2012 Crystal River and Coal Basin Aquatic Life Use Assessment

ROARING FORK CONSERVANCY

White River National Forest

A Project of the:

ROARING FORK WATERSHED PLAN

Prepared by:

ROARING FORK CONSERVANCY

PO Box 3349
Basalt, CO 81621

White River National Forest

and:

Timberline Aquatics, Inc.

155 West Harvard, Suite 302
Fort Collins, CO 80525

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Summary

In September of 2012, Roaring Fork Conservancy (RFC), in partnership with the Aspen-Sopris Ranger District of the White River National Forest (WRNF), initiated benthic macroinvertebrate sampling at five locations on the Crystal River and six locations in Coal Basin. This effort complimented past and ongoing biomonitoring and water quality monitoring at multiple sites on the Crystal River and in Coal Basin by CDPHE's Water Quality Control Division (WQCD), WRNF, RFC, and Colorado River Watch volunteers. The results of the biomonitoring conducted during 2012, a dry year, are discussed in this report and are also compared to results from biomonitoring conducted during 2011, a wet year.

For both the 2011 and 2012 sample analyses, benthic macroinvertebrate communities were assessed using Colorado's Multi-Metric Index (MMI) and several additional metrics. In 2012, MMI scores identified *impairment* of WQCD standards for aquatic life use for five of the six sites in Coal Basin. The lowest scores were for Dutch Creek and for Coal Creek downstream of Dutch Creek. The site at the mouth of Coal Creek was not impaired. Three of these sites were also sampled in 2011 and were not impaired. It is hypothesized that large sediment pulses caused by several major summer monsoonal events preceding the sampling may have caused the lower scores in 2012.

In both 2011 and 2012, MMI scores identified *attainment* of WQCD standards for aquatic life use at all the sites on the Crystal River. In 2012, scores were highest at the most upstream and downstream sites on the Crystal River and dipped in the middle reaches.

The MMI assessment methodology does not identify specific causes of impairment; low scores indicate a general stress to macroinvertebrate communities from one or more sources. Suspected stresses in Coal Basin include the spectrum of effects associated with past mining activities and associated land uses that have resulted in increased sedimentation, the alteration or destruction of riparian habitat, and physical channel alteration coupled with steep slopes and unstable geology.

Results from this study do not constitute a legal declaration of aquatic life use attainment or impairment on the Crystal River or in Coal Basin; only the CDPHE may make such a designation. Sample results have been shared with the WQCD to aid it with its surface water assessment mandate. Under the agency's listing methodology, a segment may be provisionally listed based on one failing sample. However, the State may choose to review all other relevant data concerning a particular stream segment before final determination of impairment and 303(d) listing.

1. Introduction

1.1 Purpose and Scope

In 2012, Roaring Fork Conservancy (RFC), in partnership with the White River National Forest (WRNF), conducted biomonitoring at five sites on the Crystal River and six sites in Coal Basin to better understand aquatic life conditions in benthic macroinvertebrate communities. This biomonitoring was performed as part of the larger *Crystal River Stream Management Plan* (Management Plan), a project primarily funded by a grant from the Colorado Water Conservation Board (CWCB) State Water Supply Reserve Account, with additional contributions from the Pitkin County Healthy Rivers and Streams Fund, Garfield County, Aspen Skiing Company's Environment Foundation, the West Divide Water Conservancy District and large in-kind contributions from the U.S. Forest Service - WRNF and Rocky Mountain Research Station.

The Management Plan consists of a series of assessments to identify the sources of sediment loading and the geomorphic processes that are degrading water quality and damaging instream and riparian habitat in the Coal Basin sub-watershed and contributing to sedimentation issues in the Crystal River. This information is being supplemented with new stream flow, sediment, water quality, macroinvertebrate and meteorological data, and will be used to prioritize and design a series of site- and process-specific restoration projects for the Crystal River Watershed. As part of the Management Plan, decommissioned mining road reclamation work has also been conducted as a pilot project on ten acres in Coal Basin. This road reclamation effort is assessing the cost-effectiveness and utility of using biochar, coupled with drainage improvements, to improve the water and nutrient-holding capacity of soils, and to enhance the growth of native vegetation. Another part of the Management Plan is a comprehensive assessment of water quality in the Crystal River and Coal Basin (Walker, 2014), which resulted in a recommendation for annual collections of macroinvertebrate and substrate data.

The biomonitoring work described in this report will inform the ongoing Management Plan by providing a macroinvertebrate community health assessment and ancillary substrate data to aid in the interpretation of restoration project results. This effort supplements previous biomonitoring work focused on assessing the condition of aquatic ecosystem health in the Roaring Fork Watershed (RFC & Timberline Aquatics, Inc., 2012), which helped characterize the geographic distribution of aquatic ecosystem conditions on the Crystal River and in Coal Basin, and provided an assessment of macroinvertebrate community health during a notable low-flow year. Specific questions being investigated include:

1. How does macroinvertebrate community health change with changing flow conditions?
2. Does the spatial arrangement of macroinvertebrate health impairment correspond to suspected non-point source impacts or stressors?
3. What sampling locations are needed to efficiently but adequately detect aquatic life use impacts on the Crystal River and in Coal Basin?

1.2 Project Area Description

Detailed scientific descriptions of both the project area and the Crystal River Watershed are provided in the *State of the Roaring Fork Watershed Report 2008* (Clarke *et al.,* 2008) and the stream and riparian inventories completed in 2007 for the Stream Health Initiative (Malone & Emerick, 2007). The discussion below is intended to provide a high-level overview of conditions in the watershed.

Geology and Hydrology

The Crystal River Watershed drains an area of 363 square miles, with elevations ranging from 6,000' to more than 13,000'. It includes several major drainages in addition to the Crystal River. The North and South Fork of the Crystal River are the headwaters that drain the Elk Mountain Range. Yule Creek joins the mainstem near the Town of Marble, Coal Creek enters at the Town of Redstone, and Avalanche Creek joins the Crystal River about five miles further downstream. The largest drainage area, Thompson Creek, is located in the western portion of the lower watershed. Prince Creek drains the northern flanks of Mount Sopris.

The upper watershed is a glacial valley carved mostly in Cretaceous shales. A significant portion of the upper watershed has slopes greater than 30 percent, and during heavy rains, mudflows are common on the steep, glaciated valley slopes. The Town of Marble is affected by debris flows from both Slate and Carbonate Creeks.

Assignation Ridge parallels much of the western side of the Crystal River and is comprised of parallel bands of the Maroon Formation and Triassic, Jurassic, and Cretaceous shales and sandstones. These formations are mostly stable with rock falls being the most common problem. The Town of Redstone is appropriately named for the Maroon Formation located on both the west and east sides of the river valley in that area.

Cretaceous shales are very susceptible to erosion, leading to mudflows, landslides, and other slope instability problems. A large area of Cretaceous shale is found in Coal Basin. Coal mining activities in the steep, upper part of the Dutch Creek drainage were frequently disrupted by debris flows. The area continues to experience frequent debris flows that feed coarse rock and wood into Coal Creek. This rock and wood collects at the confluence of Coal Creek and the Crystal River, causing pooling of water and erosion by both streams and exacerbating the spring flood threat to the Town of Redstone and Highway 133.

The more gently-sloping lower part of the watershed is a mixture of ancient alluviums, gravels, and alluviums. This includes the confluence of the Crystal River with the Roaring Fork River and the confluences of several tributaries with the Crystal River.

There is no significant flow alteration in the Upper Crystal River. On the Lower Crystal River, diversions for both agricultural and municipal use can cause significant flow alteration in August, September, and October. Base and peak flows are minimally altered and in some places base flow increases slightly because of return flows. Two stream gages operate in the Crystal River Watershed. The Crystal River above Avalanche Creek near Redstone gage has recorded stream flows since 1955, and the Crystal River at DOW Fish Hatchery above Carbondale gage was installed in 2006.

Within the watershed there are eighteen CWCB instream flow (ISF)[1] rights, with four on the Crystal River mainstem and the others on various tributaries and headwater stream reaches. The ISF on the Crystal River from the Town of Marble to Avalanche Creek is 80cfs from May 1st to September 30th and 40cfs from October 1st to April 30th. Below Avalanche Creek, the ISF is 100cfs from May 1st to September 30th and 60cfs from October 1st to April 30th. The ISF on the Lower Crystal River is

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1 ISF rights are non-consumptive water rights designated between two specific points to maintain a minimum in-channel flow for the preservation of the natural environment. An ISF may only be held by the CWCB.

often not met because it is junior to most of the municipal and agricultural water rights on the same reach.

Riparian Conditions

According to the Stream Health Initiative (SHI) (Malone & Emerick, 2007), both historic and recent land uses have altered the condition of the riparian habitat, and, consequently, the Crystal River channel. Over time, much of the upland and riparian areas that were historically degraded have been restored by natural processes, but riparian habitat continues to be impacted by historic land uses such as railroad grades built on stream banks, mill sites and town sites built in the floodplain, and domestic livestock grazing. More recently, agricultural, highway, residential, and recreational activities have affected riparian habitat, and new and ongoing development activities continue to encroach upon riparian habitat, alter stream bank vegetation, and degrade riparian habitat. Over 70% of the riparian habitat on the Crystal River, from the Town of Marble to the Town of Carbondale, is 'heavily-modified' or 'severely-degraded'.

1.3 Human Setting

Protected Lands and Conservation Areas

Much of the middle and upper parts of the watershed are in the White River National Forest, including parts of two wilderness areas: Maroon Bells-Snowmass and Raggeds. However, much of the land adjacent to the Crystal River and Yule Creek is private. Within Coal Basin, the headwaters, Coal Creek's confluence with the Crystal River, and several in-holdings are privately owned, as is most of the land along the Crystal River in the lower part of the watershed. Several large Pitkin County Open Space and Trails properties lie along the Crystal River.

Human Impacts

Colorado Highway 133 parallels the west bank of the Crystal River for most of the river's length between the Town of Carbondale and the base of McClure Pass. Constraining the river on the east side is a historic railroad bed. A county road follows the river west from the Highway 133 corridor through the Town of Marble. Prince Creek is also flanked by a county road. The lower sections of Coal and Avalanche Creeks have U.S. Forest Service roads adjacent to them.

The Town of Carbondale, situated between the Crystal and Roaring Fork Rivers, occupies an area of just over twenty square miles. The town currently diverts the majority of its municipal water supply from Nettle Creek, a tributary of the Crystal River. Water for the majority of the town's outdoor water use is diverted from several ditches on the Lower Crystal River. The Town of Marble and the unincorporated area of the Town of Redstone are located in the upper portion of the watershed. The Town of Marble gets its water from two wells located along Carbonate Creek and the Town of Redstone's municipal water source is East Creek.

Coal Basin has been heavily impacted from two coal mining periods (1898 to 1904 and 1955 to 1993) and their associated land use activities (*e.g.*, road building, logging and grazing). The Colorado Department of Reclamation Mining and Safety (CDRMS) completed extensive reclamation work in the area but problems remain, due to the extensive nature of the prior activities' impacts and harsh, natural conditions.

2. Sampling Locations

Several biomonitoring efforts occurred in 2011. RFC sampled twenty sites throughout the Roaring Fork Watershed, increasing the datasets for several long-term monitoring sites and providing baseline conditions for many previously unsampled sites. Five sites were sampled on the Crystal River and one site was sampled at the mouth of Coal Creek. The results of these efforts were reported in *A Review of Aquatic Life and Stream Health in the Roaring Fork Watershed* (Roaring Fork Conservancy & Timberline Aquatics, Inc., 2012). The WRNF also sampled three sites: one on the Crystal River and two in Coal Basin. CDPHE sampled one site on the Crystal River.

In 2012, sampling sites were selected along the Crystal River and in Coal Basin to establish the potential impact of Coal Creek on the Crystal River, to determine the relative influence of several tributaries within Coal Basin on the river, and to identify any potential gradients in stream conditions (*see* Figure 1, Table 1).

Table 1. Sample site descriptions.

Site Name (WQCD ID/River Watch Number/*USFS name*)	UTM E	UTM N	2011 MMI	2012 MMI (RFC and WRNF)
Coal Creek upstream Dutch Creek (*Coal 2*)	300031	4341722	60.9(WRNF)	30.3
Coal Creek downstream Dutch Creek	301262	4341445		18.9
Coal Creek downstream Bear Creek (*Coal 3*)	301832	4341131		32.9
Coal Creek at Forest Boundary (*Coal 4*)	304760	4340314		39.2
Coal Creek at Crystal River (12732A /782/*Coal conf*)	306626	4339468	71.4 (RFC)	59.2
Dutch Creek upstream Coal Creek (*Dutch 1*)	301138	4341292	62.5(WRNF)	19.1
Crystal River at Placita	303892	4333126	75.9(WRNF)	75.7
Crystal River at Genter Mine Bridge (12735/735)	306003	4328691	67.7 (RFC)	
Crystal River upstream of Coal Creek (*Crystal 18.2*)	306596	4339402		56.7
Crystal River downstream Coal Creek (*Crystal 18*)	306708	4339527	83.6(WQCD)	65.7
Crystal River above Fire Station (*Crystal 17.5*)	307075	4340427		63.1
Crystal River below Redstone (12731B/736)	307231	4341371	86 (RFC)	
Crystal River at Crystal Fish Hatchery (12731A/75)	310103	4360973	65.4 and 58.2* (RFC)	
Crystal River at CRMS Bridge (12731/78)	307987	4364462	74.8 (RFC) 63.0(WQCD)	74.6

* Replicate sample.

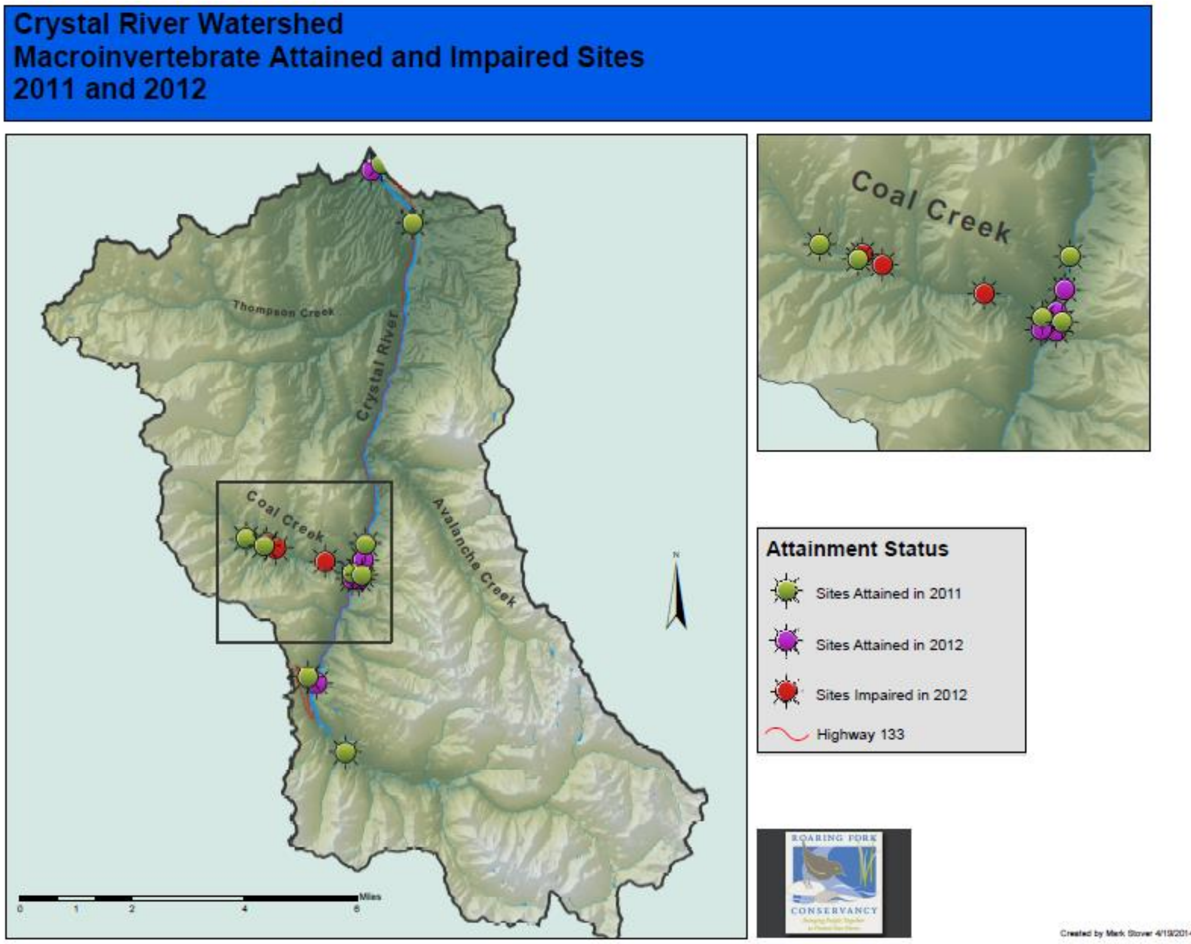

Figure 1. Site location map.

3. Methods

3.1 Benthic Macroinvertebrates

Benthic macroinvertebrate samples were collected in September of 2012, when the best representation of the aquatic insect community is found. Most species of aquatic insects in Colorado have evolved to avoid natural periods of stress associated with runoff and summer storm events. The nymph or larval stages of most aquatic insects are timed for early fall when conditions are moderate.

This study followed protocol originally written by Hawkins, *et al*. (2003), modified by Grove (2012), and developed in conjunction with RFC and Timberline Aquatics, Inc. It is considered semi-quantitative and admissible for submission to the State during WQCD data calls. A total of ten samples of .09m^2 each were taken from five different fast-water habitats when available, two from each site. When fast-water sites were unavailable, shallow slow-water habitat was used. Sampling began at the first fast-water habitat encountered and continued upstream for subsequent samples. Surber net placement was determined by generating two pairs of random numbers between zero and nine, with the first number representing the percent upstream and the second number representing the percent of the stream's width taken from the left bank. When environmental hazards prevented sampling at a site, additional random numbers were generated. When depth or the speed of the stream prohibited sampling, samples were taken near the banks.

At the selected site, the surber sampler was placed such that the mouth of the net was perpendicular to the flow of water. Invertebrates were collected by working from the upstream to the downstream edge of the plot. Stones were picked up and scrubbed directly in front of the net. Once all organic matter was dislodged, the stone was set aside. Rocks lodged in the substrate were rubbed with a focus on cracks and edges. Once all large stones were removed, small substrate was disturbed by hand, raking and stirring down to a depth of about 10cm. When no further organic material was being scrubbed into the net, the net was rinsed vertically, rendering all material to the bottom. The sample was transferred into a bucket for processing and any insects clinging to the net were placed in the sample. During this process, large debris and rocks were rinsed, checked for insects and removed.

Water was added to the bucket and swirled to separate invertebrates and organic material for the sample. Suspended material was poured through a 500µ filter where organic material was collected for inclusion in the sample. When no additional organic material could be decanted, remaining inorganic material was placed in a white plastic washtub and inspected for invertebrates for inclusion in the sample container. The sample was placed in a container filled with 95% ethanol to a concentration that, when diluted by the sample, was about 70-80%. Samples were double-bagged, labeled, and using WQD's chain-of-custody procedures, transported to Timberline Aquatics, Inc. in Fort Collins, CO for sorting and identification.

Timberline Aquatics, Inc. counted and identified macroinvertebrate samples, calculated primary and secondary metrics, and provided a discussion of results for each site. WRNF and RFC provided further analysis and interpretation of results in the context of site-specific concerns on each study reach.

Primary Macroinvertebrate Metrics

Multi-Metric Index (MMI): In the fall of 2010, CDPHE published specific guidelines for benthic macroinvertebrate sampling and analysis using an MMI (CDPHE, 2010). By utilizing five to six equally-weighted metrics, the MMI combines measures of diversity, abundance, pollution tolerance, community structure, and other factors to generate a normalized score of 0-100 for each sample. Scores may then be compared to reference threshold scores for one of three generalized Colorado biotypes: Transition, Mountains and Plains & Xeric.

Streams in the Crystal River Watershed are either Transition or Mountain (Biotype 1 or 2). Biotype 1 includes streams in the Transitional Zone between higher elevation and lower elevation habitats. Sites within Biotype 2 are higher gradient, mountain streams. For the two biotypes, Table 2 displays the range of scores indicating either attainment or impairment for Class I - Cold Water Aquatic Life Use.

Table 2. MMI scores for attainment and impairment in the two biotypes represented in the Crystal River Watershed.

Biotype	Attainment Threshold	Impairment Threshold
Transition (Biotype 1)	>52	<42
Mountains (Biotype 2)	>50	<42

Table 3. Auxiliary metric scores applied to determine attainment for those sites that initially score in the 'grey zone'.

Biotype	HBI	Diversity
Transition (Biotype 1)	<5.4	>2.4
Mountains (Biotype 2)	<5.1	>3.0

MMI scores detect alteration of biological communities resulting from general stressors such as chemical pollution, habitat impact or destruction and altered flow regimes. However, MMI scores do not determine a specific stressor or cause. When impairment is determined, sources and causes can be explored with a suite of other tools, including additional macroinvertebrate indices, and targeted water quality investigations (WQCD, 2011).

Metric scores that fall between the thresholds for attainment and impairment require further evaluation using two auxiliary metrics, the Shannon Diversity Index (Diversity) and the Hilsenhoff Biotic Index (HBI), in order to determine if the site is attaining uses or impaired. Auxiliary scores must be less than the HBI threshold *and* greater than the Diversity threshold to achieve an "attainment" designation. *See* Table 3.

Hilsenhoff Biotic Index (HBI): Most of HBI's value lies in detection of organic pollution, but it has also been used to evaluate aquatic conditions in a variety of other circumstances. Although the value indicating a certain water quality rating may vary among regions, comparison of the values produced within the same stream systems should provide information regarding sites impacted by nutrient enrichment. Values for the HBI range from 0.0 to 10.0, increasing as water quality decreases.

Shannon Diversity (Diversity): Diversity values are used to detect changes in macroinvertebrate community structure. In unpolluted waters, Diversity values typically range from 3.0 to 4.0. In polluted waters this value is generally less than 1.0.

Additional Metrics

In order to assist in the evaluation of aquatic life in the study area, Timberline Aquatics, Inc. compared additional individual metrics among sites, using metrics widely used in western streams. A description of each metric is provided below.

Taxa Richness: Taxa Richness is used to provide an indication of habitat adequacy and water quality. Taxa Richness, or the total spectrum of taxonomic groups present at a given site, will generally decrease when exposed to declining water quality or habitat degradation (Resh & Jackson 1993). The Taxa Richness measurement is reported as the total number of identifiable taxa collected from each sampling location. This metric is also utilized as part of the Biotype 2 MMI calculation.

Ephemeroptera Plecoptera Trichoptera (EPT): The EPT index is based on the assumption that the orders of *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies) and *Trichoptera* (caddisflies) are generally more sensitive to pollution and environmental stress than other benthic macroinvertebrate orders (Lenat, 1988). The value for this metric will naturally vary among river systems, but it can be an excellent indicator of relative disturbance within a specific drainage. The EPT value is expected to decrease in response to a variety of stressors, including nutrients (Wang *et al.,* 2007).

Clinger Taxa: This metric is included in both the Biotype 1 and Biotype 2 MMI calculations. Taxa defined as "clingers" have physically adapted to hold onto smooth substrates in fast water. They typically occupy the open area between rocks and cobble along the bottom of the stream, making them particularly sensitive to fine sediments that fill these spaces. Excessive sedimentation, rapid changes in discharge, or excessive algal growth can cause a reduction in this metric value (Hughes & Brossett, 2009).

Insect Taxa: The number of insect taxa was used as an individual evaluation tool in this study because it has been found to be effective at detecting stress in Colorado mountain streams (CDPHE, 2010). Insect Taxa is reported as a total count of insect taxa at each site. It is expected that the number of insect taxa will decrease as a response to disturbance. Insect taxa are generally considered more sensitive to disturbance than non-insect taxa.

3.2 Discharge

Flow data were obtained from the two stream gages on the Crystal River (*see* Table 4*)*. An ancillary study conducted for Public Counsel of the Rockies and RFC (*Snapshot Assessment of the Roaring Fork Watershed*) documented longitudinal patterns in stream flows for 2012 in the Lower Crystal River (S.K. Mason Environmental, LLC, 2013).

3.3 Substrate

Field personnel used a modified Wolman Pebble Count (Wolman, 1954) to characterize substrate size distributions at each sampling location. Pebble counts provided useful site characteristic metadata to help verify that sample collection occurred in appropriate riffle habitat exhibiting a range of substrate sizes (*i.e.*, high habitat diversity).

4. Results

4.1 Discharge

The 2012 Water Year (October 1st 2011 to September 30th 2012) was characterized by low snowpack, a warm spring with early runoff, and statewide drought; all conditions contributing to low stream flows in the Crystal River Watershed. Conversely, the 2011 Water Year was characterized by high snowpack, a cool spring with later runoff, and no drought conditions in the watershed. Comparing peak and base flows for the two gages on the Crystal River demonstrates the difference in flow between 2011 and 2012 (*see* Figure 2). In 2011, peak runoff at the Crystal River above Avalanche Creek, near the Redstone gage, was 3,790cfs, occurring during the third week of June. In 2012, it peaked at 953cfs and on May 22nd, more than a month earlier than 2011. To put these numbers in perspective, in the 58-year period of record, the 2012 peak was the lowest and the peak in 2011 was the fourth highest.

Figures 3 and 4 show how the differences in peak flows set the stage for differences in base flows for these two years. At the Crystal River above Avalanche Creek gage the river reached a low of 82cfs in early October 2011 and 47cfs in mid-September 2012. For reference, the ISF for this reach is 80cfs from May 1st to September 30th and 40cfs from October 1st to April 30th. At the Crystal River at DOW Fish Hatchery above the Carbondale gage the river reached a low of 70cfs in early October 2011 and 5 cfs in early October 2012. For the lower river, the ISF is 60cfs from October 1st to April 30th. In both of these graphs there are significant spikes in flows due to summer monsoons. Particularly noteworthy are the spikes in 2012 that contributed large pulses of sediment to the river. On July 7th, 2012 the river reached 285cfs; July 16, 304cfs; and August 23, 161cfs.

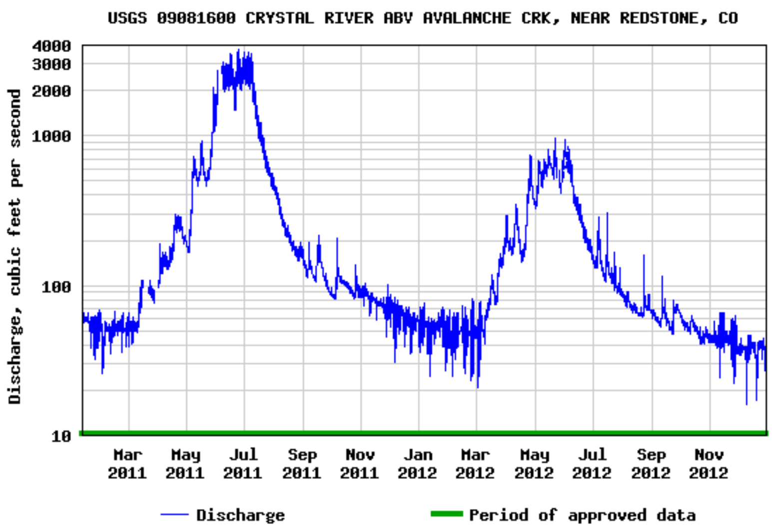

Figure 2. Crystal River hydrograph 2011 and 2012.

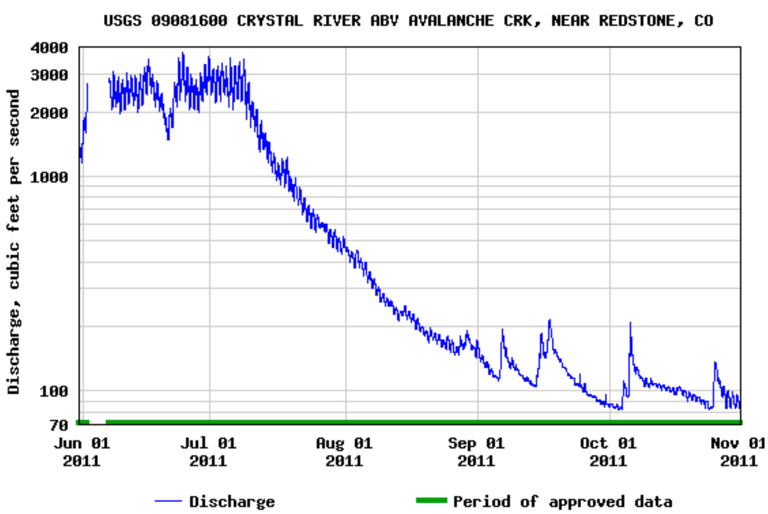

Figure 3. Crystal River hydrograph for summer and fall of 2011. Y-axis ranges from 70 to 4,000 cfs.

While the Lower Crystal Gage quantified flows, it did not adequately capture what happened along the reach, due to numerous diversions and tributary inputs. In 2012, a concurrent effort by RFC and Public Counsel of the Rockies captured longitudinal discharge profiles of streamflow in a downstream direction to characterize these impacts (*see* Figure 5), as reported in *Snapshot Assessment of the Roaring Fork Watershed* (S.K. Mason Environmental, LLC 2013). Overall, flows for 2012 were consistently below historic averages.

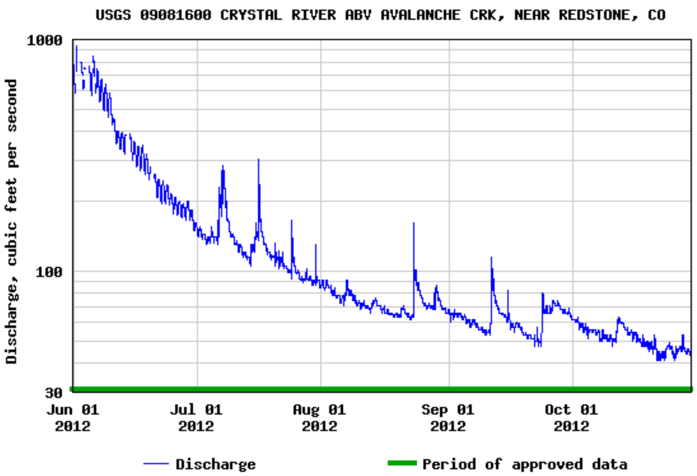

Figure 4. Crystal River hydrograph for the summer and fall of 2012. Y-axis ranges from 30 to 1,000 cfs. Noteworthy are the significant spikes in flow from summer monsoonal events.

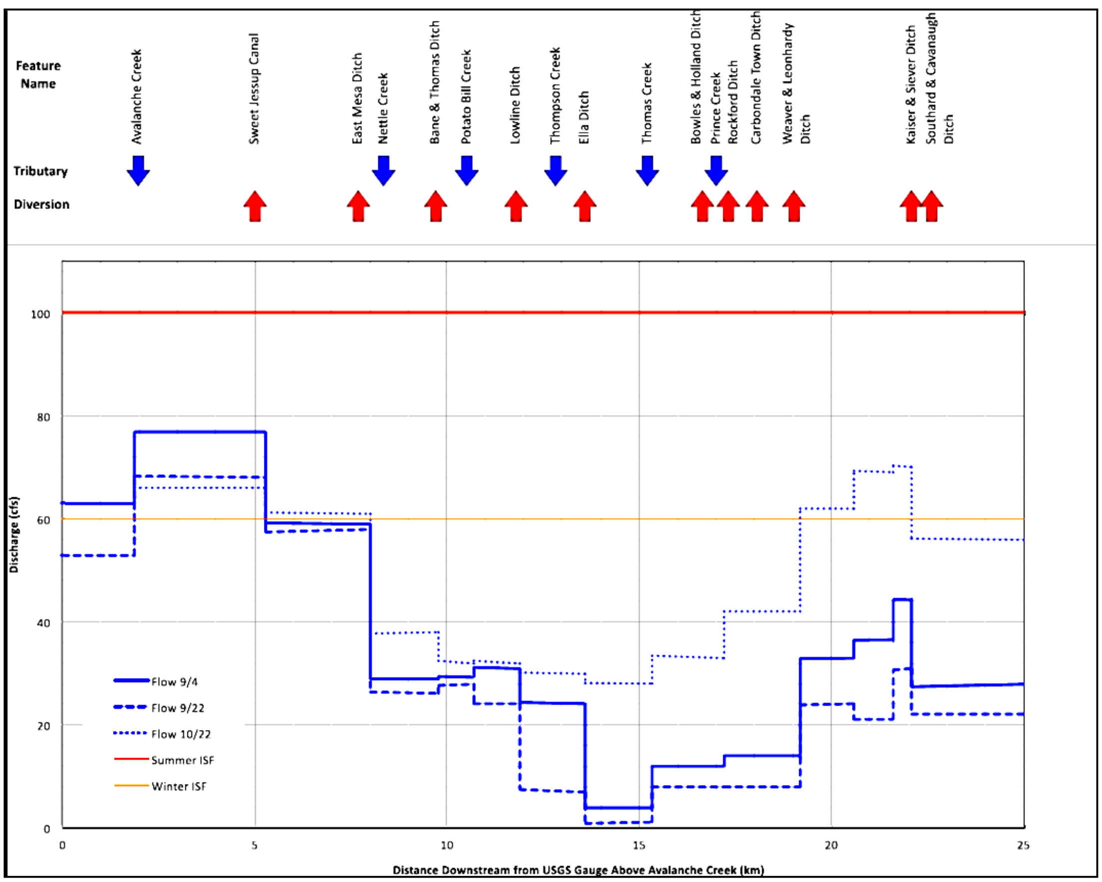

Figure 5. Longitudinal flow profiles, Lower Crystal River 2012. This figure plotted longitudinal changes in streamflow under the assumption that changes in discharge occur at discrete locations where the river experiences tributary inflows or diversions.

Table 4. Discharge at nearest stream gage on sampling dates.

	Crystal River –Placita[1]	Crystal River near Redstone Sites[1]	Crystal River–CRMS bridge[2]	Coal Basin Sites[1]
Date	8/29/2012	9/11/2012	9/11/12	9/4/2012
Flow (cfs)	79	58	7	62

[1] Crystal River above Avalanche Creek gage.
[2] Crystal River at DOW Fish Hatchery gage.

4.2 Substrate

Substrate data can be used to determine if a stream has excessive fine sediments that may impact aquatic life. What constitutes excessive fines can vary by stream size, gradient, and geology. There are various ways to determine if high levels of fine sediment are caused by human actions or are naturally occurring, such as by comparison to a reference reach, or by comparing upstream conditions to downstream, or conditions before to after restoration. Figure 6 compares the percentage of fine sediment for most of the sites where macroinvertebrates were sampled. Individual sites are discussed in more detail in the Appendix.

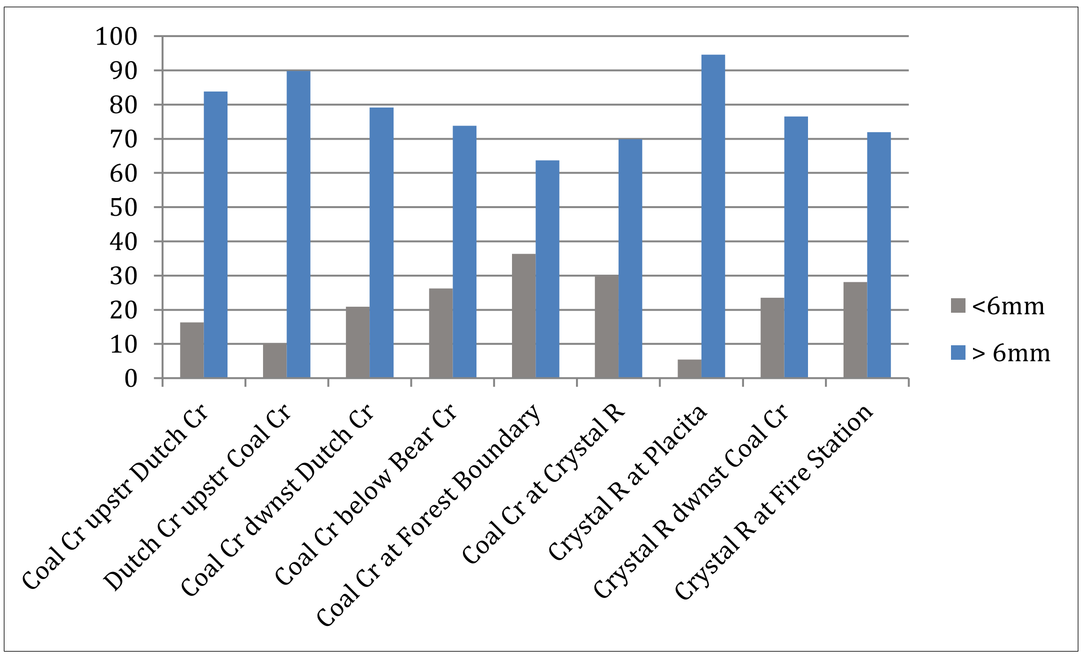

Figure 6. Comparison of percent fines for macroinvertebrate sample locations.

4.3 Macroinvertebrates

MMI Scores

MMI scores are the primary aquatic life data type used in state water quality regulation. However, several additional metrics were employed to assist in the evaluation of conditions in the Crystal River Watershed, as discussed in the following section. Individual sampling sites are discussed in more detail in the Appendix.

As noted above, sample sites in the study area spanned two biotypes, with the majority of sites falling in Biotype 2 (Mountains) and only the lowest site on the Crystal River at the CRMS Bridge falling in Biotype 1 (Transition). For this study, the highest MMI score in 2012 was produced at the Crystal River at Placita site, while the lowest MMI score was produced at the Coal Creek downstream of Dutch Creek site (*see* Figures 7 and 8). In 2011, the highest score occurred at the Crystal River at Fire Station site and the lowest score was at the Dutch Creek upstream of Coal Creek site. In 2012, only one of the six sites sampled in Coal Basin was in attainment for aquatic life use - the one at the confluence of Coal Creek and the Crystal River (*see* Table 5, Figure 7). Three of the Coal Basin sites were also sampled in 2011 and at that time they were all in attainment for aquatic life use. Although the MMI score for the site on Coal Creek at the Crystal River confluence was lower in 2012 than in 2011, it remained in attainment for aquatic life use. In 2011 and 2012 the MMI scores were very similar for most of the sites on the Crystal River and surpassed the threshold for attainment of aquatic life use (*see* Table 5, Figure 8). The MMI does not identify individual causes of impairment; scores detect alteration of biological communities resulting from general stressors or disturbances. When impairment is determined, WQCD recommends that sources and causes be explored with a suite of other tools, including additional macroinvertebrate indices, and targeted water quality investigations (WQCD, 2011).

Functional Feeding Group Composition

An analysis of functional feeding groups in Coal Creek and the Crystal River provided a measure of macroinvertebrate community function. In the fall of 2012, sites located on Coal and Dutch Creeks varied in their distribution of functional feeding groups but were generally dominated by the collector-gatherer or collector-filterer groups (*see* Table 6, Figure 9). The shifts from collector-gatherer dominance to collector-filterer dominance may have been related to a change in the dominance of stressors and subsequent impacts at these sites (*see* Table 6, Figure 9). The most sensitive and specialized macroinvertebrate feeding groups (shredders and scrapers) were present in fairly low numbers (or non-existent) throughout the Coal Creek study area and provided additional evidence of impacts to aquatic communities at these sites.

Study sites on the Crystal River were again proportionally dominated by collector-gatherer and collector-filterer feeding groups; however the shift in proportions observed in these groups at downstream sites suggested that macroinvertebrate communities attained better balance and lacked the dominance of a single feeding group, particularly at the Redstone Firehouse and CRMS Bridge sites (*see* Table 6, Figure 10). The high proportions of the collector-gatherer group produced at sites on the Crystal River upstream and downstream of Coal Creek suggested that these sites were probably the most affected by stressors in the fall of 2012.

In general, the Crystal River sites appeared to sustain a better proportional balance of all feeding groups compared to the Coal Creek sites, with a higher proportion of shredders and scrapers (more sensitive and specialized feeding groups) and higher proportions of predators at most sites (*see* Table 6, Figure 10). The distribution of functional feeding groups in the fall of 2012 indicated that only minor stress was detected at the two sites on the Crystal River near the confluence with Coal Creek; however, stressed conditions existed throughout much of the Coal Creek drainage. Aquatic communities demonstrated improvement in a downstream direction on both streams and generally supported the results obtained from other analytical tools (*see* Table 6, Figures 9 and 10).

Table 5: Metric results from 2012 samples at Coal Basin/Crystal River sample sites in Biotypes 1 and 2. MMI scores which did not meet the CDPHE requirements for attainment of aquatic life use are reported in red. Auxiliary metrics for those sites with non-attainment scores are reported in red (impaired) or green (attainment).

Sampling Area	Coal Basin / Crystal River					
MMI Biotype	Biotype 2					
Metric	Coal Creek upst Dutch Cr	Dutch Creek upst Coal Cr	Coal Creek dwnst Dutch Cr	Coal Creek dwnst Bear Cr	Coal Creek at Forest Boundary	Coal Creek at Crystal R
Taxa Richness	6	9	9	7	8	22
EPT	4	3	4	3	5	11
Clinger Taxa	2	4	4	3	2	8
Insect Taxa	6	9	9	7	7	20
Diversity	2.32	0.96	2.39	1.79	1.44	3.24
HBI	3.10	5.96	5.04	4.07	3.45	2.87
MMI	**30.3**	**19.1**	**18.9**	**32.9**	**39.2**	**59.2**
MMI (2011)	**60.9**	**62.5**		**USFS Sampled no MMI score calculated**	**USFS Sampled no MMI score calculated**	**71.4**

MMI Biotype	Biotype 2				Biotype 1
Metric	Crystal River at Placita	Crystal River upst Coal Cr	Crystal River dwnst Coal Cr	Crystal River at Fire Station	Crystal River at CRMS Bridge
Taxa Richness	28	29	25	31	28
EPT	15	8	9	13	14
Clinger Taxa	8	7	9	8	14
Insect Taxa	25	25	22	27	27
Diversity	3.19	3.44	3.15	3.73	3.50
HBI	1.82	4.65	3.79	3.55	2.24
MMI	**75.7**	**56.7**	**65.7**	**63.1**	**74.6**
MMI (2011)	**75.9**	**USFS Sampled no MMI score calculated**	**USFS Sampled no MMI score calculated**	**86***	**74.8**

* 2011 site located slightly downstream of 2012 site.

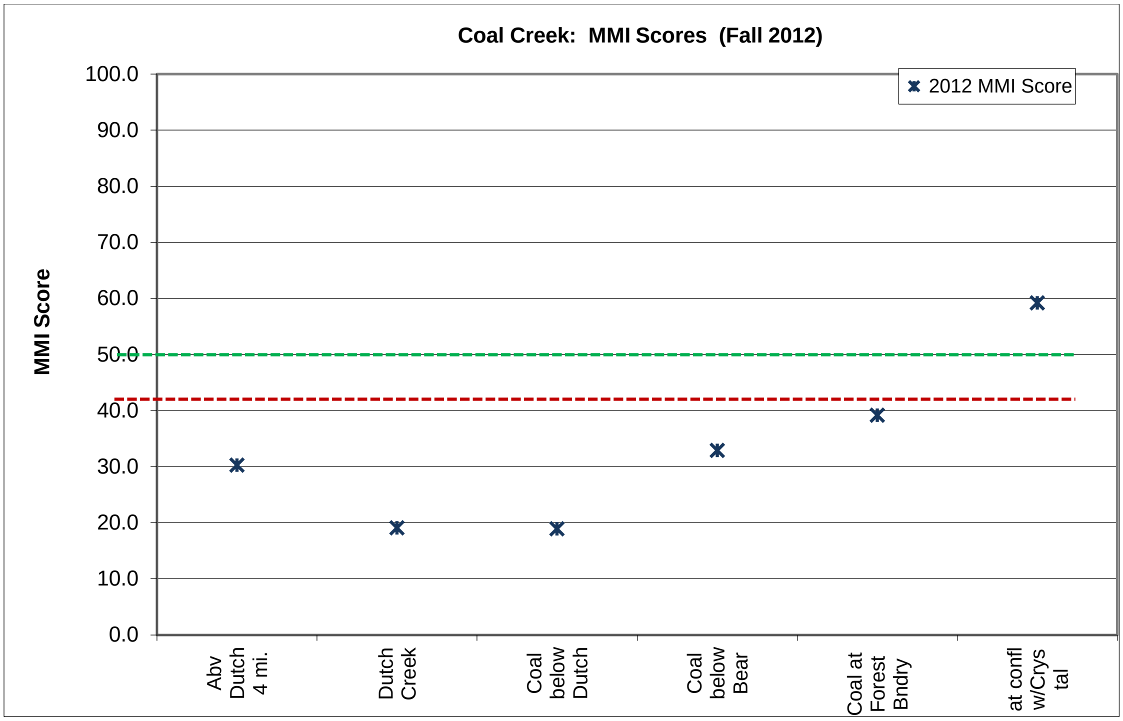

Figure 7. MMI scores in Coal Basin, 2012. The green dashed line represents aquatic life use attainment, the red represents impairment.

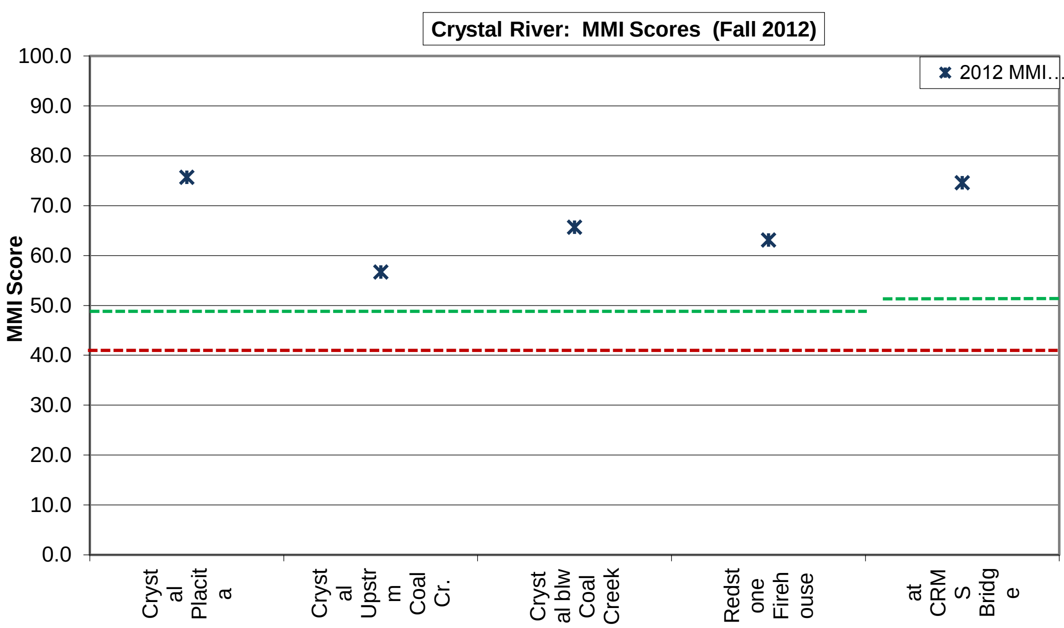

Figure 8. MMI scores on the Crystal River, 2012. The green dashed line represents aquatic life use attainment, the red represents impairment. The change in the attainment threshold at CRMS Bridge site reflects the shift from Biotype 2 to Biotype 1.

Table 6. Relative abundance of functional feeding groups at sites located in the Coal Basin/Crystal River study area in the fall of 2012.

Sampling Area	Coal Basin / Crystal River					
Metric	**Coal Creek upst Dutch Cr**	**Dutch Creek upst Coal Cr**	**Coal Creek dwnst Dutch Cr**	**Coal Creek dwnst Bear Cr**	**Coal Creek at Forest Boundary**	**Coal Creek at Crystal R**
Collector-Gatherer	50.0%	16.0%	31.0%	75.0%	75.0%	32.6%
Collector-Filterer	0.0%	83.1%	48.3%	15.9%	6.7%	9.1%
Shredder	10.0%	0.6%	10.3%	0.0%	0.8%	4.6%
Scrapers	20.0%	0.0%	3.4%	6.8%	0.0%	12.6%
Predators	20.0%	0.3%	6.9%	2.3%	17.5%	41.1%

Metric	**Crystal River at Placita**	**Crystal River upst Coal Cr**	**Crystal River dwnst Coal Cr**	**Crystal River at Fire Station**	**Crystal River at CRMS Bridge**
Collector-Gatherer	39.4%	64.8%	71.4%	35.9%	35.2%
Collector-Filterer	2.2%	4.6%	10.2%	26.3%	39.2%
Shredder	9.2%	7.2%	1.6%	2.9%	3.5%
Scrapers	38.9%	8.1%	6.6%	6.7%	17.5%
Predators	10.3%	15.3%	10.2%	28.3%	4.5%

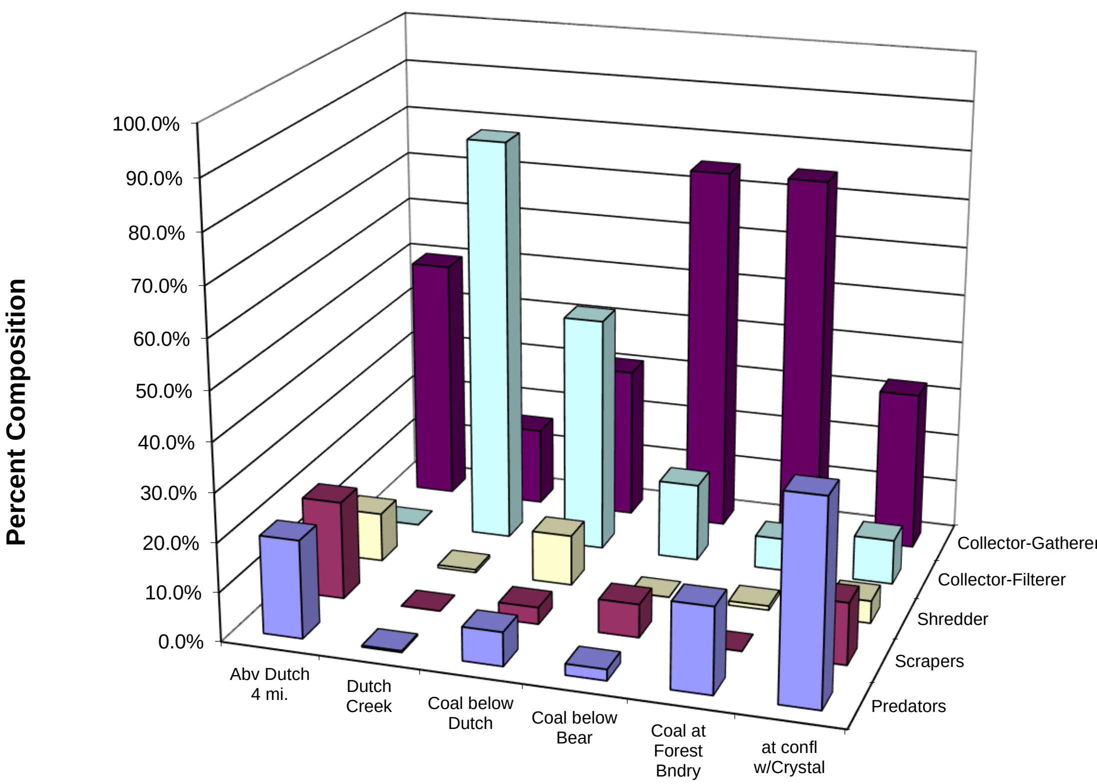

Figure 9. Functional feeding group composition for study sites in Coal Basin, Fall 2012.

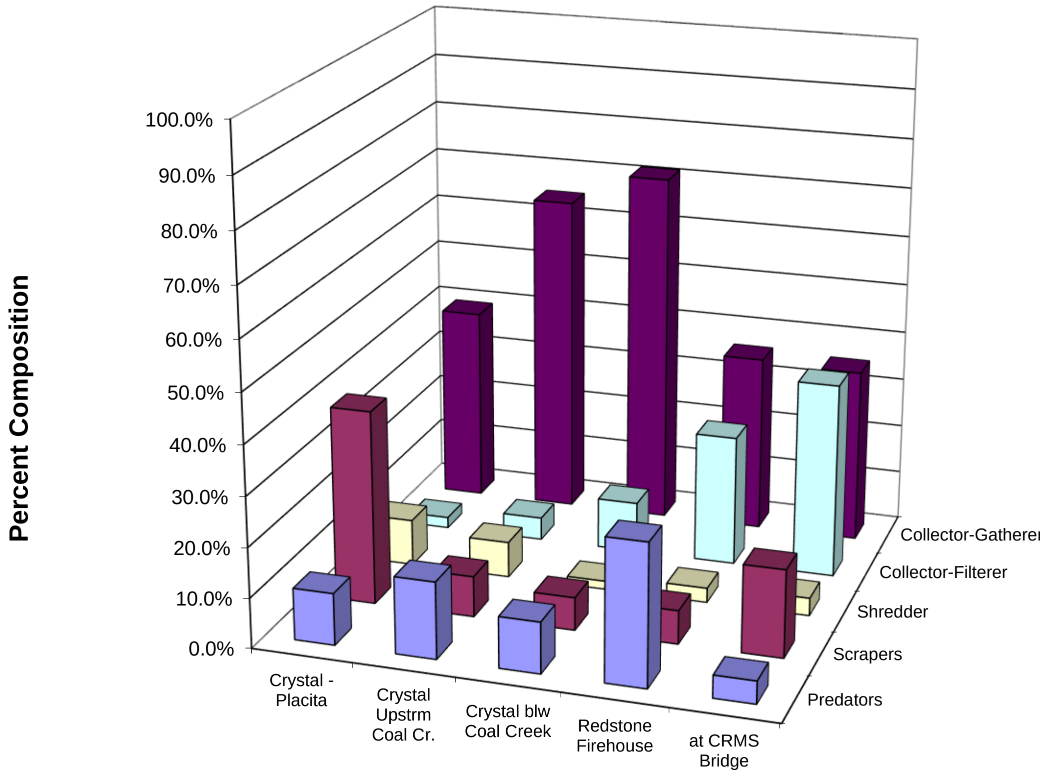

Figure 10. Functional feeding group composition for study sites on the Crystal River, Fall 2012.

5. Discussion and Recommendations

5.1 Macroinvertebrate Scores

Biomonitoring refers to the systematic use of living organisms to evaluate the aquatic environment (Merritt *et al.,* 2008). In recent years, biomonitoring has become an important tool in assessing the quality of rivers and streams (Plafkin *et al.,* 1989; Barbour *et al.,* 1999; Paul *et al.,* 2005; Hawkins, 2006). Biomonitoring programs that utilize benthic macroinvertebrates have advantages not realized by physical or chemical water quality monitoring alone (Ward *et al.,* 2002). Through evolution and ecological processes, aquatic macroinvertebrates have become dependent on specific natural environmental conditions. Consequently, macroinvertebrate assemblages are influenced and altered by a wide range of environmental disturbances and/or pollution.

Results provided by consistent sampling practices and accurate identifications can provide valuable information regarding aquatic conditions. Sustained biological monitoring is essential to understanding the effects of long-term influences, such as changes in land use practices (Likens & Lambert, 1998; Voelz *et al.,* 2005). Certain taxa can survive or even thrive in the presence of various contaminants, so it is often necessary to employ the use of several biotic indices (metrics) in the analysis of macroinvertebrate data. Bonada *et al.* (2006) found that the problems associated with individual biomonitoring tools (metrics) can be improved upon by using a multiple metric index (MMI).

Sampling conducted at six sites in Coal Basin provided a much better picture of aquatic life conditions in Coal Basin. Sites selected bracketed suspected water quality influences from mining and associated activities, and the comparison between 2011 and 2012 results for three of the sites allowed the assessment of flow-related changes. All sites sampled in 2011 and only one of the six sites sampled in 2012 attained CDPHE aquatic use standards. Impaired conditions were most prevalent on Dutch Creek and on Coal Creek downstream from Dutch Creek, with a general downstream improvement. The large negative change in MMI scores from 2011 to 2012 for the upstream sites in Coal Basin may have been caused by periodic flashy flows caused by summer monsoons that moved the very mobile channel bed - thereby negatively influencing macroinvertebrate populations. This same episodic pattern of high and low values is seen in historic macroinvertebrate data collected by the WRNF from 1989 to 1998 (RFC 2012). The number of taxa considered to be generally sensitive to pollutants (EPT taxa) for five sites in Coal Basin was compared to Bear Creek, used as a reference site to calculate a robust number of EPT taxa. All five sites had scores both above and below the robust EPT taxa number (11) at some time during the nine years of sampling (*see* Figure 11).

Functional feeding group composition analysis further supported MMI scores. Collector-filterer and collector-gatherer groups dominated on Dutch Creek and on Coal Creek downstream of Dutch Creek and were less dominant on Coal Creek at the furthest downstream site. The percentages for most sensitive and specialized macroinvertebrate feeding groups (shredders and scrapers) were low on Dutch Creek and on the Coal Creek sites below Dutch Creek. The highest numbers of predators were found on the Coal Creek at Crystal River site. The five sites sampled in 2012 on the Crystal River indicated attainment for aquatic life use which mirrored results for 2011 when three of these sites were sampled. With the exception of the Crystal River at Placita site, all sites on the Crystal River were dominated by collector-gatherer and collector-filterer feeding groups. The Crystal River at Placita site was dominated by shredders and scrapers - the most sensitive and specialized feeding groups. The high proportions of the collector-gatherer group produced at sites on the Crystal River upstream and downstream of Coal Creek suggested that these sites were probably the most affected by stressors in the fall of 2012.

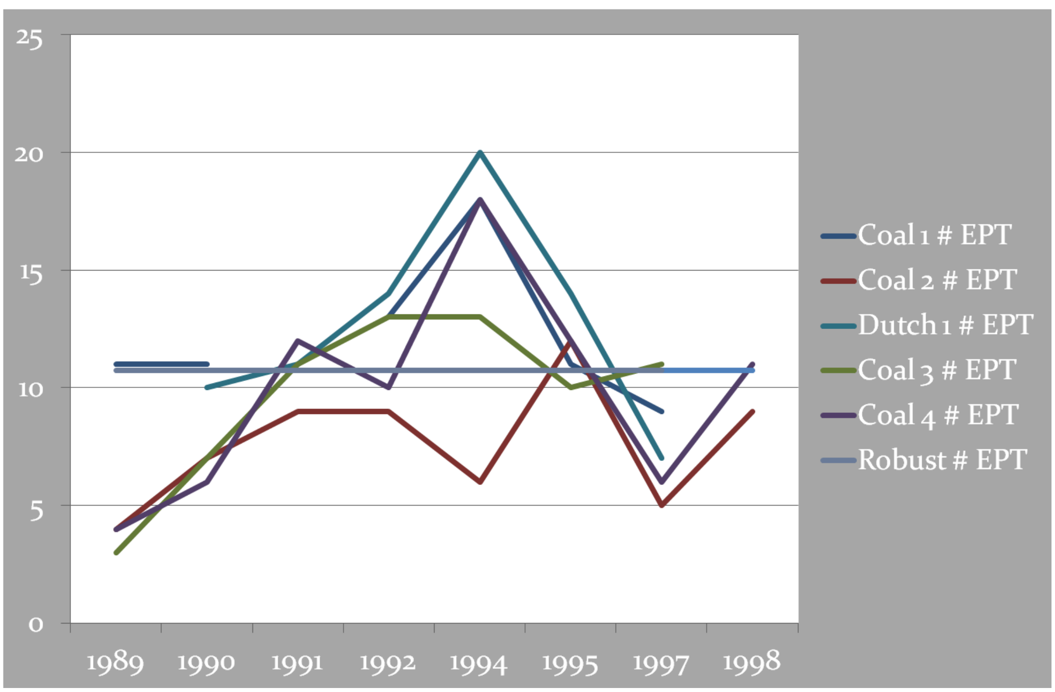

Figure 11. Historic Coal Basin number of EPT taxa comparison (Source: WRNF 2012).

As previously noted, MMI scores cannot speak to a specific cause of impairment; rather they indicate the general presence of one or more perturbations to the stream that result in macroinvertebrate communities that are less functional or balanced than healthy reference streams. In this case, multiple stressors may be contributing to stream impairment, including increased erosion, physical channel alteration and riparian habitat destruction, and altered flow regimes from mining and mine-related activities, as well as drought year flow stress.

5.2 Stress, Disturbance, and Macroinvertebrate Response

Large-scale mining activities and associated activities such as roads, wash plants, refuse piles, grazing and logging previously conducted on unstable, steep slopes, and major channel alterations at the mouth of Coal Creek have severely impacted a large area within Coal Basin. The U.S. Forest Service has identified over 645 acres of Connected Disturbed Areas (CDAs)[2] in Coal Basin that may benefit from restoration (*see* Figure 12). Noteworthy is the large area of natural clearings (6% of the watershed) that most likely contribute high volumes of sediment to the stream channel.

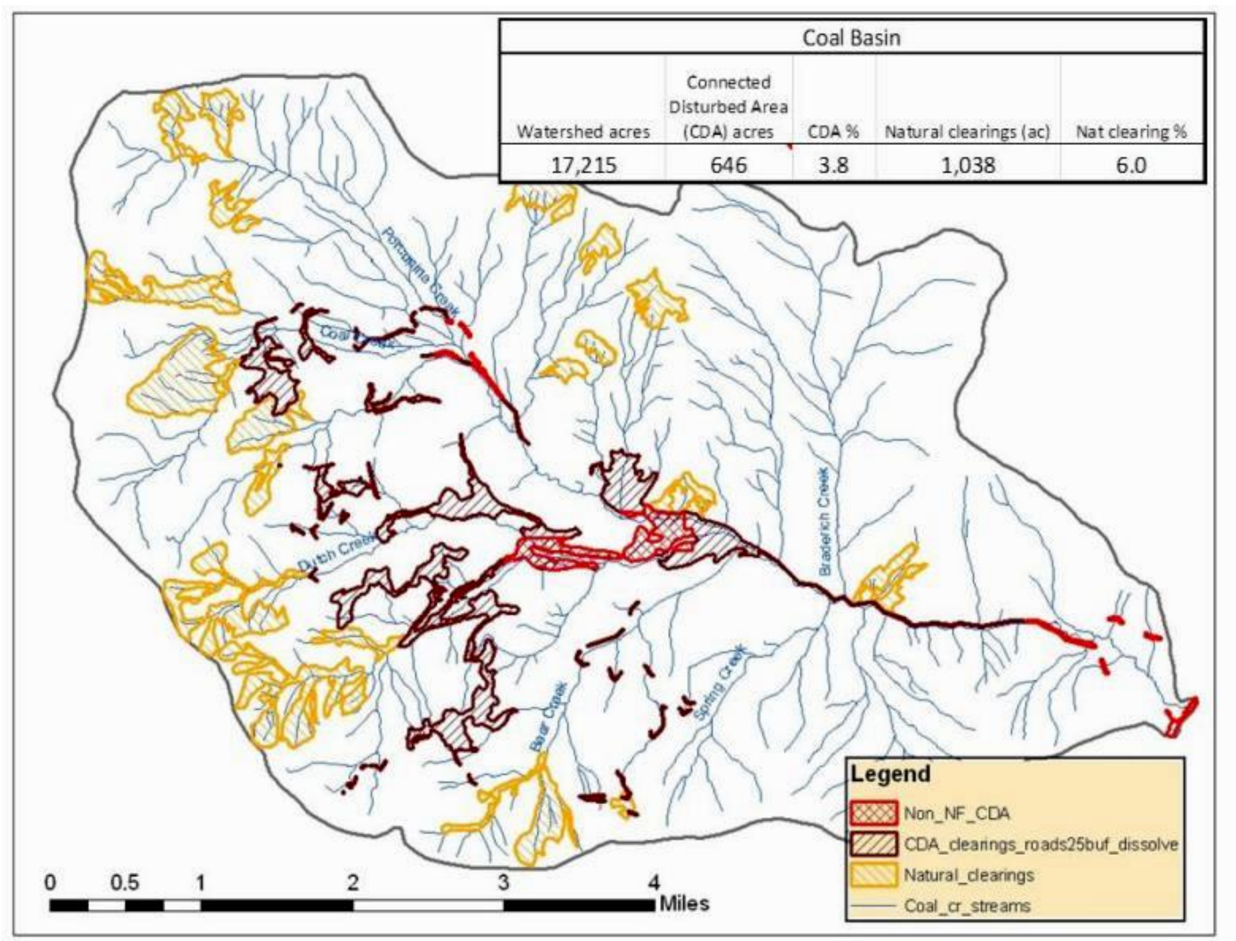

Figure 12. Connected Disturbed Areas in Coal Basin (Source: WRNF).

[2] CDAs are disturbed clearings and roads that artificially intercept and combine natural channels, thereby increasing flows, erosion and sediment transport.

Although the use of macroinvertebrate community analysis to indicate water quality and general stream degradation is well established, research linking degradation to specific causes lags. In considering land use influences on stream ecosystems, Allan (2004) identified several factors contributing to this analytical difficulty, including: 1) co-variation between human uses and natural landscape gradients; 2) multiple mechanisms simultaneously exerting water quality influences; 3) non-linear responses of species and ecosystems to stress and disturbance; and 4) separating modern-day influences from legacy/historical impacts. Each of these factors constitutes a potential issue for accurately linking aquatic life conditions to specific stressors. At this time, macroinvertebrate community analysis is still best used as an integrative measure which speaks to general stress and disturbance in a stream, but falls short of identifying causes. WQCD's current use of MMI scores in statewide assessments reflects this reality by implementing a 'provisional' 303(d) designation until causes can be further explored.

5.3 Next Steps

Continued Biomonitoring

Long-term monitoring studies are essential for the evaluation of aquatic life in systems with increasing water demands or changes in land use practices (Likens & Lambert, 1998; Voelz *et al.,* 2005). Sustained biomonitoring studies also provide a better understanding of impacts from anthropogenic disturbances when compared to natural seasonal and annual variations in benthic communities. Macroinvertebrate sampling in 2012 enhanced the data base for analyzing aquatic life use attainment in the Crystal River and in Coal Basin. Continued biomonitoring may occur at fewer locations to optimize program cost. As the length of the dataset increases, statistical comparison of community conditions with flow conditions may show a correlation between MMI scores and the drought conditions of 2012. Conversely, if no correlation exists, then flow stress may potentially be ruled out as a primary impairment stressor. Overall, extended monitoring can illuminate how conditions change over time, either towards improvement or increased degradation.

- **Recommendation: Continue annual macroinvertebrate sampling in Coal Basin as funding permits; conduct intermittent sampling of sites on the Crystal River on a longer rotating schedule.**

Flow Impairments

The CWCB holds an ISF on the Lower Crystal River from May through September for 100 cfs with an appropriation date in 1975. Most water rights on the river are senior to the ISF. Cooperative agreements with local water users, including the Town of Carbondale, have the potential to boost flows in the lower river, which may benefit aquatic life.

- **Recommendation: Continue current efforts to supplement flows, including local stakeholder agreements to augment instream flows.**
- **Recommendation: Develop more permanent 'drought year protocols' between area stakeholders that may be implemented when specific low-flow or adverse stream temperature criteria dictate.**

Targeted Water Quality Assessments

A companion report to this aquatic life use assessment discusses water quality in the Crystal River and in Coal Basin (Walker, 2014).

Sediment: There is considerable concern about large inputs of sediment into Coal Creek from disturbed areas within its watershed and input of sediment from Coal Creek into the Crystal River.

Sediment input is high during the spring runoff and during intense rainfall events that occur at other times of the year, resulting in channel instability and degradation of aquatic habitat. One approach to monitoring sediment is to focus on the physical effects of excessive sediment input, which can be tracked by periodic depth measurements at selected channel cross-sections and by periodic measurement of cobble and boulder embeddedness at selected locations in the stream bed. An experienced fluvial geomorphologist should be consulted on methodology and selection of measurement locations.

Sediment input can also be characterized by focusing on sediment suspended in the water. The proper way to characterize suspended sediment over time is to monitor sediment load, which is the mass of sediment transported past a given point during a specific time period. Suspended sediment load is the product of suspended sediment concentration times stream flow and thus requires simultaneous measurement of both quantities. Most measurements should be performed during high-flow periods, when sediment loads are expected to be greater. Relatively few measurements are needed during low-flow periods. A starting point is biweekly measurements during the rising and receding limbs of the spring runoff, with three additional measurements spread over the low-flow portion of the year. Depending on results, modification of this schedule should be considered after year three.

One approach to flow measurement in wadeable streams is to use an AA or pygmy meter to determine water velocity, and a wading rod and measuring tape to determine cross-sectional area. This approach may be appropriate for medium and low flows, but safety considerations dictate an alternate method for higher flows, such as making analogous measurements from a bridge. If a staff gage can be affixed to a bridge abutment or some other stable feature, a rating curve relating water height to stream flow could be developed over time, which would simplify future measurements of flow.

Quantification of suspended sediment in streams is problematic. Suspended sediment concentration varies greatly with changes in stream flow. At a given high stream flow, there is also significant point-to-point and moment-to-moment variability within any cross-section, so care must be taken to obtain a representative value of sediment concentration. The silt and clay fraction of the suspended sediment is considered to be evenly distributed throughout a cross-section, and can be characterized using a single grab sample taken near the water surface in the center of the stream. If larger particle sizes (*e.g.*, sand) are a significant part of the suspended sediment load, then use of a depth-integrating sampler (*e.g.*, DH-48 sampler) is better. Depth-integrated samples are collected by moving the sampler up and down from bed to surface to collect water from all depths. Depth-integrated samples from several locations within a cross-section are combined. The logistics of this operation are reminiscent of measuring stream flow, and safety again dictates that sampling would have to occur from a bridge during high flow periods. Analysis for suspended sediment is simple – a known volume of water is filtered, and the mass of the sediment collected on the filter is measured.

- **Recommendation: In order to characterize suspended sediment loads, simultaneous collection of water samples and stream flow measurement should take place at the following locations:**

    - **Coal Creek immediately upstream from its confluence with the Crystal River;**
    - **Coal Creek at other locations bracketing disturbed areas prior to and following restoration, sited so as to quantify the effect of restoration efforts on suspended sediment load;**

- **The Crystal River immediately above the confluence with Coal Creek; and**
- **The Crystal River at a suitable location downstream from the confluence with Coal Creek.**

General water quality parameters: The purpose of monitoring other water quality parameters is to compare conditions against state standards and to detect any trends or patterns that are occurring, such as improvements due to restoration work or the occurrence of new problems. Quarterly sampling should be frequent enough to establish a baseline for water quality across the variety of conditions that occur during a typical year.

If sufficient funds are available, all parameters having state standards could be monitored. Alternatively, monitoring could be limited to a subset that includes those parameters that reveal basic aspects of water quality and those that are of the most concern, based on historical data. This list could include temperature, pH, dissolved oxygen, ammonia, nitrate, nitrite, dissolved iron, total recoverable iron, and selenium. Although there are no state water quality standards for specific conductance, this should also be measured because it is an easy, indirect way to monitor changes in total dissolved solids. Unexpected values for specific conductance would be an indication that conditions had changed and warrant a more detailed study.

- **Recommendation: Water quality sampling is recommended at the following locations:**

    - **Coal Creek immediately upstream from its confluence with the Crystal River;**
    - **The Crystal River immediately above its confluence with Coal Creek; and**
    - **The Crystal River at a suitable location downstream from its confluence with Coal Creek.**

Once a stream segment is provisionally 303(d) listed, WQCD will cooperatively undertake additional water quality monitoring or further investigation and assessment with interested stakeholders to determine impairment causes. While existing baseline chemistry monitoring programs carried out by RFC, CDPHE, and other area stakeholders provide information on long-term average water quality conditions, they may miss important influences. Specifically, sampling regimes for stream chemistry and field parameters which occur on a once-a-month, quarterly, or high-flow/low-flow schedule may fail to observe important water quality influences with short durations. Stormwater runoff is one example of a water quality influence which may be missed by these standard monitoring regimes. Monitoring of stormwater runoff events can be logistically difficult and often very expensive. As a result, few entities may regularly or successfully implement such monitoring programs. However, flushes of metals, complex organics, or high TSS inputs may still contribute significantly to water quality degradation in urban watersheds. Additional water quality studies targeting a specific pollutant or process, rather than baseline monitoring, may shed further light on causes of macroinvertebrate community impairment.

- **Recommendation: Develop and implement a plan to integrate water quality sampling, macroinvertebrate sampling (including pebble counts) and flow measurements. The plan should include parameters to be sampled, frequency of sampling, and locations.**

Channel and Habitat Enhancement

Pitkin County's Stream Health Initiative (Malone & Emerick, 2007) assessed instream and riparian habitat conditions on the Crystal River. The survey did not include any streams in Coal Basin. The 10 reaches of the Crystal River were divided into two segments−Segment 1: Beaver Lake above the Town of Marble to the base of McClure Pass, and Segment 2: Base of McClure Pass to the Roaring Fork River. All of the macroinvertebrate sample sites are located in Segment 2.

The most upstream macroinvertebrate sample site was located within Reach 1. Both the stream habitat and riparian habitat in this reach were ranked as 'Slightly Modified'. The sites on the Crystal River upstream and downstream of the confluence with Coal Creek were located in Reach 3. The instream and riparian habitat condition for this reach was rated as 'Heavily Modified'. Contributing factors to this score were sediment deposition, channel alteration, narrow riparian width and channel flow status. Although flows for this reach are relatively natural, channel flow status received a lower score because "*bank erosion has resulted in stream widening and shallowing, which has effectively reduced the amount of water available to move sediment through the channel. Excessive bank erosion, road gravel, and excessive sediment from destabilized tributary streams, especially Coal Creek, all contribute to a disproportionate sediment load in relation to the amount of flow. Together these factors have created a stream imbalance*". (Malone & Emerick, 2007) The Crystal River at Fire Station site was located on the upstream end of Reach 4. Instream and riparian habitat conditions showed an improvement from upstream conditions showing improved scores in most parameters with a rating of 'Moderately Modified'. The lowest site, Crystal River at CRMS Bridge, was located in Reach 10 and received a rank of 'Heavily Modified', with low scores for sediment deposition, channel alteration, narrow riparian width and channel flow status. However, scores were not as low as they were in Reach 3.

- **Recommendation: A detailed assessment of available locations and project feasibility for geomorphic and habitat enhancement projects in Coal Basin and on the Crystal River are needed.**

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Appendix

Macroinvertebrate Site Descriptions

Overview

This Appendix includes specific location information and site descriptions for each of the macroinvertebrate sampling sites. The short discussion accompanying each site description includes the results of any previous sampling and specifically-identified stream issues from other reports or from expert local knowledge. Table 5 and Figures 9 and 10 from earlier in this report are reproduced below for ease of reference.

Macroinvertebrate samples were collected by WRNF staff and analyzed by Timberline Aquatics, Inc. Site information was provided by WRNF.

Table 5 (reproduced): Metric results from 2012 samples at Coal Basin/Crystal River sample sites in Biotypes 1 and 2. MMI scores which did not meet the CDPHE requirements for attainment of aquatic life use are reported in red. Auxiliary metrics for those sites with non-attainment scores are reported in red (impaired) or green (attainment).

Sampling Area	**Coal Basin / Crystal River**					
MMI Biotype	**Biotype 2**					
Metric	**Coal Creek upst Dutch Cr**	**Dutch Creek upst Coal Cr**	**Coal Creek dwnst Dutch Cr**	**Coal Creek dwnst Bear Cr**	**Coal Creek at Forest Boundary**	**Coal Creek at Crystal R**
Taxa Richness	6	9	9	7	8	22
EPT	4	3	4	3	5	11
Clinger Taxa	2	4	4	3	2	8
Insect Taxa	6	9	9	7	7	20
Diversity	2.32	0.96	2.39	1.79	1.44	3.24
HBI	3.10	5.96	5.04	4.07	3.45	2.87
MMI	**30.3**	**19.1**	**18.9**	**32.9**	**39.2**	**59.2**

MMI Biotype	**Biotype 2**				**Biotype 1**
Metric	**Crystal River at Placita**	**Crystal River upst Coal Cr**	**Crystal River dwnst Coal Cr**	**Crystal River at Fire Station**	**Crystal River at CRMS Bridge**
Taxa Richness	28	29	25	31	28
EPT	15	8	9	13	14
Clinger Taxa	8	7	9	8	14
Insect Taxa	25	25	22	27	27
Diversity	3.19	3.44	3.15	3.73	3.50
HBI	1.82	4.65	3.79	3.55	2.24
MMI	**75.7**	**56.7**	**65.7**	**63.1**	**74.6**

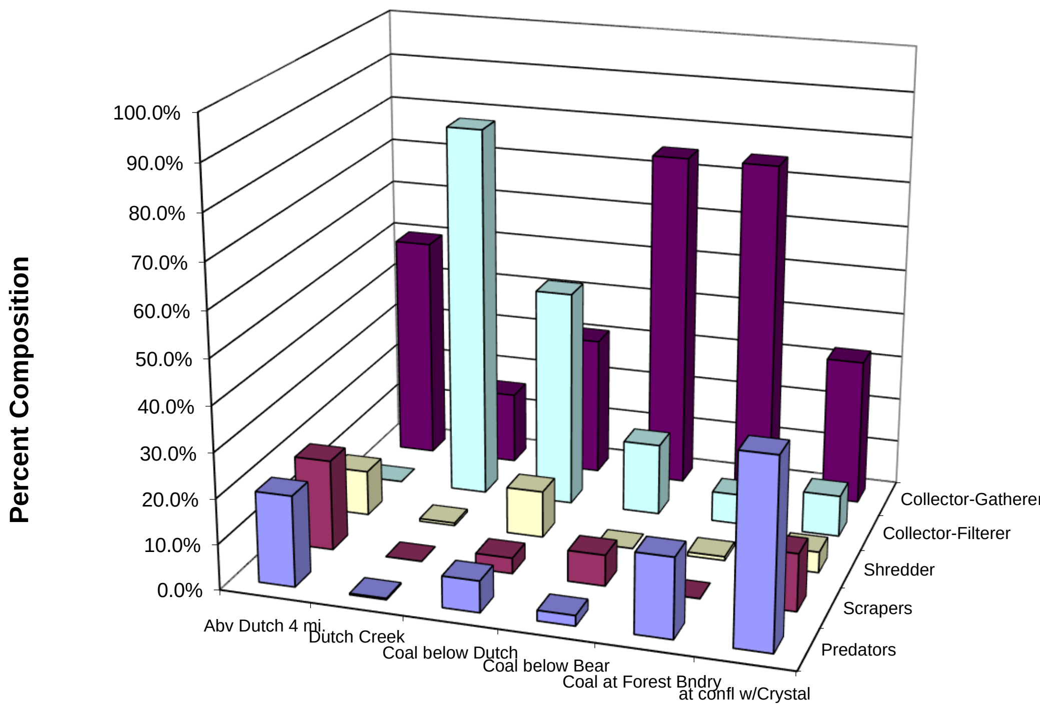

Figure 9 (reproduced). Functional feeding group composition for study sites in Coal Basin, Fall 2012.

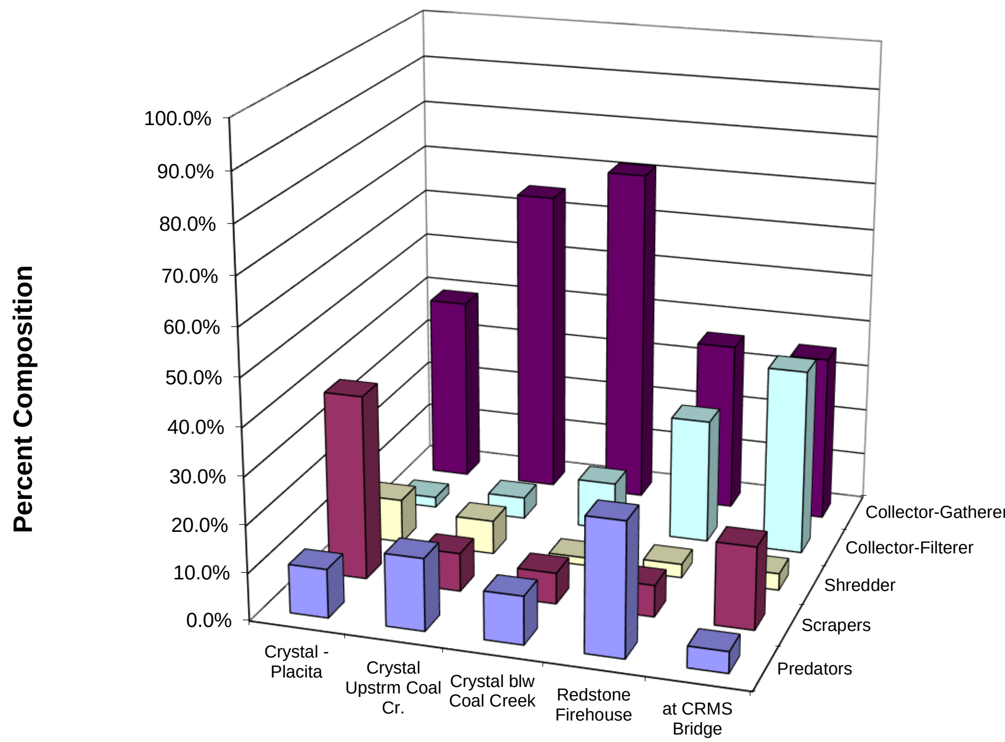

Figure 10 (reproduced). Functional feeding group composition for study sites in Coal Basin, Fall 2012.

A.1 Coal Creek upstream Dutch Creek

River/Stream: Upper Coal Creek
Site ID: Coal Creek upstream Dutch Creek
Location: Coal Creek upstream of Dutch Creek at the White River National Forest boundary at the 160 acre in-holding downstream of Porcupine Creek
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): 13 S E 300031 N 4341722

Site Description:
This site is located on Coal Creek approximately 1 mile upstream of the confluence of Dutch and Coal Creeks. There is a parking lot at the confluence and the road forks, with one fork going up Dutch Creek and the other fork going up Coal Creek. The site is approximately 1 mile past the confluence and is located to the south of the Sooty refuse pile on Coal Creek. The channel width is approximately 15 feet wide and the gradient is between 2% and 4%. The riparian vegetation is a thin strip of willow and cottonwood that is heavily impacted from flashy flows and past mining activity. The upland vegetation is some willow and cottonwood with spruce/fir further up slope. The substrate is cobble with gravel. The channel is hillslope constrained in a Rosgen B type channel. Substrate fines consisted of 16.3% less than 6mm and 83.7% greater than 6mm. The stream is heavily modified at this location from channelization and other upland disturbances.

Benthic Macroinvertebrate Review:
The Upper Coal Creek site was located upstream from Dutch Creek in Biotype 2. This site was selected because it was downstream of previous mining activities and channelization - potential sources of materials causing impairment of the aquatic community. The MMI score produced at the Coal Creek above Dutch Creek site (30.3) indicated that this site was impaired for aquatic life use during 2012 (*see* Table 5). Additional metrics measuring community balance (Taxa Richness and Diversity) and sensitive/specialized taxa (EPT, Insect Taxa, and Clinger Taxa) produced relatively low values and suggested that the macroinvertebrate community at this site was responding negatively to elevated levels of stress. The anthropogenic activities that occurred upstream of this site (mining, channelization, additional disturbances, etc.) were likely the main causes of the site perturbations affecting the macroinvertebrate community, and this conclusion was supported by many of the applied metrics in the fall of 2012. The relatively low HBI metric value of 3.10 suggested that nutrient enrichment was an unlikely contributor to sources of perturbation at this site in the fall of 2012 (*see* Table 5).

The MMI score for 2011 indicated that the stream was in attainment for aquatic life use (*see* Table 7). Several large summer monsoon events occurred between the 2011 and 2012 sampling events. This is likely the cause of the significant decrease in the MMI score from 2011 to 2012. 2011's higher HBI score, an indicator of organic pollution, might be attributable to closer cattle grazing.

Table 7. Comparison of results for 2011 and 2012.

Year	Taxa Richness	EPT	Clinger Taxa	MMI	HBI	Diversity
2011				60.9	4.67	2.92
2012	6	4	2	30.3	3.1	2.32

Site Photo:

Figure 13. Approximately 1/4 mile downstream of the sampling site on Coal Creek.
The actual sampling site had sediment basins on the right bank,
approximately 100 feet from the stream, and a coal refuse pile. (USFS, April 2012)

A.2 Dutch Creek upstream Coal Creek

River/Stream: Dutch Creek
Site ID: Dutch Creek upstream Coal Creek
Location: Dutch Creek upstream of the confluence with Coal Creek approximately 300 feet.
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): 13 S E 301138 N 4341292

Site Description:
This site is located on Dutch Creek, approximately 300 feet from the confluence with Coal Creek and near a low water crossing. The confluence area was very industrialized during the mining era with multiple conveyors belts, a wash plant, load out, coal refuse piles and roads. FS Road 1A follows Coal Creek up to the confluence with Dutch Creek - where it forks. The main road continues up Dutch Creek and FS Road 307 follows Coal Creek. The site is located adjacent to the parking lot. There is an old coal refuse pile located approximately 1,000 feet from Dutch Creek. Historically, the stream confluence area had complex stream habitat, but during the time of the mine operation Dutch Creek was relocated to a 20-foot by 30-foot concrete box culvert/flume that dropped 30 feet vertically into Coal Creek. The recreated channel is heavily modified and simplified. Channel width is approximately 15 feet wide and the gradient is between 2% and 4%. There is no riparian vegetation along this reach. The channel has minimal sinuosity, is unconstrained, and classified as a Rosgen D3 type channel. The stream substrate is cobble with gravel. Substrate fines consisted of 10.2% less than 6mm and 89.8% greater than 6mm. There is no topsoil adjacent to the stream. Further upstream the stream is hillslope constrained and has an overstory of spruce/fir and cottonwood.

Benthic Macroinvertebrate Review:
Impacts from mining development and operations that occurred at this location in the past have produced measurable impacts to the aquatic community. The channelization and lack of riparian vegetation at this site are also potential stressors - likely detected in the macroinvertebrate data analysis (*see* Table 5). The Dutch Creek site was located in Biotype 2 and produced one of the lowest MMI scores (19.1), indicating that this site was impaired for aquatic life use in 2012. Additionally, the auxiliary metrics included in MMI analysis (Diversity and HBI) both produced values indicating that aquatic conditions were severely affected by site perturbation (*see* Table 5). The relatively high HBI value (usually an indication of nutrient enrichment) detected stress, but may have been negatively biased by the poorly-developed macroinvertebrate community at this site (likely the result of historical mining operations, channelization, lack of riparian vegetation and sedimentation). Other individual metrics designed to measure community balance (Taxa Richness) and specialized/sensitive taxa (EPT, Insect Taxa, and Clinger Taxa) produced low values that provided additional evidence of stress to the aquatic community (*see* Table 5).

The 2012 MMI scores were significantly lower than 2011, when Dutch Creek was in attainment for aquatic life use. The diversity score and HBI scores also indicated better conditions for aquatic life use in 2011. Several large summer monsoon events occurred between the 2011 and 2012 sampling events, which is the likely cause of the significant decrease in the MMI score from 2011 to 2012 (*see* Table 8).

Table 8. Comparison of results for 2011 and 2012.

Year	Taxa Richness	EPT	Clinger Taxa	MMI	HBI	Diversity
2011				62.5	3.88	3.81
2012	9	3	4	19.1	5.96	0.96

Site Photos:

Figure 14. Confluence of Dutch Creek (top) with Coal Creek (right).
Sample site is at the top of the photo where the stream bends to the right. (USFS, May 2008)


Figure 15. Confluence of Dutch and Coal Creeks during a summer monsoon event. (USFS, July 16, 2012)


Figure 16. Close up of the same area as the previous photo, capturing the significant sediment load. (USFS, July 16, 2012)

A.3 Coal Creek downstream Dutch Creek

River/Stream: Coal Creek
Site ID: Coal Creek downstream Dutch Creek
Location: Coal Creek just downstream of Dutch Creek
River Watch Site Name and (Number): N/A
WQCD Site ID:N/A
Coordinates (NAD 83): 13 S E 301262 N 4341445

Site Description:
This site is located on Coal Creek approximately 5.5 miles upstream from Hwy 133 on FS Road 307. It is located just downstream of Dutch Creek. The channel is approximately 15 to 20 feet wide with a gradient between 2% and 4%. The riparian vegetation is a thin strip of willow and small cottonwood saplings that is heavily impacted from the flashy flow regime, channel instability and historic land use. There is no topsoil adjacent to the stream. The confluence area was very heavily industrialized during the mining era with multiple conveyors belts, a wash plant, load out, refuse piles, etc. One of the refuse piles is located on the south side of Coal Creek - where the streams

historically converged creating a large alluvial fan. The stream now transports large quantities of sediment and bedload that were historically stored in this alluvial fan. The substrate is cobble with gravel. Substrate fines consisted of 20.9% less than 6mm and 79.1% greater than 6mm. The channel is hillslope constrained in a Rosgen D3 type channel.

Benthic Macroinvertebrate Review:
The Coal Creek site downstream of Dutch Creek was located in Biotype 2 and had potential impacts from the historical mining operations on Coal Creek, as well as the previously discussed impacts associated with Dutch Creek. The lowest MMI score in the study area occurred at this site (18.9), indicating impairment for aquatic life use in 2012 (*see* Table 5). Auxiliary metrics included in the MMI analysis indicated that community balance (measured by Diversity) was impaired, while the HBI value (5.04) was near the threshold for impairment (*see* Table 5). Metrics designed to measure sensitive taxa (EPT and Insect Taxa), along with specialized taxa (Clinger Taxa), were also relatively low and provided additional evidence that the macroinvertebrate community at this site was impaired. The visible sedimentation, lack of topsoil/vegetation, and historical mining operations were likely the top contributors to aquatic perturbation at this Coal Creek site in 2012.

Site Photo:

Figure 17. Coal Creek looking downstream. Dutch Creek enters from the right side. Coal refuse and a road are located on the left side. Coal refuse is also seen on the right side of the photo. (USFS, May 2010)

A.4 Coal Creek downstream Bear Creek

River/Stream: Coal Creek
Site ID: Coal Creek downstream Bear Creek
Location: Coal Creek just downstream of Bear Creek
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): 13 S E 301832 N 4341131

Site Description:
This site is located on Coal Creek downstream of Bear Creek, approximately four miles upstream from Hwy 133 on FS Road 307. The channel is approximately 15 to 20 feet wide with a gradient between 2% and 4%. The riparian vegetation is cottonwood and spruce/fir with a red osier dogwood and willow understory. The channel is hillslope constrained in a Rosgen B/D type channel. The substrate is cobble with gravel. Substrate fines consisted of 26.2% less than 6mm and 73.8% greater than 6mm. The site has been modified due to industrial coal mining operations that ended in the mid 1990's. There was a bridge at this location that was removed in the fall of 2012, but the concrete footers still impact the channel. The sample site is located upstream of the old bridge footers and the confluence with Bear Creek.

Benthic Macroinvertebrate Review:
Conditions at the Coal Creek site downstream of the confluence with Bear Creek have been influenced by extensive channelization, historical mining operations, and sedimentation occurring upstream, as well as localized impacts from the bridge removal and construction that occurred in the fall of 2012. This site was located in Biotype 2 and produced an MMI score (32.9) indicating that aquatic life use was impaired in 2012 (*see* Table 5). Metrics designed to measure community balance (Taxa Richness and Diversity), sensitive taxa (EPT and Insect Taxa) and specialized habits of macroinvertebrates (Clinger Taxa) suggested there was a similar level of stress at this site compared to upstream sites on Coal Creek. The relatively low HBI value (4.07) produced at this site suggested that nutrient-enrichment was probably not a major stress contributor in the fall of 2012 (*see* Table 5). Most individual metric values and the MMI score suggested that macroinvertebrate communities at Coal Creek downstream of Bear Creek reflected continued impairment due to anthropogenic impacts (mining, construction, channelization, etc.) in the fall of 2012.

Site Photos:

Figure 18. Bear Creek confluence with Coal Creek during a summer monsoon event. (USFS, July 2012)

Figure 19. Coal Creek downstream of Bear Creek, looking upstream at the old bridge and stream gage site. The sampling site is at the top of the photo. (USFS, September 2012)

A.5 Coal Creek at Forest Boundary

River/Stream: Coal Creek
Site ID: Coal Creek at Forest Boundary
Location: Coal Creek at lower Forest boundary
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): 13 S E 304760 N 4340314

Site Description:
This site is located on Coal Creek at the White River National Forest boundary, approximately one mile upstream from Hwy 133 on FS Road 307. It is less than ¼ mile upstream of the road crossing with a large culvert on Coal Creek. There is a cattle guard at this location. The channel is approximately 15 feet wide with a gradient between 2% and 4%. The riparian vegetation is cottonwood and spruce/fir overstory with a red osier dogwood and willow understory. The channel is hillslope constrained in a Rosgen B/D type channel. The substrate is cobble, gravel, and small boulders. Substrate fines consisted of 36.3% less than 6mm and 63.7% greater than 6mm. The wood in the channel is comprised of single loose pieces that provide little instream habitat or stability.

Benthic Macroinvertebrate Review:
The Coal Creek sampling site at the lower Forest boundary was located in Biotype 2 and produced an MMI score (39.2) indicating that this site was improved compared to upstream sites, but still impaired for aquatic life use in the fall of 2012 (*see* Table 5). The Diversity and Taxa Richness values produced at the Forest Boundary site suggested poor macroinvertebrate community balance and the EPT value (5) indicated conditions were still not adequate to support diverse communities with sensitive taxa (*see* Table 5). Despite the consensus of metric scores detecting impairment, there was still some improvement in the MMI score compared to upstream sites on Coal Creek (*see* Table 5). It is likely that many upstream sources of site perturbation on Coal Creek continued to influence the macroinvertebrate community downstream, but to a lesser degree at this location.

Sedimentation may have been a dominant source of site perturbation in 2012, based on the Clinger Taxa value (2). Clinger Taxa include macroinvertebrates that require clean substrate and excessive sedimentation often contributes to their absence. Nutrient-enrichment did not appear to be a source of stress in 2012 based on the HBI value (3.45) produced at this Coal Creek site. Results from 2012 macroinvertebrate data analysis suggest that aquatic conditions were moderately disturbed and impaired for aquatic life use at Coal Creek at the lower Forest boundary.

Site Photo:

Figure 20. Coal Creek downstream of Braderich Creek - one mile upstream of the National Forest boundary. This is not the exact sample site, but the in-channel habitat is similar. (USFS, October 2012)

A.6 Coal Creek at Crystal River

River/Stream: Coal Creek
Site ID: Coal Creek at Crystal River
Location: Crystal River/Coal Creek Confluence (In Coal Creek)
River Watch Site Name and (Number): Redstone Park @ Confluence (782)
WQCD Site ID: 12732A
Coordinates (NAD 83): 13 S E 306626 N 4339468

Site Description:
This site is located in the Town of Redstone, between the Hwy 133 bridge that crosses Coal Creek and the Crystal River. The sample site is located on the alluvial fan at the confluence with the Crystal River. The channel is approximately 17 feet wide and averages 0.5 feet deep, with primarily riffles and runs. Gradient is 2% to 4%. The estimated bank full width is 54 feet wide and the channel location changes drastically on a yearly basis. Rosgen channel type is a B/D channel. Substrate is predominately cobble and the riparian zone is a highly mobile alluvial fan with some

cottonwood and shrubs on the north side and no vegetation on the south side (parking lot) at Elk Park. Substrate fines consisted of 30.1% less than 6mm and 69.9% greater than 6mm.

Based primarily on River Watch data, the *2006 Roaring Fork Watershed Water Quality Report* placed this creek on the Watch List due to its placement on the CDPHE watch list for suspended solids (sediment). Exceedances of pH, total phosphorus, aluminum, and iron have been found at this site (*see 2008 State of the Roaring Fork Watershed Report*). Total suspended solid concentrations ranged from < 10 mg/L to 1260 mg/L. On the Crystal River above the confluence with Coal Creek, concentrations ranged from < 10 mg/L to 44 mg/L, while below Coal Creek concentrations ranged from 1.1 mg/L to 215 mg/L.

Benthic Macroinvertebrate Review:
Coal Creek at its confluence with the Crystal River has potential impacts from historical mining operations and other anthropogenic perturbations that mostly exist further upstream. This site was located in Biotype 2 and produced an MMI score of 59.2. It was the only site in the Coal Creek study area that was in attainment for aquatic life use in the fall of 2012 (*see* Table 5). Both auxiliary metrics (Diversity and HBI) also produced values indicating attainment. The HBI value (2.87) suggested that nutrient-enrichment was not a source of disturbance, and the Diversity value (3.24) indicated good community balance at this location (*see* Table 5). The application of additional individual metrics suggested that this site contained fairly healthy aquatic communities with good numbers of sensitive and specialized taxa (measured by EPT and Clinger Taxa metrics). The MMI score in 2012 was lower than 2011, but still in attainment for aquatic life (*see* Table 9)

Table 9. Comparison of results for 2011 and 2012.

Year	Taxa Richness	EPT	Clinger Taxa	MMI	HBI	Diversity
2011	23	14	11	71.4	3.46	2.65
2012	22	11	8	59.2	2.87	3.24

Site Photos:

Figure 21. Coal Creek looking upstream. On the upstream side of
the bridge the channel is highly modified, significantly down cut and
no longer interacting with the floodplain or lower terrace. (RFC, October 2012)

Figure 22. Coal Creek looking downstream at the Crystal River. (RFC, October 2012)

A.7 Crystal River at Placita

River/Stream: Crystal River
Site ID: Crystal River at Placita
Location: At Placita (park at upstream end in a parking lot adjacent to Hwy 133.)
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): 13 S E 303892 N 4333126

Site Description:
This site is located on the White River National Forest approximately 4 miles south of the Town of Redstone along Hwy 133. The channel type is Rosgen type D. The riparian community is mature cottonwood and spruce trees with an understory of willow that provides excellent habitat for a wide array of avian, terrestrial and aquatic species. The channel where macroinvertebrates were sampled is approximately 30 feet wide with an average depth of 0.5 feet to 1 foot. There are 2 year-round channels in this reach and one seasonal channel (spring). The substrate is gravel and cobble. Substrate fines consisted of 5.4% less than 6mm and 94.6% greater than 6mm. Gradient is less than 2%.

Benthic Macroinvertebrate Review:
The study site on the Crystal River at Placita was located in an area that appeared to be upstream of most impacts from anthropogenic sources. This site was located in Biotype 2 and produced the highest MMI score among sites in the Coal Creek/Crystal River study area (75.7), which was well above the threshold for attainment of aquatic life use in the fall of 2012 (*see* Table 5). All individual metrics (Taxa Richness, EPT, Clinger Taxa, Diversity, and HBI) applied to the macroinvertebrate data from this site produced values suggesting minimal or non-detectable perturbations to aquatic life in 2012 (*see* Table 5). The evaluation of community balance (measured by Taxa Richness and Diversity), proportions of sensitive/specialized taxa (EPT, Insect Taxa, and Clinger Taxa), and presence of nutrient-tolerant taxa (HBI) appeared to indicate well-balanced aquatic communities dominated by disturbance-sensitive species at this site (Table 5). The location of the Crystal River at Placita site within the White River National Forest likely limits the impacts associated with human-related activities.

2011 sampling by the WRNF staff showed very similar MMI, HBI and Diversity scores to 2012 (*see* Table 10).

Table 10. Comparison of results for 2011 and 2012.

Year	Taxa Richness	EPT	Clinger Taxa	MMI	HBI	Diversity
2011				75.9	2.3	3.12
2012	25	15	8	75.7	1.82	3.19

Site Photos:

Figure 23. Crystal River at Placita - looking downstream (USFS, June 2010).

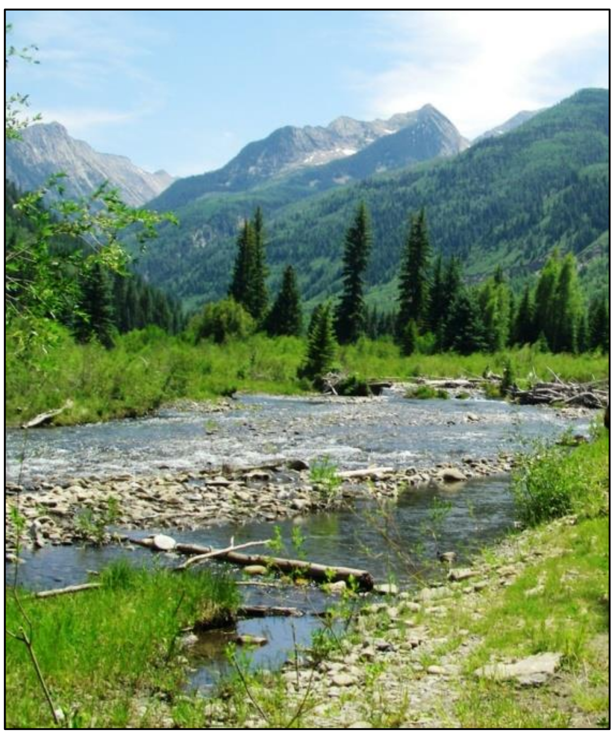

Figure 24. Crystal River at Placita - looking upstream (RFC, June 2012).

A.8 Crystal River upstream of Coal Creek

River/Stream: Crystal River
Site ID: Crystal River upstream of Coal Creek
Location: Between the North Bridge and Coal Creek
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): 13 S E 306596 N 4339402

Site Description:
This site is located between the north Redstone bridge and Coal Creek. The town is on the east bank and Elk Park is on the west bank. It is a heavily modified river segment. The channel type is Rosgen type B. The riparian community is absent on the east bank and the west bank is a steep bank (approximately 15 feet above the channel) with a narrow band of cottonwood and ponderosa pine. Gradient is 2% to 4 %. The channel is approximately 40 feet wide and 0.5 to 1.5 feet deep. The substrate is gravel dominated with cobbles. No pebble count information was collected.

Benthic Macroinvertebrate Review:
The Crystal River upstream of Coal Creek site was located in a somewhat developed area that was potentially impacted by channelization, lack of riparian habitat, and other stressors associated with the development of the Town of Redstone and Elk Park. This site was located in Biotype 2 and produced an MMI score (56.7) indicating that aquatic life use at this location was above the threshold for attainment in the fall of 2012 (*see* Table 5). Additional metrics applied to the macroinvertebrate data at this site produced values suggesting that the community balance (measured by Taxa Richness and Diversity) was relatively healthy (*see* Table 5). Metrics designed to measure sensitive taxa (EPT and Insect Taxa) and specialized taxa (Clinger Taxa) also produced relatively good values. The HBI value (4.65) was at a level suggesting that nutrient-enrichment was not a major source of perturbation at this site (*see* Table 5).

Site Photos:

Figure 25. Sampling site is slightly upstream of the pedestrian bridge. (RFC, August 2012)

Figure 26. Sampling site starts at the boulder on the left and goes downstream. (RFC, August 2012)

A.9 Crystal River downstream of Coal Creek

River/Stream: Crystal River
Site ID: Crystal River downstream Coal Creek
Location: Downstream of Coal Creek approximately 100 meters.
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): 13 S E 306708 N 4339527

Site Description:
This site is located approximately 325 feet downstream of Coal Creek. The Town of Redstone is on the east bank and the stream bank is riprap with no woody vegetation. The west bank has an overstory of mature cottonwood and conifers and the shrub community is dominated by willows. While the historic channel is heavily modified, the west bank riparian area is in good condition. The channel type is Rosgen type B and is approximately 59 feet wide. The gradient is 2% to 4 %. The substrate is gravel dominated with cobbles. Substrate fines consisted of 23.5% less than 6mm and 76.5% greater than 6mm.

Benthic Macroinvertebrate Review:
The Crystal River below Coal Creek site had the potential for impacts from the nearby development of the Town of Redstone and the potential for water quality issues associated with receiving water from Coal Creek. This site was located in Biotype 2 and produced an MMI score (65.7) in attainment for aquatic life use (*see* Table 5). Both auxiliary metrics (Diversity and HBI) also produced values (3.15 and 3.79, respectively) above their thresholds for attainment and provided additional evidence that aquatic life in the Crystal River below Coal Creek was not impacted by stress in the fall of 2012 (*see* Table 5). Additional metrics designed to measure sensitive taxa (EPT and Insect Taxa) and specialized taxa (Clinger Taxa) produced values suggesting fairly healthy aquatic conditions. The HBI value (3.79) indicated that nutrient enrichment was probably not a major source of perturbation at this site in 2012 (*see* Table 5).

Site Photo:

Figure 27. Coal Creek is on the left. Macroinvertebrates were sampled on the Crystal River between the children and the point bar. (RFC, August 2012)

A.10 Crystal River at Fire Station

River/Stream: Crystal River
Site ID: Crystal River at Fire Station
Location: At Redstone Fire Station
River Watch Site Name and (Number): N/A
WQCD Site ID: N/A
Coordinates (NAD 83): 13 S E 307075 N 4340427

Site Description:
This site is located 0.5 miles north of the Town of Redstone on Redstone Blvd behind the fire station. The channel type is Rosgen type F. The riparian community is willow with a mature cottonwood overstory with interspersed spruce. The channel is approximately 40 feet wide and 0.5 to 1.5 feet deep. The substrate is gravel dominated with cobbles. Substrate fines consisted of 28.1% less than 6mm and 71.9% greater than 6mm. Gradient is 2% to 4 %.

Benthic Macroinvertebrate Review:
The Crystal River at Fire Station site was located near the Town of Redstone due to its potential to exhibit impacts associated with residential development. The site is located in Biotype 2 and produced an MMI score of 63.1 in 2012, indicating that it was above the threshold for attainment of aquatic life use (*see* Table 5). The analysis of additional metrics also suggested that aquatic conditions were relatively healthy at this site. Community balance (measured by Taxa Richness and Diversity) and numbers of sensitive/specialized taxa (EPT, Insect Taxa, and Clinger Taxa) appeared to be minimally impacted by site perturbations (*see* Table 5). The HBI value (3.55) indicated that nutrients were not a major source of stress to macroinvertebrates in the fall of 2012.

Site Photos:

Figure 28. Photo taken from the east bank of the Crystal River - looking upstream during spring flow. The sampling site is in the upper right corner of the photo. (USFS, June 2010)

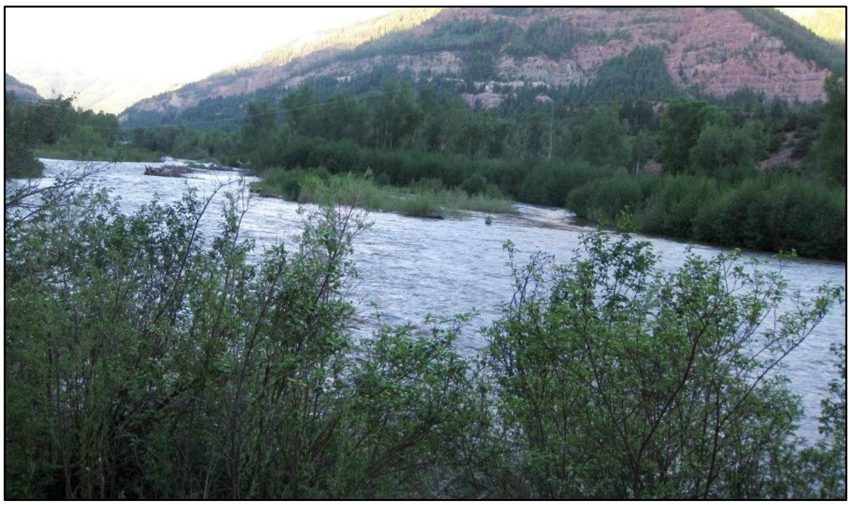

Figure 29. Photo taken from the fire station property - looking upstream at the sampling site. (USFS, June 2010).

A.11 Crystal River at CRMS Bridge

River/Stream: Crystal River
Site ID: Crystal River at CRMS Bridge
Location: CRMS Bridge
River Watch Site Name and (Number): CRMS Bridge (78)
WQCD Site ID: 12731
Coordinates (NAD 83): 13S E 307987 N 4364462

Site Description:
This site is located on the north end of the Town of Carbondale and on the downstream side of the bridge on CR 108, adjacent to the Colorado Rocky Mountain School (CRMS). The site is 0.8 miles from the confluence with the Roaring Fork River. The Rosgen type channel is B. The river at the sample location is approximately 65 feet wide and averages 1.5 feet deep with primarily runs. Substrate is predominately cobble/boulder and the riparian zone is mature cottonwoods and a shrub understory. Stream gradient is between 2% and 4 %. No pebble count was obtained.

The *2006 Roaring Fork Watershed Water Quality Report*, based primarily on River Watch data, placed the entire lower reach of the Crystal River on the Impacted List due to both water quality and quantity concerns. This particular site has exceeded state standards for aluminum in the spring. Macroinvertebrate data collected in 2001 near this site received a Family Biotic Index score indicating that some organic pollution was likely. Exceedances of temperature, aluminum, and iron were found at this site (*see 2008 State of the Roaring Fork Watershed Report*).

Benthic Macroinvertebrate Review:
This site was the farthest downstream sampling location on the Crystal River. It was located in Biotype 1 and had the potential for impacts to the aquatic environment from nearby residential developments, roads, and all of the previously described disturbances upstream. In the fall of 2012, the Crystal River at CRMS Bridge site produced an MMI score of 74.6, indicating that the site was well above the threshold for aquatic life use attainment (*see* Table 5). Additional metrics applied to the data also suggested that the site maintained one of the healthiest aquatic communities in the study in 2012. Metrics designed to measure community balance (Taxa Richness and Diversity), sensitive taxa (EPT and Insect Taxa), and specialized taxa (Clinger Taxa) produced values detecting almost no evidence of disturbance (*see* Table 5). The HBI value (2.24) produced at this site did not detect a negative influence from nutrient enrichment during the sampling event (*see* Table 5). The MMI, HBI and Diversity metrics for this site in 2012 were very similar to 2011 data (*see* Table 11).

Table 11. Comparison of results for 2011 and 2012.

Year	Taxa Richness	EPT	Clinger Taxa	MMI	HBI	Diversity
2011 RFC	32	15	12	74.8	3.4	3.91
2011 WQCD	26	12	12	63	4.39	3.26
2012 WRNF	28	14	14	74.6	2.24	3.5

Site Photos:

Figure 30. Photo taken from the CRMS bridge - looking upstream. (RFC, August 2012)

Figure 31. Photo looking downstream of the CRMS bridge at the sampling site. (RFC, August 2012)