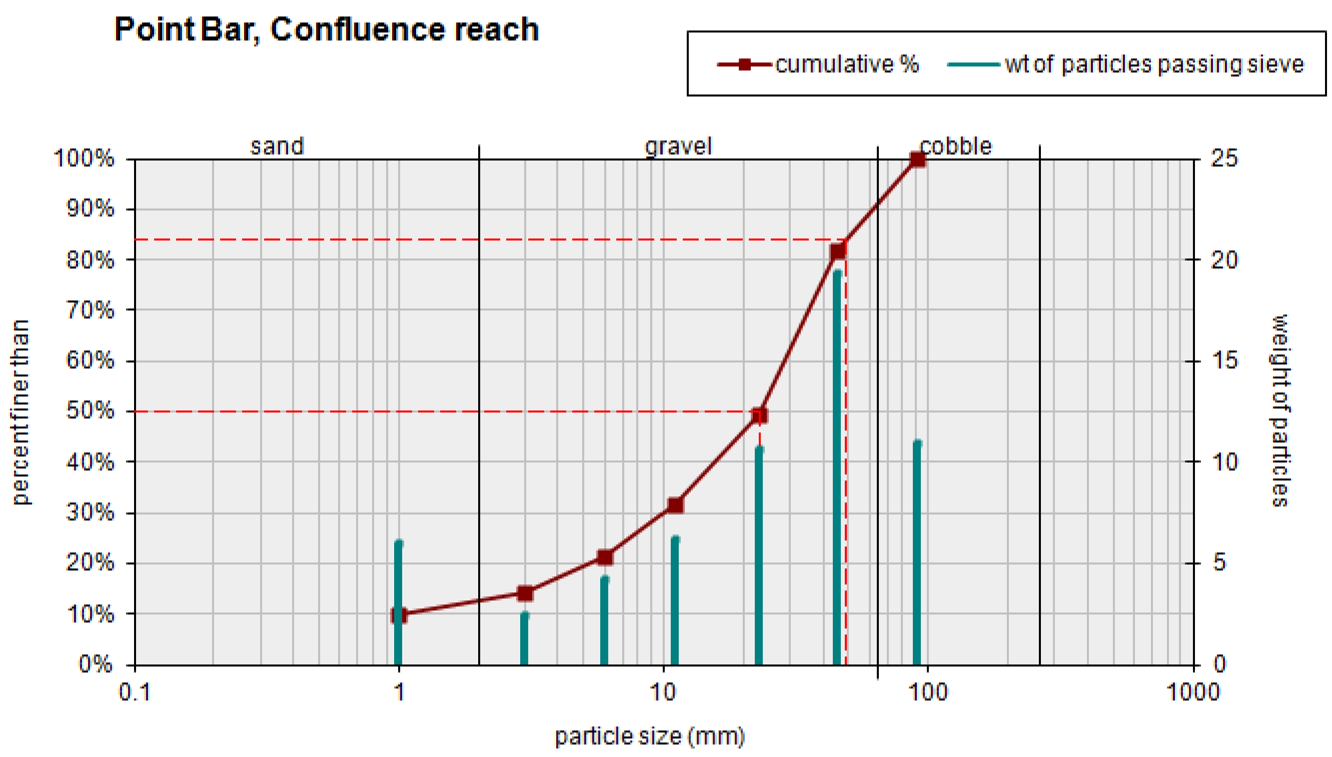


Size (mm)		
D16	0.15	3.4
D35	4.4	12
D50	9.9	17
D65	18	20
D84	38	29
D95	60	39

Size Distribution	
mean	2.4
dispersion	34.9
skewness	-0.40

Type	
silt/clay	14%
sand	15%
gravel	67%
cobble	3%
boulder	0%

Figure A12



	Size (mm)		
D16	3.6	D65	32
D35	13	D84	49
D50	23	D95	74

Appendix 2
Vegetation Survey Results

Table 2-1: Plants Observed in the Riparian Zone of Coal Creek on the Confluence Parcel

	Common Name	Scientific Name
	Woody Plants	
1	Speckled alder	*Alnus incana*
2	Coaltown sagebrush	*Artemisia cana*
3	Big sagebrush	*Artemisia tridentata*
4	Golden hardhack	*Dasiphora fruticosa*
5	Fourline honeysuckle	*Lonicera involucrata*
6	Engelmann's spruce	*Picea engelmannii*
7	Common red raspberry	*Rubus ideaus*
8	Narrowleaf willow	*Salix exigua*
9	Drummond's willow	*Salix drummondiana*
10	Park willow	*Salix monticola*
11	Tealeaf willow	*Salix planifolia*
12	Idaho willow	*Salix wolfii*
	Herbaceous Plants	
13	Common yarrow	*Achillea millefolium*
14	Letterman's needlegrass	*Achnatherum lettermani*
15	Black bent	*Agrostis gigantea*
16	Rough bent	*Agrostis scabra*
17	Field meadow foxtail	*Alopecurus pratensis*
18	Rosy pussytoes	*Antennaria rosea*
19	Smooth brome	*Bromus inermis*
20	Blue-joint	*Calamagrostis canadensis*
21	Slimstem reedgrass	*Calamagrostis stricta*
22	Parry's bellflower	*Campanula parryi*
23	Shepard's purse	*Capsella bursa-pastoris*
24	Leafy tussock sedge	*Carex aquatilis*
25	Smallwing sedge	*Carex microptera*
26	Woolly sedge	*Carex pellita*

	Common Name	Scientific Name
27	Clustered field sedge	*Carex praegracilis*
28	Northwest territory sedge	*Carex utriculata*
29	Sulphur Indian paintbrush	*Castilleja sulphurea*
30	Meadow thistle	*Cirsium scariosum*
31	Rocky Mountain hemlock parsley	*Conioselinum scopulorum*
32	Gypsy flower	*Cynoglossum officinale*
33	Parry’s oatgrass	*Danthonia parryi*
34	Tufted hairgrass	*Deschampsia caespitosa*
35	Slender wildrye	*Elymus trachycaulus*
36	Tall annual willowherb	*Epilobium brachycarpum*
37	Slenderfruit willowherb	*Epilobium leptocarpum*
38	Field horsetail	*Equisetum arvense*
39	Southwest fescue	*Festuca calligera*
40	Virginia strawberry	*Fragaria virginiana*
41	Largeleaf avens	*Geum macrophyllum*
42	Old man’s whiskers	*Geum triflorum*
43	Hairy false golden aster	*Heterotheca villosa*
44	American cow parsnip	*Heracleum maximum*
45	Meadow barley	*Hordeum brachyantherum*
46	Arctic rush	*Juncus arcticus*
47	Daggerleaf rush	*Juncus ensifolius*
48	Flatspine stickseed	*Lappula occidentalis*
49	Field pepperweed	*Lepidium campestre*
50	Oxeye daisy	*Leucanthemum vulgare*
51	Butter and eggs	*Linaria vulgaris*
52	Stemless dwarf lupine	*Lupinus caespitosus*
53	Starry False Solomon’s seal	*Maianthemum stellatum*
54	Tall fringed bluebells	*Mertensia ciliata*
55	Seep monkeyflower	*Mimulus guttatus*
56	Fendler’s cowbane	*Oxypolis fendleri*

	Common Name	Scientific Name
57	Bull elephant's head	*Pedicularis groenlandica*
58	Pincushion beardtounge	*Penstemon procerus*
59	Mountain timothy	*Phleum alpinum*
60	Timothy	*Phleum pratense*
61	Great plantain	*Plantago major*
62	Kentucky bluegrass	*Poa pratensis*
63	Flatstem bluegrass	*Poa compressa*
64	Douglas' knotweed	*Polygonum douglasii*
65	Cinquefoil	*Potentilla sp.*
66	Bluntleaf yellowcress	*Rorippa curvipes*
67	Common sheep sorrel	*Rumex acetosella*
68	California willow dock	*Rumex californicus*
69	Missouri goldenrod	*Solidago missouriensis*
70	Hooded ladies'-tresses	*Spiranthes romanzoffiana*
71	Western American aster	*Symphyotrichum ascendens*
72	Common tansy	*Tanacetum vulgare*
73	Common dandelion	*Taraxacum officinale*
74	Fendler's meadowrue	*Thalictrum fendleri*
75	Yellow salsify	*Tragopogon dubius*
76	Alsike clover	*Trifolium hybridum*
77	Red clover	*Trifolium pratense*
78	Scentless false mayweed	*Tripleurospermum perforatum*

[1] Nomenclature presented in this table follows the National Wetland Plant List (Lichvar and Kartesz 2009); if the species is not listed, then nomenclature follows the PLANTS database (NRCS 2012).

Transect Summary Sheet

Project Name: Coal Creek Confluence Parcel	**Date:** August 14, 2012	**Page:** 1 of 1
Investigator: Andy Herb	**Length of Transect:** 100 feet	
Transect Number: XS-1		

Measurement on Transect (feet)	**Vegetation Associations**								**Unvegetated Cover**		
	Sedge	**Willow/ Sedge**		**Willow/ Other**		**Mixed Graminoid**	**Cinquefoil**	**Upland**	**Log**	**Rock**	**Channel**
	Length	**Length**	**Height Class**	**Length**	**Height Class**	**Length**	**Length**	**Length**	**Length**	**Length**	**Length**
101 to 84	-	-	-	-	-	-	17	-	-	-	-
84 to 61	-	-	-	-	-	-	-	-	-	-	23
61 to 49	-	-	-	-	-	12	-	-	-	-	-
49 to 47	-	-	-	-	-	-	-	-	-	-	-
47 to 45	-	-	-	2	c	-	-	-	-	-	-
45 to 43	-	-	-	2	-	-	-	-	-	-	-
43 to 39	-	-	-	4	b	-	-	-	-	-	-
39 to 37	-	-	-	2	c	-	-	-	-	-	-
37 to 20	-	17	c	-	-	-	-	-	-	-	-
20 to 7	-	13	-	-	-	-	-	-	-	-	-
7 to 5	-	2	d	-	-	-	-	-	-	-	-
5 to 1	-	5	-	-	-	-	-	-	-	-	-
Percent Cover	**0**	**37**		**10**		**12**	**17**	**0**	**0**	**0**	**23**

Willow Canopy Cover by Height (%)	
a (0-1')	
b (1-3')	
c (3-5')	
d (5'+)	
Total	

Note: Willows are not present along the entire length of the transect within willow-dominated communities. Willows only have to comprise at least 30 percent of the plant association to be classified as willow-dominated.

Transect Summary Sheet

Project Name: Coal Creek Confluence Parcel	**Date:** August 14, 2012	**Page:** 1 of 1
Investigator: Andy Herb	**Length of Transect:** 100 feet	
Transect Number: XS-2		

Measurement on Transect (feet)	**Vegetation Associations**								**Unvegetated Cover**		
	Sedge	**Willow/ Sedge**		**Willow/ Other**		**Mixed Graminoid**	**Cinquefoil**	**Upland**	**Log**	**Rock**	**Channel**
	Length	**Length**	**Height Class**	**Length**	**Height Class**	**Length**	**Length**	**Length**	**Length**	**Length**	**Length**
105 to 87	-	-	-	-	-	-	18	-	-	-	-
87 to 57.5	-	-	-	-	-	-	-	-	-	-	28.5
57.5 to 53	-	-	-	-	-	4.5	-	-	-	-	-
53 to 50	-	-	-	3	b	-	-	-	-	-	-
50 to 43.5	-	-	-	6.5	-	-	-	-	-	-	-
43.5 to 37	-	-	-	6.5	b	-	-	-	-	-	-
37 to 34.5	-	-	-	2.5	-	-	-	-	-	-	-
34.5 to 31	-	-	-	3.5	b	-	-	-	-	-	-
31 to 29.5	-	-	-	1.5	-	-	-	-	-	-	-
29.5 to 29	-	-	-	0.5	c	-	-	-	-	-	-
29 to 26.5	-	-	-	2.5	-	-	-	-	-	-	-
26.5 to 24.5	-	-	-	2	c	-	-	-	-	-	-
24.5 to 21	-	-	-	3.5	-	-	-	-	-	-	-
21 to 18.5	-	-	-	2.5	c	-	-	-	-	-	-
18.5 to 18	-	-	-	0.5		-	-	-	-	-	-
18 to 7	11	-	-	-	-	-	-	-	-	-	-
7 to 5	-	2	d	-	-	-	-	-	-	-	-
Percent Cover	**11**	**2**		**35**		**4.5**	**18**	**0**	**0**	**0**	**28.5**

Willow Canopy Cover by Height (%)	
a (0-1')	0
b (1-3')	13
c (3-5')	5
d (5'+)	2
Total	**20**

Note: Willows are not present along the entire length of the transect within willow-dominated communities. Willows only have to comprise at least 30 percent of the plant association to be classified as willow-dominated.

Transect Summary Sheet

Project Name: Coal Creek Confluence Parcel
Date: August 14, 2012
Page: 1 of 1
Investigator: Andy Herb
Length of Transect: 100 feet (sediment deposit)
Transect Number: XS-3

Measurement on Transect (feet)	Vegetation Associations								Unvegetated Cover		
	Sedge	Willow/ Sedge		Willow/ Other		Mixed Graminoid	Cinquefoil	Upland	Log	Rock	Channel
	Length	Length	Height Class	Length	Height Class	Length	Length	Length	Length	Length	Length
101 to 100	-	1	-	-	-	-	-	-	-	-	-
100 to 95	-	5	d	-	-	-	-	-	-	-	-
95 to 91	-	4	c	-	-	-	-	-	-	-	-
91 to 86	-	5	-	-	-	-	-	-	-	-	-
86 to 37	-	-	-	-	-	-	-	-	-	-	49
37 to 25	-	-	-	-	-	12	-	-	-	-	-
25 to 20	-	-	-	5	b	-	-	-	-	-	-
20 to 13	-	-	-	7	-	-	-	-	-	-	-
13 to 1	-	-	-	-	-	-	12	-	-	-	-
Percent Cover	**0**	**15**		**12**		**12**	**12**	**0**	**0**	**0**	**49**

Note: Willows are not present along the entire length of the transect within willow-dominated communities. Willows only have to comprise at least 30 percent of the plant association to be classified as willow-dominated.

Willow Canopy Cover by Height (%)	
a (0-1')	0
b (1-3')	5
c (3-5')	4
d (5'+)	5
Total	**14**

Transect Summary Sheet

Project Name: Coal Creek Confluence Parcel
Date: August 14, 2012
Page: 1 of 1
Investigator: Andy Herb
Length of Transect: 100 feet (riprap bank area)
Transect Number: XS-4

Measurement on Transect (feet)	Vegetation Associations								Unvegetated Cover		
	Sedge	Willow/ Sedge		Willow/ Other		Mixed Graminoid	Cinquefoil	Upland	Log	Rock	Channel
	Length	Length	Height Class	Length	Height Class	Length	Length	Length	Length	Length	Length
101 to 94	-	-	-	-	-	-	-	7	-	-	-
94 to 89	-	-	-	5	-	-	-	-	-	-	-
89 to 67	-	-	-	-	-	-	-	-	-	-	22
67 to 63.5	-	-	-	3.5	-	-	-	-	-	-	-
63.5 to 60.5	-	-	-	3	b	-	-	-	-	-	-
60.5 to 54	-	-	-	6.5	-	-	-	-	-	-	-
54 to 52.5	-	-	-	1.5	b	-	-	-	-	-	-
52.5 to 43.5	-	-	-	9	-	-	-	-	-	-	-
43.5 to 37	-	-	-	6.5	b	-	-	-	-	-	-
37 to 33	-	-	-	4	-	-	-	-	-	-	-
33 to 26	-	-	-	7	b	-	-	-	-	-	-
26 to 21	-	-	-	5	-	-	-	-	-	-	-
21 to 1	-	-	-	-	-	-	20	-	-	-	-
Percent Cover	**0**	**0**		**51**		**0**	**20**	**7**	**0**	**0**	**22**

Willow Canopy Cover by Height (%)	
a (0-1')	0
b (1-3')	18
c (3-5')	0
d (5'+)	0
Total	**18**

Note: Willows are not present along the entire length of the transect within willow-dominated communities. Willows only have to comprise at least 30 percent of the plant association to be classified as willow-dominated.

Transect Summary Sheet

Project Name: Coal Creek Confluence Parcel	**Date:** August 14, 2012 **Page:** 1 of 1
Investigator: Andy Herb	**Length of Transect:** 100 feet
Transect Number: XS-5	

Measurement on Transect (feet)	**Vegetation Associations**								**Unvegetated Cover**		
	Sedge	**Willow/ Sedge**		**Willow/ Other**		**Mixed Graminoid**	**Cinquefoil**	**Upland**	**Log**	**Rock**	**Channel**
	Length	**Length**	**Height Class**	**Length**	**Height Class**	**Length**	**Length**	**Length**	**Length**	**Length**	**Length**
215 to 210.5	-	-	-	4.5	-	-	-	-	-	-	-
210.5 to 204	-	-	-	6.5	c	-	-	-	-	-	-
204 to 197	-	-	-	7	b	-	-	-	-	-	-
197 to 171.5	-	-	-	-	-	-	-	-	-	-	25.5
171.5 to 167	-	-	-	-	-	4.5	-	-	-	-	-
167 to 139	-	-	-	-	-	-	28	-	-	-	-
139 to 127	-	12	d	-	-	-	-	-	-	-	-
127 to 119	-	-	-	-	-	-	8	-	-	-	-
119 to 115	-	4	d	-	-	-	-	-	-	-	-
Percent Cover	**0**	**16**		**18**		**4.5**	**36**	**0**	**0**	**0**	**25.5**

Willow Canopy Cover by Height (%)	
a (0-1')	0
b (1-3')	7
c (3-5')	6.5
d (5'+)	16
Total	**29.5**

Note: Willows are not present along the entire length of the transect within willow-dominated communities. Willows only have to comprise at least 30 percent of the plant association to be classified as willow-dominated.

Transect Summary Sheet

Project Name: Coal Creek Confluence Parcel
Date: August 14, 2012
Page: 1 of 1
Investigator: Andy Herb
Length of Transect: 100 feet
Transect Number: XS-6

Measurement on Transect (feet)	Vegetation Associations								Unvegetated Cover		
	Sedge	Willow/ Sedge		Willow/ Other		Mixed Graminoid	Cinquefoil	Upland	Log	Rock	Channel
	Length	Length	Height Class	Length	Height Class	Length	Length	Length	Length	Length	Length
105 to 94	-	11	b	-	-	-	-	-	-	-	-
94 to 93	-	1	-	-	-	-	-	-	-	-	-
93 to 83	-	10	b	-	-	-	-	-	-	-	-
83 to 80	-	3	-	-	-	-	-	-	-	-	-
80 to 78	-	2	b	-	-	-	-	-	-	-	-
78 to 77.5	-	0.5	-	-	-	-	-	-	-	-	-
77.5 to 77	-	0.5	b	-	-	-	-	-	-	-	-
77 to 75	-	2	-	-	-	-	-	-	-	-	-
75 to 72	-	3	b	-	-	-	-	-	-	-	-
72 to 71	-	1	-	-	-	-	-	-	-	-	-
71 to 69.5	-	-	-	1.5	-	-	-	-	-	-	-
69.5 to 69	-	-	-	0.5	b	-	-	-	-	-	-
69 to 66	-	-	-	3	-	-	-	-	-	-	-
66 to 41	-	-	-	-	-	-	-	-	-	-	25
41 to 40	-	1	b	-	-	-	-	-	-	-	-
40 to 37	-	3	-	-	-	-	-	-	-	-	-
37 to 20	-	-	-	17	-	-	-	-	-	-	-
20 to 18	-	-	-	2	b	-	-	-	-	-	-
18 to 17	-	-	-	1	-	-	-	-	-	-	-
17 to 13	-	-	-	4	c	-	-	-	-	-	-
13 to 8	-	-	-	5	-	-	-	-	-	-	-
8 to 5	-	-	-	3	c	-	-	-	-	-	-
Percent Cover	**0**	**38**		**37**		**0**	**0**	**0**	**0**	**0**	**25**

Willow Canopy Cover by Height (%)	
a (0-1')	0
b (1-3')	30
c (3-5')	7
d (5'+)	0
Total	**37**

Note: Willows are not present along the entire length of the transect within willow-dominated communities. Willows only have to comprise at least 30 percent of the plant association to be classified as willow-dominated.

Transect Summary Sheet

Project Name: Coal Creek Confluence Parcel

Date: August 14, 2012

Page: 1 of 1

Investigator: Andy Herb

Length of Transect: 100 feet

Transect Number: XS-7

Measurement on Transect (feet)	Vegetation Associations								Unvegetated Cover		
	Sedge	Willow/ Sedge		Willow/ Other		Mixed Graminoid	Cinquefoil	Upland	Log	Rock	Channel
	Length	Length	Height Class	Length	Height Class	Length	Length	Length	Length	Length	Length
105 to 94.5	-	-	-	-	-	-	-	10.5	-	-	-
94.5 to 87	-	-	-	-	-	-	-	-	-	7.5	-
87 to 52	-	-	-	-	-	-	-	-	-	-	35
52 to 36	-	-	-	-	-	16	-	-	-	-	-
36 to 30	-	-	-	6	b	-	-	-	-	-	-
30 to 23	-	-	-	7	d	-	-	-	-	-	-
23 to 20	-	3	-	-	-	-	-	-	-	-	-
20 to 17	-	3	d	-	-	-	-	-	-	-	-
17 to 16.5	-	0.5	-	-	-	-	-	-	-	-	-
16.5 to 14.5	-	2	b	-	-	-	-	-	-	-	-
14.5 to 11	-	3.5	-	-	-	-	-	-	-	-	-
11 to 10	-	1	b	-	-	-	-	-	-	-	-
10 to 5	-	5	-	-	-	-	-	-	-	-	-
Percent Cover	**0**	**18**		**13**		**16**	**0**	**10.5**	**0**	**7.5**	**35**

Willow Canopy Cover by Height (%)	
a (0-1')	0
b (1-3')	7
c (3-5')	0
d (5'+)	10
Total	**17**

Note: Willows are not present along the entire length of the transect within willow-dominated communities. Willows only have to comprise at least 30 percent of the plant association to be classified as willow-dominated.

Transect Summary Sheet

Project Name: Coal Creek Confluence Parcel	**Date:** August 14, 2012 **Page:** 1 of 1
Investigator: Andy Herb	**Length of Transect:** 100 feet
Transect Number: XS-8	

Measurement on Transect (feet)	**Vegetation Associations**								**Unvegetated Cover**		
	Sedge	**Willow/ Sedge**		**Willow/ Other**		**Mixed Graminoid**	**Cinquefoil**	**Upland**	**Log**	**Rock**	**Channel**
	Length	**Length**	**Height Class**	**Length**	**Height Class**	**Length**	**Length**	**Length**	**Length**	**Length**	**Length**
101 to 99.5	-	-	-	1.5	-	-	-	-	-	-	-
99.5 to 66	-	-	-	33.5	c	-	-	-	-	-	-
66 to 21	-	-	-	-	-	-	-	-	-	-	45
21 to 14.5	-	6.5	b	-	-	-	-	-	-	-	-
14.5 to 9.5	-	5	-	-	-	-	-	-	-	-	-
9.5 to 4	-	5.5	b	-	-	-	-	-	-	-	-
4 to 1	-	-	-	3	-	-	-	-	-	-	-
Percent Cover	**0**	**17**		**38**		**0**	**0**	**0**	**0**	**0**	**45**

Willow Canopy Cover by Height (%)	
a (0-1')	0
b (1-3')	12
c (3-5')	33.5
d (5'+)	0
Total	**45.5**

Note: Willows are not present along the entire length of the transect within willow-dominated communities. Willows only have to comprise at least 30 percent of the plant association to be classified as willow-dominated.

Appendix 3
Vegetation Photographs

Photo 1: XS-1 from left bank endpoint

Photo 2: XS-1 from right bank endpoint

Photo 3: XS-2 from left bank endpoint

Photo 4: XS-2 from right bank endpoint

Photo 5: XS-3 from left bank endpoint

Photo 6: XS-3 from right bank endpoint

Photo 7: XS-4 from left bank endpoint

Photo 8: XS-4 from right bank endpoint


Photo 9: XS-5 from left bank endpoint


Photo 10: XS-5 from right bank endpoint


Photo 11: XS-6 from left bank endpoint


Photo 12: XS-6 from right bank endpoint


Photo 13: XS-7 from left bank endpoint


Photo 14: XS-7 from right bank endpoint


Photo 15: XS-8 from left bank endpoint


Photo 16: XS-8 from right bank endpoint

Photo 17: Sedge Association

Photo 18: Willow/Sedge Association

Photo 19: Willow/Other Association

Photo 20: Mixed Graminoid Association

Photo 21: Cinquefoil Association

Appendix 4
Channel Survey Photographs

Photopoint 1: looking upstream and downstream

Photopoint 2: looking upstream and downstream

Photopoint 3: looking upstream and downstream

Photopoint 4: looking upstream and downstream

Photopoint 5: looking upstream and downstream

Photopoint 6: looking across the stream

Photopoint 7: looking upstream

Photopoint 7: looking across and upstream