COLORADO
Parks and Wildlife
Department of Natural Resources

Water Resources Section – Aquatic,
Terrestrial, and Natural Resources
Branch

February 23, 2021

Ms. Linda Bassi, Chief
Stream and Lake Protection Section
Colorado Water Conservation Board
1313 Sherman Street, Suite 721
Denver CO 80203

Subject: Instream Flow Recommendations for Cow Creek in Water Division 4, Ouray County to be presented at the March 2021 CWCB Meeting

Dear Ms. Bassi:

The information contained in and referred to in this letter forms the scientific and biological basis for an instream flow (ISF) recommendation on Cow Creek in Water Division 4. The field investigations quantifying this ISF recommendation were conducted by Colorado Parks and Wildlife (CPW) personnel in 2019 and 2020. Investigations related to this ISF were initiated in 2014 with data collection on CPW's Billy Creek State Wildlife Area (SWA), approximately 1.5 miles upstream of the lower terminus of the proposed ISF reach. CPW is interested in protecting this reach of Cow Creek to support the fish, wildlife, and biotic communities, which are important natural resources along Billy Creek SWA Beckett Tract. For a number of reasons, the ISF recommendation was postponed until 2021. This stream reach was presented to interested parties at a number of past ISF Workshops, to the Ouray County and Upper Uncompahgre Basin Needs Assessment Steering Committee in 2019, and to Ouray County Commissioners in December 2020. It is CPW staff's opinion that the information contained in this letter is sufficient for the CWCB's staff to recommend an ISF appropriation to the Board on Cow Creek and to specifically address the findings required in Rule 5(i) of the Instream Flow Program Rules.

CPW participates in the ISF Program and develops instream flow recommendations for the Board's consideration in an effort to address CPW's legislative declarations "… that the wildlife and their environment are to be protected, preserved, enhanced, and managed for the use, benefit, and enjoyment of the people of this state and its visitors … and that, to carry out such program and policy, there shall be a continuous operation of planning, acquisition, and development of wildlife habitats and facilities for wildlife-related opportunities" (See §33-1-101 (1) C.R.S.), and "… that the natural, scenic, scientific, and outdoor recreation areas … be protected, preserved, enhanced and managed for the use, benefit, and enjoyment of the people of this state and (its) visitors … and that, to carry out such program and policy, there shall be a continuous operation of acquisition, development, and management of … lands, waters, and facilities.” (See §33-10-101 (1) C.R.S.).

In addition to these broad statutory guidelines, CPW’s strategic planning document (CPW Strategic Plan, 2015) explains current agency goals to, “[c]onserve wildlife and habitat to ensure healthy sustainable populations and ecosystems.” In order to, “protect and enhance water resources for fish and wildlife populations,” by pursuing, “partnerships and agreements to enhance instream flows, protect reservoir levels, and influence water management activities,” and to, “[a]dvocate for water quality and quantities to conserve aquatic resources.” In addition to the CPW strategic plan, the agency’s fish and wildlife conservation activities are also directed by the State Wildlife Action Plan (2002, Revised 2015). The goals and priorities from these documents direct CPW to advocate for the preservation of the state’s fish and wildlife resources and natural environment, and therefore link CPW’s mission to the goals and priorities of CWCB’s ISF/NLL Program.

Recommended Segments

CPW is proposing an ISF recommendation on Cow Creek from the confluence with Lou Creek (UTM 13S 265665.02, 4231002.60) to the confluence with the Uncompahgre River (UTM 13S 258039.02, 4237591.58). The reach is approximately 7.4 miles in length. Approximately 77 percent of the proposed reach flows through private lands, 4 percent of the reach is on Bureau of Land Management (BLM) lands, and 19 percent of the reach is managed by the state as part of the Billy Creek SWA and Ridgway State Park.

Natural Environment and Biological Summary

Cow Creek is a tributary of Uncompahgre River northeast of the town of Ridgway. The stream drains approximately 108 square miles on the west side of Cimarron Ridge in the northern San Juan Mountains. It is the first tributary input to the Uncompahgre River immediately downstream of Ridgway Reservoir. The stream’s hydrology is snowmelt dominated and flashy; the stream exhibits very high peaks during spring runoff and very depleted baseflow during the irrigation season because of a number of agricultural diversions above the Billy Creek SWA. The basin receives approximately 27 inches of precipitation a year. Average basin elevation is 9,600 feet. The recommended reach of Cow Creek is a third order stream.

Cow Creek is a dynamic river that transports significant sediment with a pronounced diurnal fluctuation. The channel is a mixture of braided and single thread, with notable braiding near the creek’s confluence with the Uncompahgre River. Cow Creek’s natural flow and temperature regimes are an important contribution to the Uncompahgre River tailwaters below Ridgway Reservoir. Directly below the dam, there is low diversity and high biomass of macroinvertebrates. Below Cow Creek’s confluence, the Uncompahgre River has fresh gravels and cobbles, which provide interstitial space for spawning and macroinvertebrate production, and substrate is generally less embedded than above the confluence. This correlates to a higher number of taxa on the Uncompahgre River below Cow Creek’s confluence – including multiple species of stonefly, mayfly, and more pollutant-sensitive taxa overall. Macroinvertebrate diversity is higher downstream of the Cow Creek confluence than above suggesting that the aquatic community in the Uncompahgre River is healthier due to Cow Creek inflows (UWP Water Quality Report, 2012).

In addition to supporting the fishery in the Uncompahgre River below the dam, Cow Creek supports populations of cutthroat, brown, and rainbow trout, along with native populations of bluehead sucker, mottled sculpin, and speckled dace. The bluehead sucker is listed as a Tier 1 Species of Greatest Conservation Need in Colorado, and the Cow Creek population is the last known remaining remnant of the population that historically inhabited the Upper Uncompahgre River Basin. The stream supports complex fish habitat including riffles, runs, pools, and slow-velocity side channel habitat. The macroinvertebrate community in Cow Creek is diverse and abundant; macroinvertebrates noted in the field include two species of caddisfly, stonefly, chironomid, and midge. Cow Creek exhibits a notable diurnal fluctuation, which provides important temperature refuge for the resident fish. During the irrigation season, the daily peaks in the diurnal fluctuation correlate with water temperatures that are below the state chronic standard, as evidenced by CPW's temperature loggers deployed in 2019 (Supplemental Flow and Temperature Data Analysis, Gardunio 2019).

R2Cross Background

Initial biological instream flow recommendations were developed using the R2Cross methodology (Espegren, 1996). R2Cross uses field data that has been collected in a riffle habitat type. Riffles are often the limiting habitat type in streams during low flow events, so maintaining specific conditions across riffle habitat types will also maintain aquatic habitat in pools and runs for most life stages of fish and macroinvertebrates (Nehring, 1979). The R2Cross model uses field data, including a survey of cross-sectional channel geometry, a longitudinal slope of the water surface, and a flow measurement, as input to a single transect hydraulic model. R2Cross uses Manning's equation to model a stage-discharge relationship and compute corresponding hydraulic parameters of average depth, average velocity, and percent wetted perimeter over modeled stages. Maintaining these three hydraulic parameters at specified levels should ensure conditions that allow movement of fish from riffle to riffle and adequate depths, velocities, and oxygenation for production of macroinvertebrates and development of trout eggs.

Baseflow recommendations are typically developed based on the flows that meet two of three hydraulic criteria and summer flow recommendations are based on hydraulic criteria that meet three of three hydraulic criteria (as described in Nehring 1979 and Espergren 1996). Manning's equation relies on a roughness coefficient computed with information collected at the time of the survey, so the most accurate application of the model is for flows ranging between 40 to 250 percent of the surveyed flow.

Initial Biological Flow Recommendations

CPW collected four cross-sectional data sets on Cow Creek in 2019 and 2020. The results of the R2Cross analysis are summarized below.

Cross-Section	Bankfull Channel Width	Date	Flow Measured	Model Accuracy Range	Flow Meeting Two Criteria	Flow Meeting Three Criteria
XS-1	56.9 ft	8/7/2019	90.7 cfs	36 – 227 cfs	Out of range	53.23 cfs
XS-2	44.7 ft	9/11/2019	3.5 cfs	1.4 – 9 cfs	7.43 cfs	Out of range
XS-3	51.8 ft	8/6/2020	5.7 cfs	2.3 – 14 cfs	8.63 cfs	Out of range
XS-4	36.0 ft	8/6/2020	6.0 cfs	2.4 – 15 cfs	5.52 cfs	Out of range
Average Results					**7.2 cfs**	**53 cfs**

The initial biological recommendation is 53 in the summer, which maintains all three hydraulic parameters. The initial biological recommendation over the baseflow period is 7.2 cfs, which maintains the velocity and wetted perimeter criteria but not the depth criteria.

Water Availability (WA)

In order to make a preliminary determination whether water is available for the R2Cross-based flow recommendations and to determine appropriate seasonal transition dates, CPW examined basic hydrologic data using the DWR administrative gage Cow Creek near Ridgway Reservoir (COWCRKCO), which has a period of record from 2008 to 2020. Based on the gage data, water is available for this appropriation.

CWCB also analyzed water availability at key diversions and tributaries to assess water availability limitations over the reach due to complexities from diversions and return flows above the gage. This analysis showed a water availability limitation in late August through mid-September at a select few modeled locations above the gage. Based on these water availability refinements, CPW recommends the following flow rates to preserve the natural environment in Cow Creek to a reasonable degree:

- Runoff Period Flow Recommendation (May 1 – June 30): 53.0 cfs
    - Maintains adequate depth, velocity, and wetted perimeter in the early summer months when fish are active and may wish to move throughout the reach.
- Receding Limb Flow Recommendation (July 1 – July 31): 20.0 cfs
    - Maintains adequate velocity and wetted perimeter and sufficient depths that allow fish to move to more stable habitat as flows being to recede.
- Recessional Step Flow Recommendation (August 1 – August 15): 15.0 cfs
    - Maintains adequate velocity and wetted perimeter and sufficient depths over another transitional period, which allows fish to move to stable habitat as flows recede and water temperatures are high.
- Baseflow Recommendation (August 16 – August 28): 7.2 cfs
    - Maintains adequate velocity and wetted perimeter supporting available habitat for fish in the late summer period when temperatures are high.
- Baseflow Recommendation (Reduced Due to WA August 29 – September 19): 5.9 cfs
    - Maintains sufficient wetted perimeter to provide habitat for fish during the late irrigation season. Larger-bodied fish may be limited to pools and deeper glides during this time period and flow conditions supporting the desired thermal regime may not be met when ambient air temperatures are high.

- Baseflow Recommendation (September 20 – March 31): 7.2 cfs
    - Maintains adequate velocity and wetted perimeter supporting available habitat for fish in pools and deep glides over the overwintering period.
- Rising Limb Recommendation (April 1 through April 30): 20 cfs
    - Maintains adequate velocity and wetted perimeter and sufficient depths to allow fish to move as spring runoff approaches.

CPW is aware of the following major water rights within the proposed reach. Impacts of these diversions on water availability were assessed by CWCB staff and are reflected in the final flow recommendations.
Jolly Ditch (WDID 6800624)
Shortline D Ditch (WDID 6800729)
East Side Ditch (WDID 6800565)
Hayes Teague Ditch (WDID 6800601)
Chaffee Ditch (WDID 6800523)

Conclusion

The purpose of this letter is to formally transmit an ISF recommendation on Cow Creek to CWCB for their Board's consideration. Based on CPW's opinion that there is a flow-dependent natural environment in Cow Creek; this stream can be preserved to a reasonable degree with an ISF appropriation. Please refer to attachments which include; R2Cross field forms, R2Cross output, fish photographs and fish survey data, and photographs at each cross section location.

CPW personnel will be available at the March 2021 CWCB meeting to answer any questions that the Board might have regarding these flow recommendations. We appreciate your consideration.

Sincerely,

Katie Birch

Katie Birch
CPW Instream Flow Program Coordinator
Attachments (as stated)

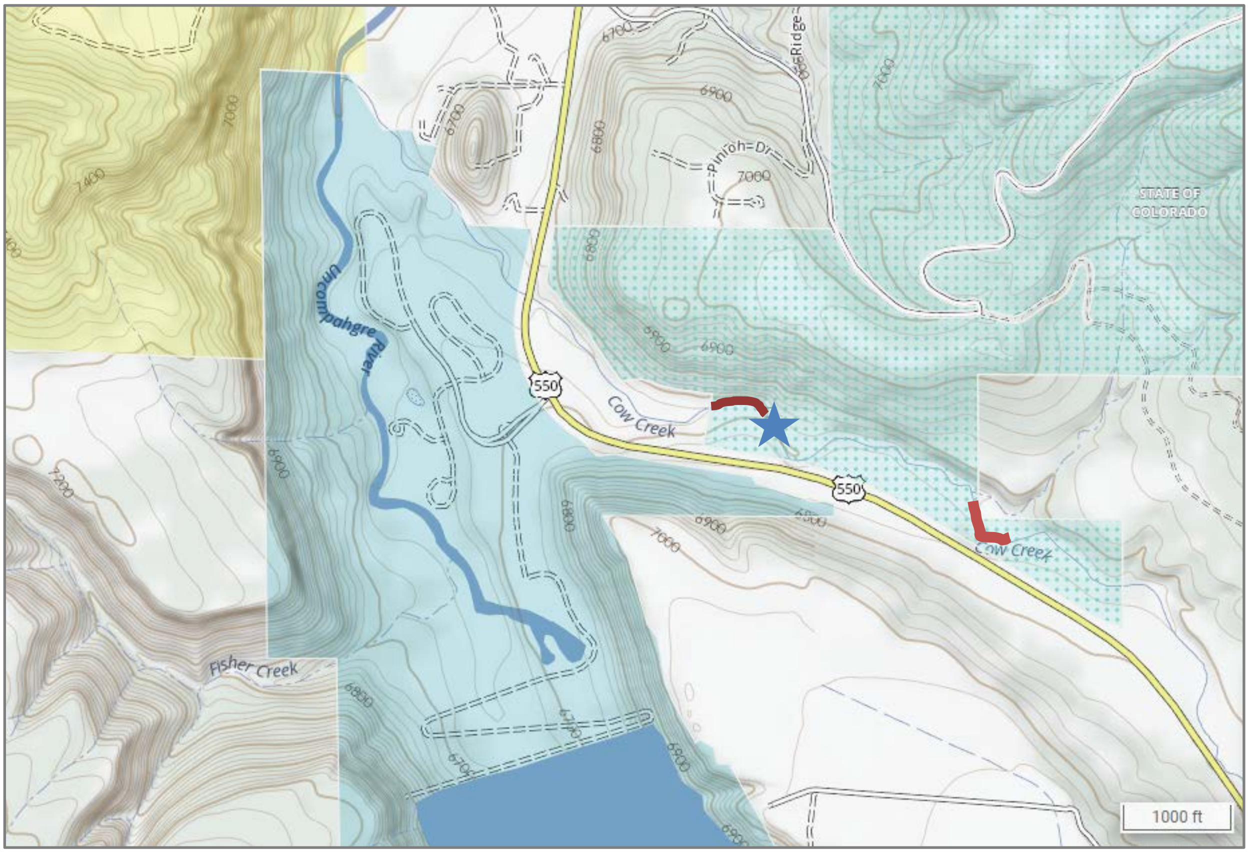
Cow Creek

Eric Gardunio
Aquatic Biologist
Southwest Region

Water: Cow Creek
Location: GU4205 and GU4206
Sampling Date: 8/5/2019 and 9/11/2019
Gear: 3x LR-24 backpack electrofisher
Drainage: Gunnison
Water Code: 39380

OBJECTIVE

Cow Creek was sampled on the Billy Creek State Wildlife Area (SWA) in 2019 to determine the status of the fishery pertaining to a water use study that may further impact water availability in the drainage. Additionally, sampling was done upstream and downstream of a gauging station on the SWA to evaluate the fishery one either side of this potential fish barrier.



Map 1: Map of 2019 Cow Creek sampling locations (red) and gauging station (blue star).

HISTORY

Cow Creek is a heavily diverted, flashy stream that flows north out of the San Juan Mountains east of the town of Ridgway, eventually joining the Uncompahgre River approximately 1.1 miles downstream of Ridgway Reservoir on Ridgway State Park. A USGS gauging station is located on the SWA approximately one mile upstream of the Uncompahgre River confluence. It is currently managed as a Category 302 Salmonid Recreation Stream, with limited recruitment potential, particularly in the upstream section of the stream located on Forest Service land. This section is supplemented with fingerling cutthroat trout plants to maintain a sport fishery. Near the Forest boundary, diversions begin to take water for irrigation purposes, limiting the potential for the fishery. On the downstream end where there is public access on the Billy Creek SWA, the stream is heavily impacted by water diversions, however, there is reportedly a seasonal fishery where fish potentially move in and out of the stream from the Uncompahgre River. These movements may be important, given the tumultuous nature of the system. In summer, when the water is most highly diverted, and much of the stream flow is comprised of return flows, the water may reach temperatures that are too warm, conversely, the system drains a large steep drainage, and often "flashes" causing high flows and often highly turbid water. These changing conditions may necessitate movement from the fish in the stream, and the gauging station could be limiting their ability to reestablish following downstream movements. The 2019 sampling was meant to evaluate the status of the fishery, and to determine if the USGS gauging station on the SWA is limiting these movements by comparing fish populations from a site upstream and downstream of the gauging station. An initial sampling effort was conducted at both sites on August 5, 2019, but high flows limited sampling efficiency, precluding obtaining a population estimate at the upstream site. The two sites were repeated on September 11, 2019 when flows subsided, and population estimates were obtained at both sites. Catch rates were low for some species during individual sampling events, precluding formal population estimates. These estimates are noted below, and represent a minimum population size, given the number of fish sampled.

RESULTS

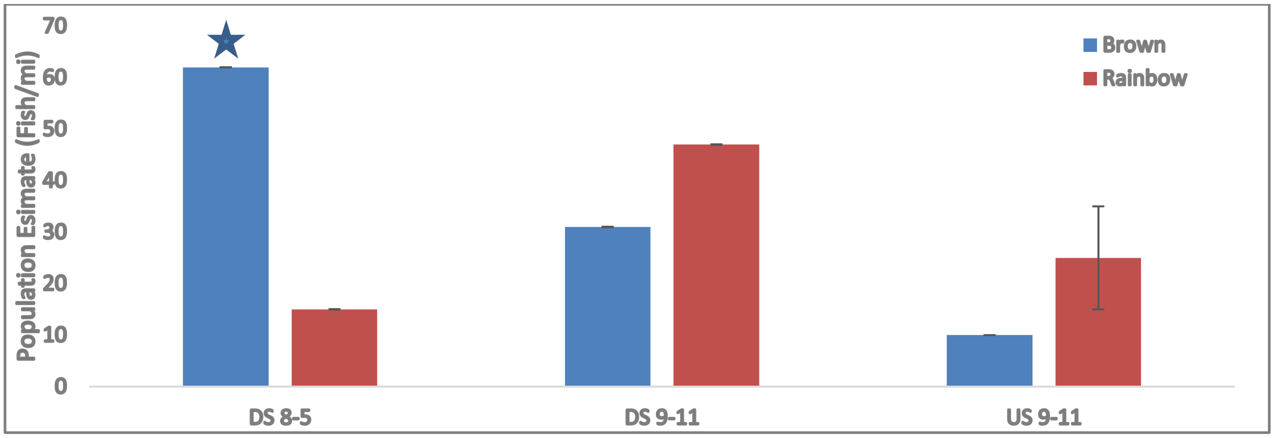


Figure 1: Population estimate (fish/mile) for rainbow (red) and brown (blue) trout including 95% confidence interval for trout captured at either the upstream (US) or downstream (DS) sites on Cow Creek on 8-5-2019 and 9-11-2019. Star indicates minimum population based on true total catch rather than formal population estimates due to insufficient capture rate or depletion.

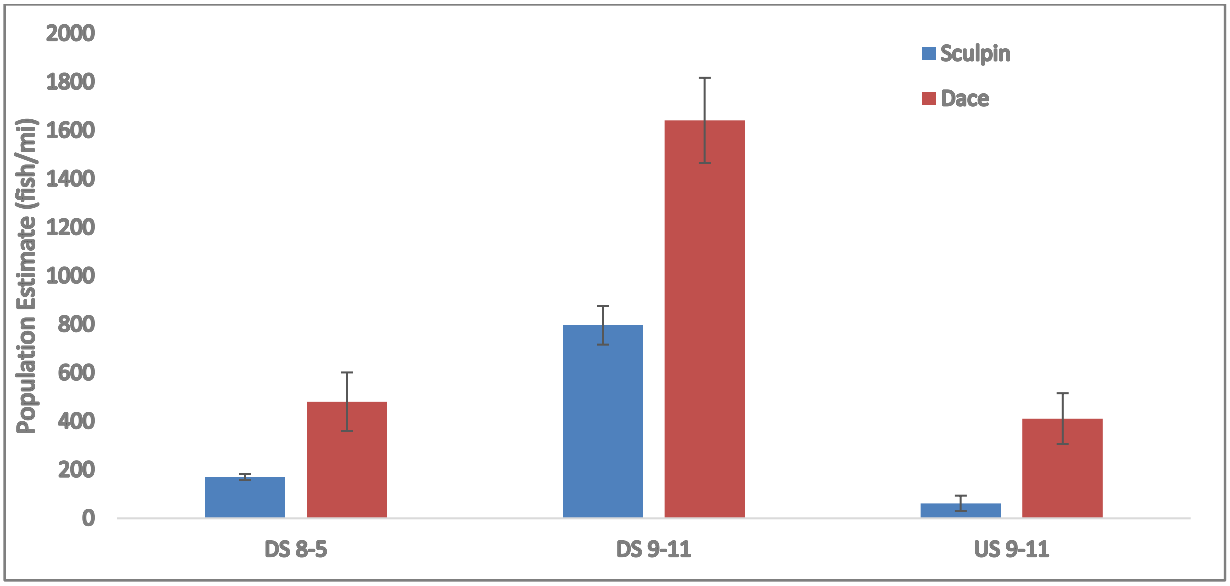


Figure 2: Population estimate (fish/mile) for speckled dace (red) and mottled sculpin (blue) including 95% confidence interval for fish captured at either the upstream (US) or downstream (DS) sites on Cow Creek on 8-5-2019 and 9-11-2019.

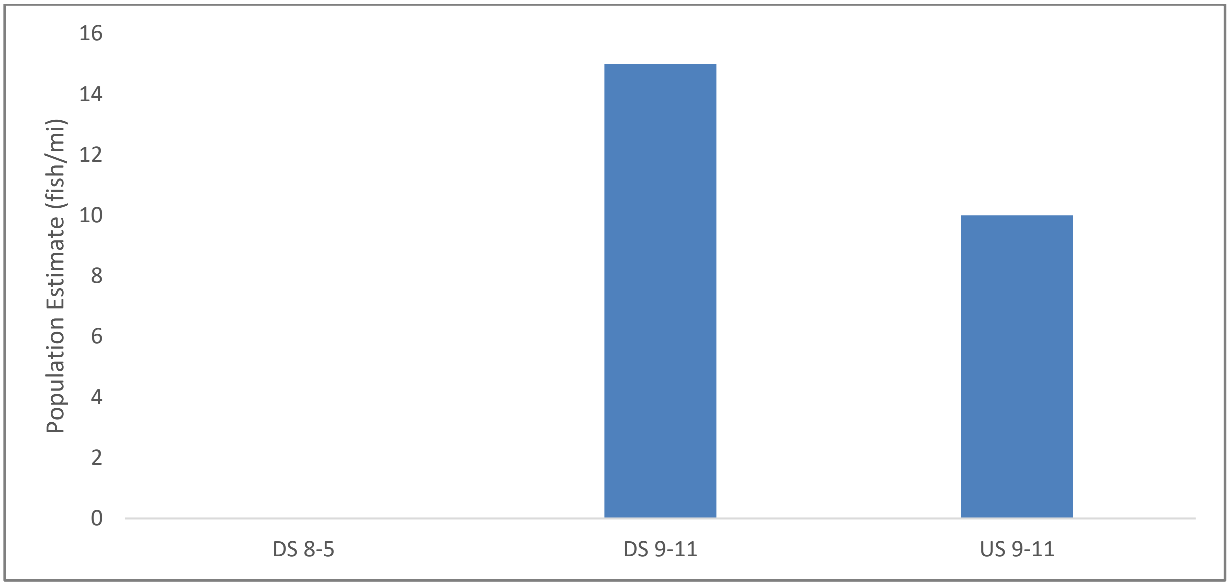


Figure 3: Minimum population estimated by true catch rate (fish/mile) for bluehead sucker captured at either the upstream (US) or downstream (DS) sites on Cow Creek on 8-5-2019 and 9-11-2019.

CONCLUSIONS

The 2019 sampling captured brown and rainbow trout, along with native mottled sculpin, speckled dace and most notably bluehead sucker. Rainbow trout numbers increased at the site downstream of the gauging station from 8-5 until 9-11 (Figure 1), while brown trout numbers decreased. The 9-11 sampling was the only chance to compare upstream to downstream estimates, and the estimates were lower at the upstream site for both rainbow and brown trout. Sculpin and dace numbers were robust in all sampling events (Figure 2), but were somewhat depressed in the 8-5 sampling due to the higher flows. Similar to the trout numbers, on 9-11 the dace and sculpin numbers were higher at the downstream site (Figure 2). The 9-11 sampling resulted in the capture of three bluehead suckers (Figure 3), which was surprising. These fish are probably representative of a remnant population of the native suckers that have subsisted in Cow Creek following the implementation of diversion structures that prevent movement of the species throughout the Uncompahgre River. The inundation of Ridgway Reservoir in 1977 likely further isolated this population to Cow Creek, due to lower water temperatures in the tailwater section of the Uncompahgre River downstream of Ridgway Reservoir.

The fishery on Cow Creek is an interesting one. It appears that the gauging station is a likely barrier, and could be limiting the quality of the fishery on the SWA. The structure is degrading, and fish passage should be a criteria for any new design. Temperature loggers were placed in Cow Creek on the SWA and the Forest Service section in addition to a logger on the Uncompahgre River just upstream of the Cow Creek confluence to evaluate thermal conditions that may facilitate movement into or out of Cow Creek. Utilizing mobile Pit tag reader arrays could be utilized to determine fish movement and the impact of the gauging station on that movement in Cow Creek. This data, paired with thermal data could prove valuable for informing the proposed water project in the drainage, and should be pursued. The fishery on the SWA is average, but the access is great. Supplemental stocking could greatly improve the fishery and should be considered. Stocking sub-catchables in Cow Creek may also provide a rearing opportunity for the fishery in the Uncompahgre.

MANAGEMENT RECOMMENDATION SUMMARY

1. *Management:* Continue to manage a category 302 Salmonid Stream.
2. *Stocking*: Consider stocking either catchable or sub-catchable trout to supplement the fishery.
3. *Regulations:* Given the light angling pressure, general regulations are suitable.
4. *Habitat Improvement*: Evaluate gauging station, and try to replace with passable structure.
5. *Access/Facilities:* Public access is great.
6. *Information/Education:* None necessary.

Large brown trout with Cow Creek gauging station in background

Population Estimates

Water **39380** **Cow Creek** Date **8/5/2019**

Station **GU4205** **On Billy Creek SWA downstream of gauging station**

Species	Total Catch	Min.Cut inch	Max.Cut inch	Total Used	Pass 1	Pass 2	Population Biomass Lb	No./Mile Lb/Mile	No./Acre Lb/Acre
BROWN TROUT	4	4.72		4	2	2			
						95% CI (+/-)			
						Low 95%CL			
						High 95% CL			
MOTTLED SCULPIN	11	0.00		11	10	1	11.00	170.82	56.37
						95% CI (+/-)	0.80	12.46	4.11
						Low 95%CL			
						High 95% CL			
RAINBOW TROUT	2	7.87		1	1	0	1.00	15.53	5.12
						95% CI (+/-)	0.00		
							0.95	14.69	4.85
						Low 95%CL			
						High 95% CL			
SPECKLED DACE	28	0.00		28	21	7	31.00	481.41	158.87
						95% CI (+/-)	7.78	120.80	39.86
						Low 95%CL			
						High 95% CL			
						Overall totals	43	667.76	220.36
							0.95	14.69	4.85

Notes: Water was high ~100 CFS

Combined Summaries

Water **39380** **Cow Creek** Date **8/5/2019**

Station **GU4206** **Upstream end of Billy Creek SWA accessed via S. gate**

Drainage **Gunnison River** UtmX **259623** UtmY **4236460** Elevation **6726 ft**

Length **1040 ft** Width **25.00 ft** Area **0.60 acre**

Surveyors **Gardunio, Birch, Untreiner, Anderson, Kimber**

Gear **3x BPEF** Effort Metric Protocol **PRESENCE/ABSENCE**

Proportional Stocking Density and Catch/Unit Effort

Species	Total Catch	Min Cut inch	Max Cut inch	Total used	Proportional Stock Density (%)	Percent Stock Size	Percent Quality Size	Percent Preferred Size	Percent Memorable Size	Percent Trophy Size	Max Length inches
MOTTLED SCULPIN	1	0.00		1							3.62
RAINBOW TROUT	1	7.87		1	0.00	100.00					10.28
SPECKLED DACE	6	0.00		6							2.99

Mean, Minimum and Maximum Length and Weight

Species	Total Catch	Min cut inch	Max cut inch	Total Used	Length (inches)			Weight (lb)		
					Mean	Minimum	Maximum	Mean	Minimum	Maximum
MOTTLED SCULPIN	1	0.00		1	3.62	3.62	3.62		0.00	0.00
RAINBOW TROUT	1	7.87		1	10.28	10.28	10.28	0.47	0.47	0.47
SPECKLED DACE	6	0.00		6	2.43	1.73	2.99		0.00	0.00

Relative Abundance and Catch/Unit Effort

Species	Total Catch	Min.Cut inch	Max.Cut inch	Total used	Weight Lbs	Percent		Catch per Unit Effort	
						Number	Weight	Number/Effort	Lbs/Effort
MOTTLED SCULPIN	1	0.00		1	0.00	12.50	0.00		
RAINBOW TROUT	1	7.87		1	0.47	12.50	100.00		
SPECKLED DACE	6	0.00		6	0.00	75.00	0.00		

Abundance and Biomass

Species	Total Catch	Min.Cut inch	Max.Cut inch	Total Used	Population estimate	Biomass Lbs	Percent		Density estimates		
							Number	Weight	Lb/Acre	Fish/Acre	Fish/Mile
MOTTLED SCULPIN	1	0.00		1		0.00	12.50	0.00	0.00	1.68	5.08
RAINBOW TROUT	1	7.87		1		0.47	12.50	100.00	0.78	1.68	5.08
SPECKLED DACE	6	0.00		6		0.00	75.00	0.00	0.00	10.05	30.46

Notes: Water was high ~100 CFS

Population Estimates

Water **39380** **Cow Creek** Date **9/11/2019**
Station **GU4205** **On Billy Creek SWA downstream of gauging station**

Drainage **Gunnison River** UtmX **259046** UtmY **4236636** Elevation **6690 ft**
Length **340 ft** Width **25.00 ft** Area **0.20 acre**
Surveyors **Gardunio, Birch, Untreiner, Anderson, Kimber**
Gear **2x BPEF** Effort Metric **PASS** Protocol **TWO-PASS REMOVAL**

Species	Total Catch	Min.Cut inch	Max.Cut inch	Total Used	Pass 1	Pass 2	Population Biomass Lb	No./Mile Lb/Mile	No./Acre Lb/Acre
BLUEHEAD SUCKER	1	5.91		0	0	0			
						95% CI (+/-)			
						Low 95%CL			
						High 95% CL			
BROWN TROUT	4	4.72		2	2	0	2.00	31.06	10.25
						95% CI (+/-)	0.00		
						Low 95%CL			
						High 95% CL			
MOTTLED SCULPIN	49	0.00		49	40	9	51.32	797.01	263.01
						95% CI (+/-)	5.14	79.82	26.34
						Low 95%CL			
						High 95% CL			
RAINBOW TROUT	5	7.87		3	3	0	3.00	46.59	15.37
						95% CI (+/-)	0.00		
						Low 95%CL			
						High 95% CL			
SPECKLED DACE	97	0.00		97	75	22	105.72	1,641.72	541.77
						95% CI (+/-)	11.34	176.09	58.11
						Low 95%CL			
						High 95% CL			
						Overall totals	162	2,516.38	830.41
							0.00	0.00	0.00

Notes: Observed YOY SPD.

Population Estimates

Water **39380** **Cow Creek** Date **9/11/2019**
Station **GU4206** **Upstream end of Billy Creek SWA accessed via S. gate**

Drainage **Gunnison River** UtmX **259623** UtmY **4236460** Elevation **6726 ft**
Length **1040 ft** Width **25.00 ft** Area **0.60 acre**
Surveyors **Gardunio, Birch, Untreiner, Anderson, Kimber**
Gear **2x BPEF** Effort Metric **PASS** Protocol **TWO-PASS REMOVAL**

Species	Total Catch	Min.Cut inch	Max.Cut inch	Total Used	Pass 1	Pass 2	Population Biomass Lb	No./Mile Lb/Mile	No./Acre Lb/Acre
BLUEHEAD SUCKER	2	5.91		2	1	1			
						95% CI (+/-)			
						Low 95%CL			
						High 95% CL			
BROWN TROUT	3	4.72		2	2	0	2.00	10.15	3.35
						95% CI (+/-)	0.00		
						Low 95%CL			
						High 95% CL			
MOTTLED SCULPIN	11	0.00		11	8	3	12.20	61.94	20.44
						95% CI (+/-)	6.24	31.68	10.46
						Low 95%CL			
						High 95% CL			
RAINBOW TROUT	5	7.87		5	4	1	5.00	25.38	8.38
						95% CI (+/-)	1.95	9.89	3.26
						Low 95%CL			
						High 95% CL			
SPECKLED DACE	67	0.00		67	47	20	81.07	411.61	135.83
						95% CI (+/-)	20.69	105.03	34.66
						Low 95%CL			
						High 95% CL			
						Overall totals	100	509.08	168.00
							0.00	0.00	0.00

Notes: Observed YOY SPD

COLORADO WATER
CONSERVATION BOARD

FIELD DATA
FOR
INSTREAM FLOW DETERMINATIONS

COLORADO DIVISION OF WILDLIFE

LOCATION INFORMATION

STREAM NAME: Cow Creek
CROSS-SECTION NO.: 1
CROSS-SECTION LOCATION: on SWA
DATE: 8/7/19
OBSERVERS: Birch Fardunio
LEGAL DESCRIPTION ¼ SECTION: SECTION: TOWNSHIP: N/S RANGE: E/W PM:
COUNTY:
WATERSHED:
WATER DIVISION:
DOW WATER CODE:
MAP(S): USGS: 13S 0259916 4236234
USFS:

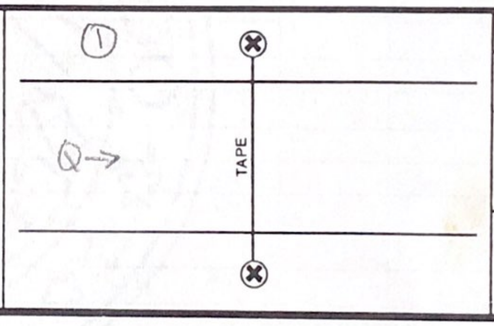
SUPPLEMENTAL DATA

SAG TAPE SECTION SAME AS DISCHARGE SECTION: [✓ YES]/ NO
METER TYPE: FlowTracker File = "Cow.01"
METER NUMBER:
DATE RATED:
CALIB/SPIN: ______ sec
TAPE WEIGHT: ______ lbs/foot
TAPE TENSION: ______ lbs
CHANNEL BED MATERIAL SIZE RANGE:
PHOTOGRAPHS TAKEN: YES/NO
NUMBER OF PHOTOGRAPHS:

CHANNEL PROFILE DATA

STATION	DISTANCE FROM TAPE (ft)	ROD READING (ft)
⊗ Tape @ Stake LB	0.0	~ 5.94
⊗ Tape @ Stake RB	0.0	~ 6.06
① WS @ Tape LB/RB	0.0	/
② WS Upstream	78	5.40
③ WS Downstream	"	5.98
SLOPE		

SKETCH



LEGEND:
Stake ⊗
Station ①
Photo ◇→
Direction of Flow ← →

AQUATIC SAMPLING SUMMARY

STREAM ELECTROFISHED: YES/NO
DISTANCE ELECTROFISHED: ______ ft
FISH CAUGHT: YES/NO
WATER CHEMISTRY SAMPLED: YES/NO

LENGTH - FREQUENCY DISTRIBUTION BY ONE-INCH SIZE GROUPS (1.0-1.9, 2.0-2.9, ETC.)

SPECIES (FILL IN)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15	TOTAL
See recent fish survey																	
results																	

AQUATIC INSECTS IN STREAM SECTION BY COMMON OR SCIENTIFIC ORDER NAME:

COMMENTS

Flow taken in nearby run. High flow somewhat turbid.

FORM #ISF FD 1-85

Benchmark 4.69 -> 4.69

DISCHARGE/CROSS SECTION NOTES

STREAM NAME: Crw Creek

CROSS-SECTION NO.: 1

DATE: 8/7/19

SHEET ___ OF ___

BEGINNING OF MEASUREMENT

EDGE OF WATER LOOKING DOWNSTREAM: (0.0 AT STAKE) [✓ LEFT] / RIGHT

Gage Reading: ______ft

TIME:

Features: Stake (S) Grassline (G) Waterline (W) Rock (R)	Distance From Initial Point (ft)	Width (ft)	Total Vertical Depth From Tape/Inst (ft)	Water Depth (ft)	Depth of Observation (ft)	Revolutions	Time (sec)	Velocity (ft/sec)		Area (ft²)	Discharge (cfs)
								At Point	Mean in Vertical		
Stake	0		4.78	-							
	23.4		4.86	-							
BF	28.5		4.79	-							
WS	30.0		5.94	0							
	32.5		6.53	0.65							
	35.0		6.66	0.8							
	37.5		6.35	0.5							
	40.0		6.60	0.9							
	42.5		6.85	1.15							
	45		7.05	1.25							
	47.5		7.00	1.25							
	50		6.85	1.10							
	52.5		6.85	1.10							
	55.0		6.79	1.10							
	57.5		6.75	0.95							
	60		6.70	1.05							
	62.5		6.75	1.00							
	65.0		6.65	0.90							
	67.5		6.50	0.7							
	70		6.30	0.4							
	72.5		6.35	0.4							
	75		6.35	0.4							
	77.5		6.50	0.5							
	80.0		6.45	0.5							
	82.5		6.35	0.3							
WS	84.0		6.06	0							
BF	85.4		4.82	-							
Stake	92.1		4.85	-							
TOTALS:											

End of Measurement

Time:

Gage Reading: ______ ft

CALCULATIONS PERFORMED BY:

CALCULATIONS CHECKED BY:

COLORADO WATER
CONSERVATION BOARD

FIELD DATA FOR INSTREAM FLOW DETERMINATIONS

COLORADO DIVISION OF WILDLIFE

LOCATION INFORMATION

STREAM NAME: Cow OZ

CROSS-SECTION NO.: 02

CROSS-SECTION LOCATION: Above near SWA

DATE: 9/11/19

OBSERVERS: Birch Garduno Anderson Kimber

LEGAL DESCRIPTION

¼ SECTION:

SECTION:

TOWNSHIP: N/S

RANGE: E/W

PM:

COUNTY:

WATERSHED:

WATER DIVISION:

DOW WATER CODE:

MAP(S): USGS:

USFS:

SUPPLEMENTAL DATA

SAG TAPE SECTION SAME AS DISCHARGE SECTION: YES / [✓ NO]

METER TYPE: Flow Tracker

METER NUMBER:

DATE RATED:

CALIB/SPIN: ______ sec

TAPE WEIGHT: ______ lbs/foot

TAPE TENSION: ______ lbs

CHANNEL BED MATERIAL SIZE RANGE:

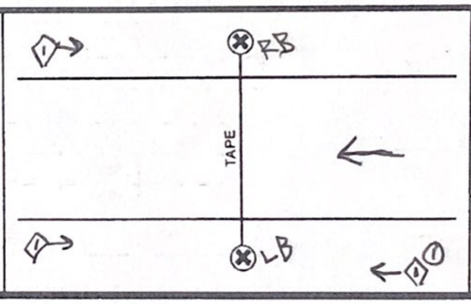
PHOTOGRAPHS TAKEN: [✓ YES] NO

NUMBER OF PHOTOGRAPHS:

CHANNEL PROFILE DATA

STATION	DISTANCE FROM TAPE (ft)	ROD READING (ft)
⊗ Tape @ Stake LB	0.0	3.34
⊗ Tape @ Stake RB	0.0	
① WS @ Tape LB/RB	0.0	RB=5.~~87~~92 LB=5.93
② WS Upstream	45'	5.82
③ WS Downstream	6.41	6.41
SLOPE		

SKETCH



LEGEND:

Stake ⊗

Station ①

Photo ◇→

Direction of Flow ← →

AQUATIC SAMPLING SUMMARY

STREAM ELECTROFISHED: [✓ YES]/NO

DISTANCE ELECTROFISHED: ______ ft

FISH CAUGHT: YES/NO

WATER CHEMISTRY SAMPLED: YES/NO

LENGTH - FREQUENCY DISTRIBUTION BY ONE-INCH SIZE GROUPS (1.0-1.9, 2.0-2.9, ETC.)

SPECIES (FILL IN)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15	TOTAL

AQUATIC INSECTS IN STREAM SECTION BY COMMON OR SCIENTIFIC ORDER NAME:

COMMENTS

Flow measured in run 50 feet upstream of transect
Flow taken w/ Flow tracker

FORM #ISF FD 1-85

DISCHARGE/CROSS SECTION NOTES

STREAM NAME: Cow Creek

CROSS-SECTION NO.: 2

DATE: 9/11/19

SHEET __ OF __

BEGINNING OF MEASUREMENT

EDGE OF WATER LOOKING DOWNSTREAM: (0.0 AT STAKE) LEFT / [✓ RIGHT]

Gage Reading: _____ft

TIME:

Features: Stake (S) Grassline (G) Waterline (W) Rock (R)	Distance From Initial Point (ft)	Width (ft)	Total Vertical Depth From Tape/Inst (ft)	Water Depth (ft)	Depth of Observation (ft)	Revolutions	Time (sec)	Velocity (ft/sec) At Point	Velocity (ft/sec) Mean in Vertical	Area (ft²)	Discharge (cfs)
S	0				3.34						
	9.2				3.69						
Bankfull	17.9				4.34						
	19.7				5.60						
W	21.6			0	5.93						
	22			0.05	6.00						
	23			0.05	6.00						
	24			0.05	6.00						
	25			0.15	6.05						
	26			0.25	6.10						
	27			0.30	6.30						
	28			0.30	6.15						
	29			0.40	6.25						
	30			0.40	6.25						
	31			0.40	6.25						
	32			0.25	6.15						
	33			0.15	6.00						
	34			0.20	6.10						
	35			0.20	6.00						
	36			0.10	5.95						
	37			0.20	6.00						
	38			0.10	5.95						
	39			0.35	6.20						
	40			0.15	5.95						
	41			0.10	5.95						
	42			0.25	6.05						
	43			0.10	5.95						
W	44.2			0	5.92						
	57.4				4.75						
Bankfull	62.7				4.40						
S	75.9				4.80						

CALCULATIONS PERFORMED BY:

CALCULATIONS CHECKED BY:

COLORADO WATER CONSERVATION BOARD

FIELD DATA FOR INSTREAM FLOW DETERMINATIONS

COLORADO DIVISION OF WILDLIFE

LOCATION INFORMATION

STREAM NAME: Cow Creek

CROSS-SECTION NO.: 20-01(3)

CROSS-SECTION LOCATION: 13S260022 ; 4236199
on Billy creek SWA , Above Diversion

DATE: 8/6/20

OBSERVERS: Birch , Le

LEGAL DESCRIPTION: ¼ SECTION: SECTION: TOWNSHIP: N/S RANGE: E/W PM:

COUNTY:

WATERSHED:

WATER DIVISION:

DOW WATER CODE:

MAP(S): USGS:

USFS:

SUPPLEMENTAL DATA

SAG TAPE SECTION SAME AS DISCHARGE SECTION: [✓ YES] NO

METER TYPE: FlowMeter -"cw 2011"

METER NUMBER:

DATE RATED:

CALIB/SPIN: ______ sec

TAPE WEIGHT: ______ lbs/foot

TAPE TENSION: ______ lbs

CHANNEL BED MATERIAL SIZE RANGE:

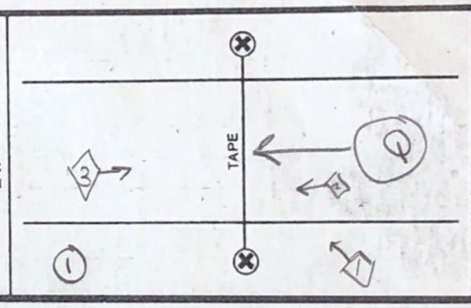
PHOTOGRAPHS TAKEN: [✓ YES] NO

NUMBER OF PHOTOGRAPHS:

CHANNEL PROFILE DATA

STATION	DISTANCE FROM TAPE (ft)	ROD READING (ft)
⊗ Tape @ Stake LB	0.0	✓
⊗ Tape @ Stake RB	0.0	~
① WS @ Tape LB/RB	0.0	4.86 / 4.86
② WS Upstream	4ft	4.83
③ WS Downstream	71ft	6.09
SLOPE	70 1.265 /75 = 0.0168	

SKETCH



LEGEND:
Stake ⊗
Station ①
Photo ◇→
Direction of Flow

AQUATIC SAMPLING SUMMARY

STREAM ELECTROFISHED: YES/NO

DISTANCE ELECTROFISHED: ______ ft

FISH CAUGHT: YES/NO

WATER CHEMISTRY SAMPLED: YES/NO

LENGTH - FREQUENCY DISTRIBUTION BY ONE-INCH SIZE GROUPS (1.0-1.9, 2.0-2.9, ETC.)

SPECIES (FILL IN)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15	TOTAL
Fish observed ~2 large trout																	

AQUATIC INSECTS IN STREAM SECTION BY COMMON OR SCIENTIFIC ORDER NAME:

COMMENTS

shrubs and perennial vegetation along banks/riparian. Deciduous trees more inland and on outer edge of shrubs. undercut present, lack of shading in water. Dominant - gravel/medium cobble substrate. A few boulders present. case-making caddis, chronamids, stonefly larva, midges

FORM #ISF FD 1-85

Q=5.781 cfs
Measured at 12:37

T=69.7° F
measured ~15' u/s in glide.

DISCHARGE/CROSS SECTION NOTES

STREAM NAME: Crw creek

CROSS-SECTION NO.: 20-1

DATE: 8/6/20

SHEET 2 OF 2

BEGINNING OF MEASUREMENT 11:80

EDGE OF WATER LOOKING DOWNSTREAM: (0.0 AT STAKE) LEFT / [✓ RIGHT]

Gage Reading: N/A ft

TIME: 11:56 End

Features: Stake (S) Grassline (G) Waterline (W) Rock (R)	Distance From Initial Point (ft)	~~Width (ft)~~ Depth(')	Total Vertical Depth From Tape/Inst (ft)	~~Water Depth (ft)~~	Depth of Observation (ft)	Revolutions	Time (sec)	Velocity (ft/sec) At Point	Velocity (ft/sec) Mean in Vertical	Area (ft²)	Discharge (cfs)
S	0		3.12								
	1.2	1.2	3.2								
BF	2.5		3.5	) Top of undercut							
~~BF~~	2.7		3.65	Bottom of undercut							
	2.9		4.1								
	3.3		4.25								
	3.9		4.55								
WS	5.0	0	4.86								
	6.5	.1	4.9								
	8.0	0.5	4.9								
micro Rock pile island	11.0	.1	4.95								
feature	12.5	.17	5								
	14	.2	5.05								
	15.5	.1	4.95								
	17	.2	5.1								
	18.5	.05	4.95								
	20.0	.3	5.2								
	21.5	.36	5.25								
	23.0	.4	5.3								
	24.5	.3	5.2								
	26	.4	5.25								
	27.5	.35	5.25								
	29	.33	5.2								
	30.5	.25	5.15								
	32	.35	5.25								
	33.5	.1	5.0								
	35	.2	5.1								
WS	36.6	0	4.86								
	38		4.85								
	40.9		4.4								
	44.3		4.2								
	47.1		3.95								
	49.7		3.85								
	52.6		3.85								
	53.5		3.7								
BF	54.3		3.5								
S	56		3.15								
TOTALS:											

End of Measurement

Time:

Gage Reading: ______ ft

CALCULATIONS PERFORMED BY:

CALCULATIONS CHECKED BY:

FIELD DATA
FOR
INSTREAM FLOW DETERMINATIONS

COLORADO WATER CONSERVATION BOARD

LOCATION INFORMATION

STREAM NAME: Cow creek					CROSS-SECTION NO.: 20-02 (4)
CROSS-SECTION LOCATION: Billy Creek SWA UTM 13S 260020 4236172					
DATE: 8/6/20	OBSERVERS: Birch, Le				
LEGAL DESCRIPTION	¼ SECTION:	SECTION:	TOWNSHIP: N/S	RANGE: E/W	PM:
COUNTY:	WATERSHED:	WATER DIVISION:	DOW WATER CODE:		
MAP(S):	USGS:				
	USFS:				

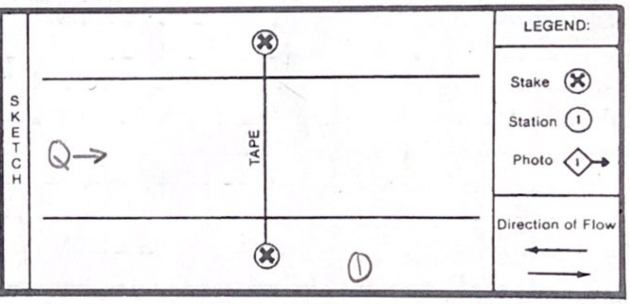
SUPPLEMENTAL DATA

SAG TAPE SECTION SAME AS DISCHARGE SECTION: [✓ YES] NO	METER TYPE: FlowTracker "Cow.20-2"			
METER NUMBER:	DATE RATED:	CALIB/SPIN: ______ sec	TAPE WEIGHT: ______ lbs/foot	TAPE TENSION: ______ lbs
CHANNEL BED MATERIAL SIZE RANGE:		PHOTOGRAPHS TAKEN: YES/NO	NUMBER OF PHOTOGRAPHS:	

RWS ✓4.99 4.97

CHANNEL PROFILE DATA

STATION	DISTANCE FROM TAPE (ft)	ROD READING (ft)
⊗ Tape @ Stake LB	0.0	~
⊗ Tape @ Stake RB	0.0	~
① WS @ Tape LB/RB	0.0	4.99/4.97
② WS Upstream	27.3'	4.72
③ WS Downstream	29'	5.45
SLOPE	56.3'	= 0.012966



AQUATIC SAMPLING SUMMARY

STREAM ELECTROFISHED: YES/NO	DISTANCE ELECTROFISHED: ______ ft	FISH CAUGHT: YES/NO	WATER CHEMISTRY SAMPLED: YES/NO

LENGTH - FREQUENCY DISTRIBUTION BY ONE-INCH SIZE GROUPS (1.0-1.9, 2.0-2.9, ETC.)

SPECIES (FILL IN)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15	TOTAL
caddis ~case makers (2)		juvenile otter!															
chironomids, diptera		2 large trout in pool															
stonefly		many small fry															
snails																	

AQUATIC INSECTS IN STREAM SECTION BY COMMON OR SCIENTIFIC ORDER NAME:

↑ diverse & abundant macro community

COMMENTS

shrub dominant on riparian; presence of few deciduous tree, partial shading on left bank. Gravel dominant, few medium-sized cobble, no boulders. undercut present

Riffle selected bc of limited braiding. Very active channel working it's way left u/s of riffle. Abandoned side channel on RB. BF elevation at top of island feature. XS 1 was taken u/s of island feature.

Q = 5.95 cfs measured in u/s glide. T = 73.9°F 3:03 Slightly more laminar flow than XS 2 glide.

FORM #ISF FD 1-85

DISCHARGE/CROSS SECTION NOTES

STREAM NAME: Cow Creek

CROSS-SECTION NO.:

DATE:

SHEET ___ OF ___

BEGINNING OF MEASUREMENT

EDGE OF WATER LOOKING DOWNSTREAM: (0.0 AT STAKE) LEFT / [✓ RIGHT]

Gage Reading: ______ ft

TIME:

Features: Stake (S) Grassline (G) Waterline (W) Rock (R)	Distance From Initial Point (ft)	Width (ft)	Total Vertical Depth From Tape/Inst (ft)	Water Depth (ft)	Depth of Observation (ft)	Revolutions	Time (sec)	Velocity (ft/sec)		Area (ft²)	Discharge (cfs)
								At Point	Mean in Vertical		
S	0		3.15								
	1.7		3.525								
	3.0		3.75								
BF	3.5		3.95								
	4.1		4.35								
	6.1		4.4			continued...					
	10.3		4.9			39.2	4.8	→ add		39.4	4.2
RWS	12.2		4.99	0		~~38.6~~	~~3.75~~		BF	39.6	3.85
	13.0		5.05	0.05		40.0	3			39.9	3.65
	13.8		5.1	0.1						40.3	3.45
	14.6		5.15	0.12					X	41.8	3.35
	15.4		5.12	0.1						428	3.25
	16.2		5.1	0.1							
	17.0		5.15	0.13							
	17.8		5.25	0.25							
	18.6		5.4	0.4							
	19.4		5.4	0.35							
	20.2		5.25	0.25							
	21.0		5.3	0.25							
Rock	218		5.05	0.05							
	22.6		5.35	0.35							
	23.4		5.35	0.35							
	24.2		5.25	0.25							
	25.0		5.32	0.3							
	25.8		5.15	0.1							
	26.6		5.23	0.25							
	27.4		5.25	0.25							
	28.2		5.2	0.15							
	29.0		5.25	0.25							
	29.8		5.35	0.35							
	30.6		5.28	0.3							
	31.4		5.2	0.2							
	32.2		5.23	0.25							
	33.0		5.3	0.3							
	33.8		5.17	0.2							
	34.6		5.15	0.15							
	35.4		5.17	0.15							
	36.2		5.3	0.35							
	37.0		5.32	0.35							
	37.8		5.32	0.35							
LWS	38.6		4.97	0							
TOTALS:											

End of Measurement

Time:

Gage Reading: ______ ft

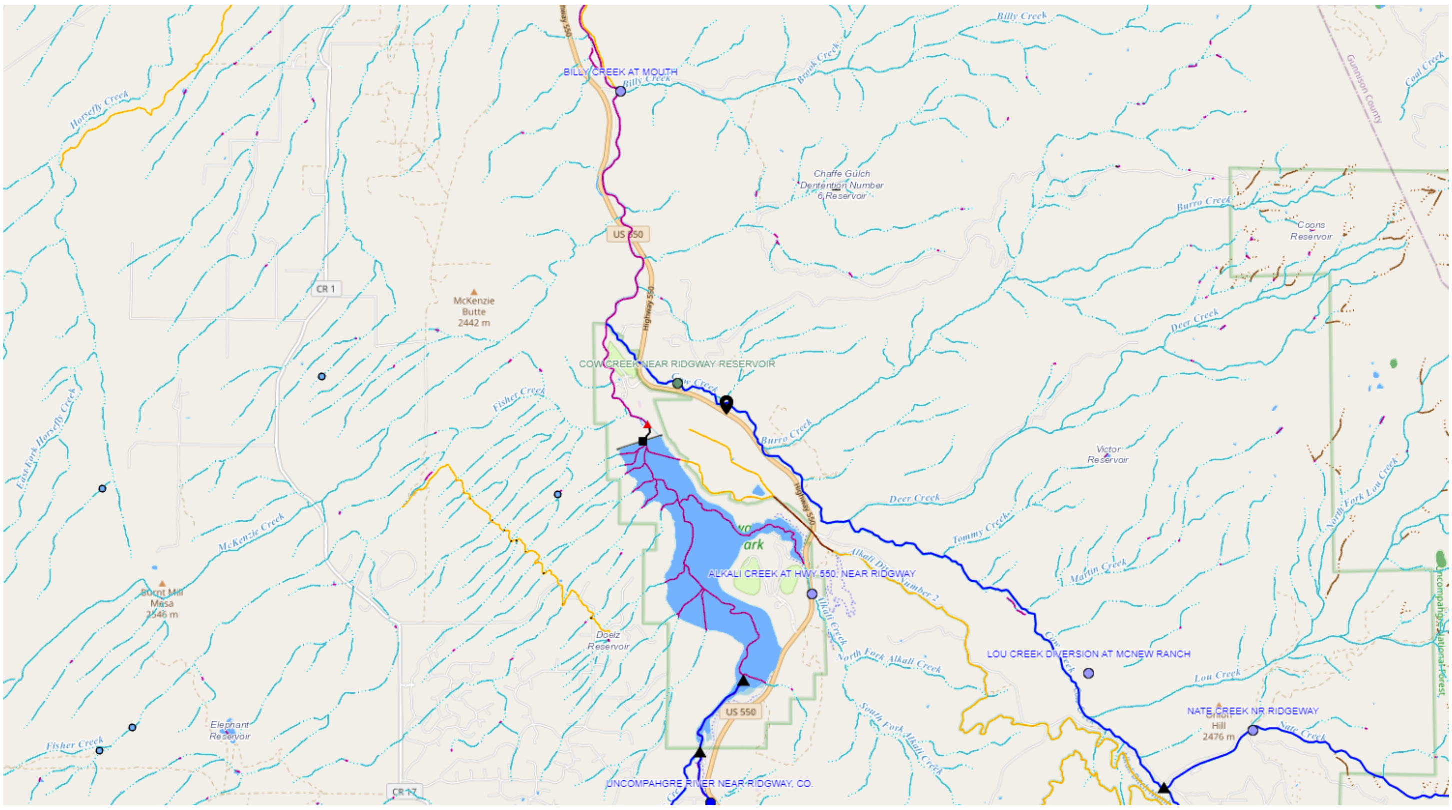
CALCULATIONS PERFORMED BY:

CALCULATIONS CHECKED BY:

R2Cross RESULTS

Stream Name: Cow Creek
Stream Locations: On SWA
Fieldwork Date: 08/07/2019
Cross-section: 1
Observers: Birch Gardunio
Coordinate System: UTM Zone 13
X (easting): 259916
Y (northing): 4236234
Date Processed: 12/12/2020
Slope: 0.0074
Computation method: Manning's n
R2Cross data filename: R2CrossData_Cow1_8-7-2019-Q=90.7 flowtracker.xlsx
R2Cross version: 1.1.16

LOCATION



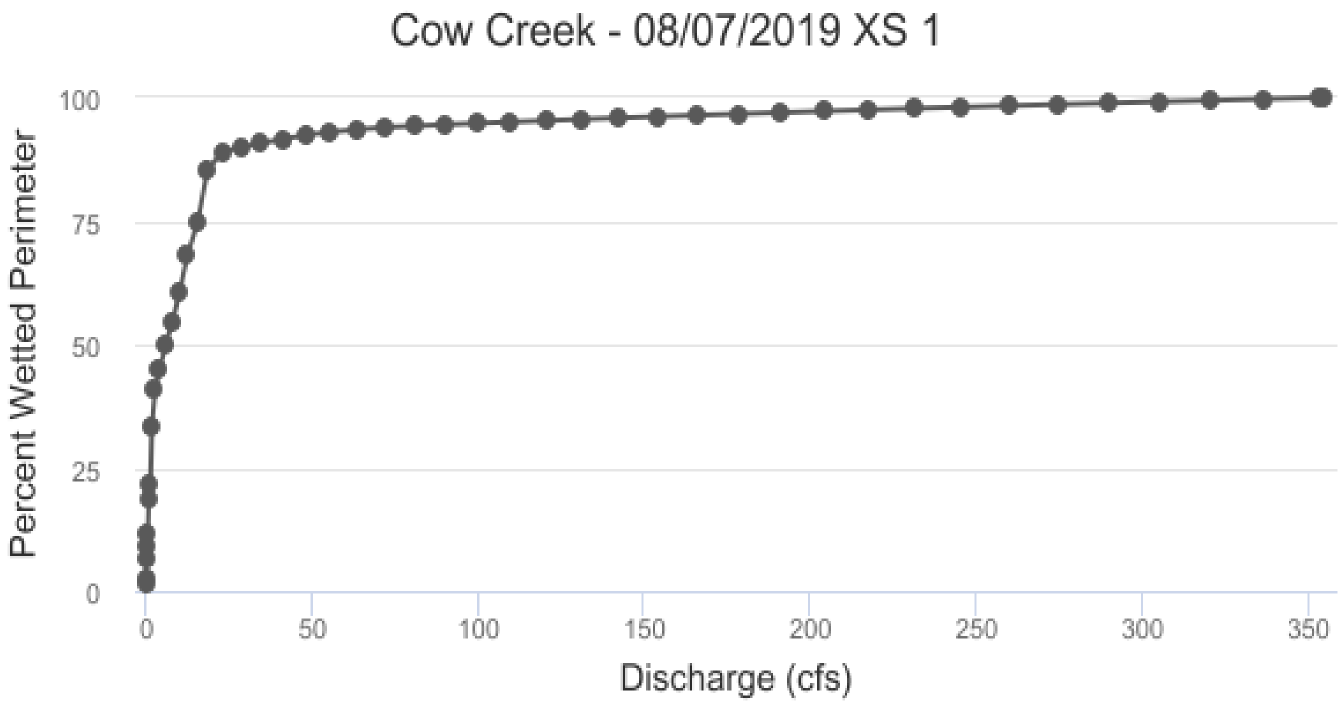
ANALYSIS RESULTS

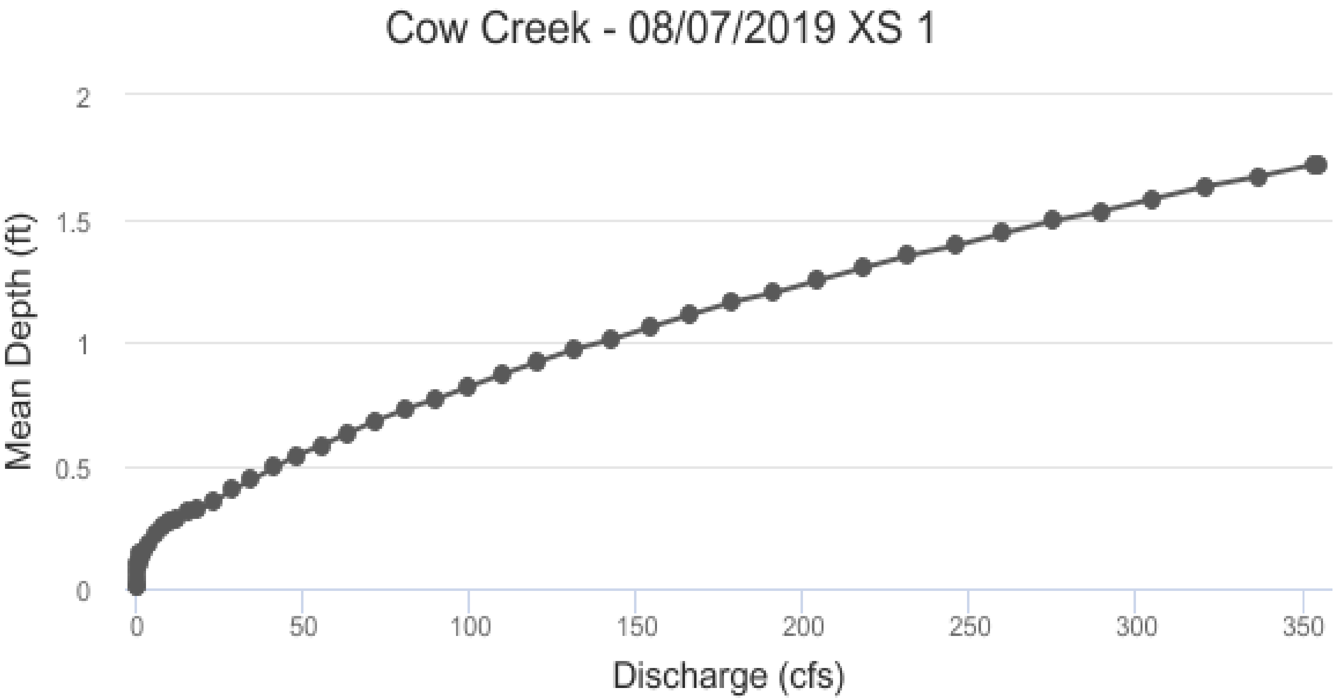
Habitat Criteria Results

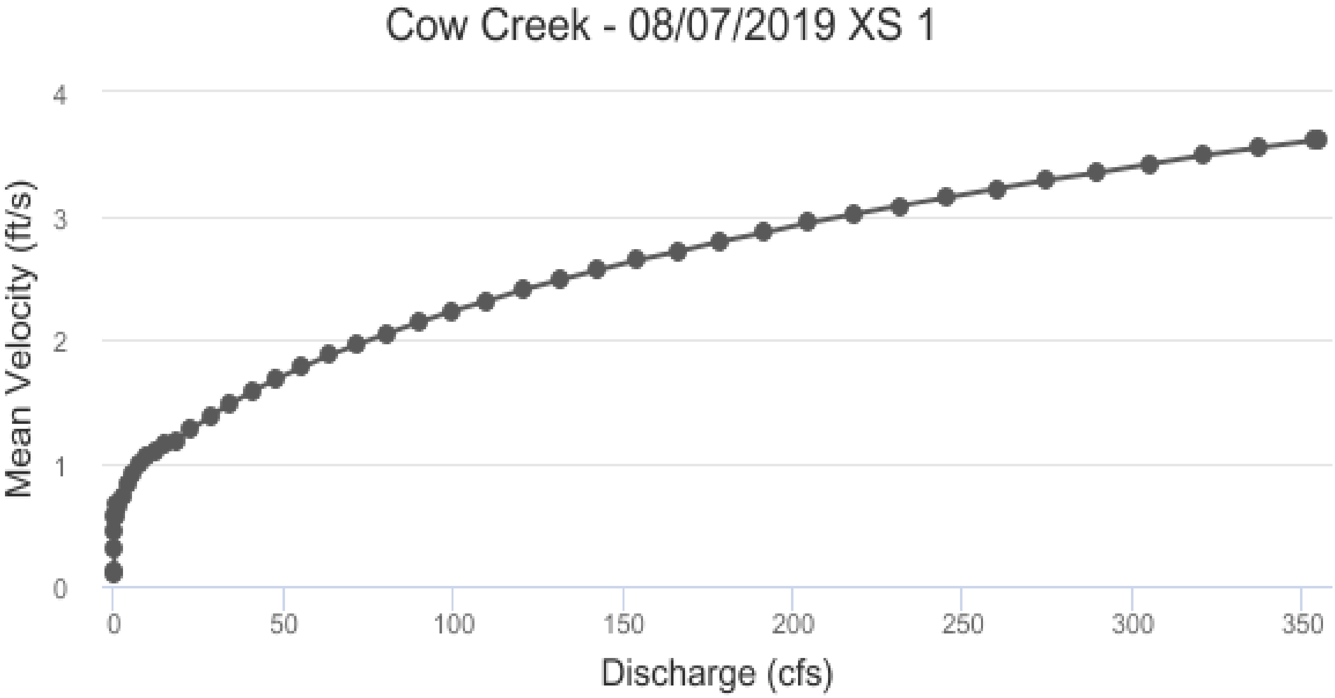
Bankfull top width (ft) = 56.86

	Habitat Criteria	Discharge (cfs) Meeting Criteria
Mean Depth (ft)	0.57	53.23
Percent Wetted Perimeter (%) **	58.43	9.16
Mean Velocity (ft/s) **	1.0	7.78

**Values highlighted in yellow indicate that the discharge is less than 40% of measured Q or greater than 250% of measured Q.







R2Cross RESULTS: Cow Creek - 08/07/2019 XS 1, Analysis Method: [Manning's n]

STAGING TABLE

Feature	Distance to Water (ft)	Top Width (ft)	Mean Depth (ft)	Maximum Depth (ft)	Area (SQ ft)	Wetted Perimeter (ft)	Percent Wetted Perimeter	Hydraulic Radius (ft)	Mean Velocity (ft/s)	Discharge (cfs)
Bankfull	4.82	56.86	1.72	2.23	98.05	57.89	100.00%	1.69	3.62	355.12
	4.83	56.85	1.72	2.22	97.73	57.88	99.97%	1.69	3.61	353.25
	4.88	56.73	1.67	2.17	94.89	57.72	99.70%	1.64	3.55	336.93
	4.93	56.6	1.63	2.12	92.06	57.56	99.42%	1.6	3.49	320.91
	4.98	56.48	1.58	2.07	89.23	57.4	99.15%	1.55	3.42	305.21
	5.03	56.36	1.53	2.02	86.41	57.24	98.88%	1.51	3.35	289.83
	5.08	56.24	1.49	1.97	83.59	57.09	98.61%	1.46	3.29	274.77
	5.13	56.12	1.44	1.92	80.78	56.93	98.34%	1.42	3.22	260.03
	5.18	56.0	1.39	1.87	77.98	56.77	98.06%	1.37	3.15	245.63
	5.23	55.87	1.35	1.82	75.19	56.61	97.79%	1.33	3.08	231.55
	5.28	55.75	1.3	1.77	72.39	56.46	97.52%	1.28	3.01	217.81
	5.33	55.63	1.25	1.72	69.61	56.3	97.25%	1.24	2.94	204.4
	5.38	55.51	1.2	1.67	66.83	56.14	96.97%	1.19	2.86	191.35
	5.43	55.39	1.16	1.62	64.06	55.98	96.70%	1.14	2.79	178.63
	5.48	55.27	1.11	1.57	61.29	55.83	96.43%	1.1	2.71	166.28
	5.53	55.14	1.06	1.52	58.53	55.67	96.16%	1.05	2.64	154.27
	5.58	55.02	1.01	1.47	55.78	55.51	95.89%	1.0	2.56	142.64
	5.63	54.9	0.97	1.42	53.03	55.35	95.61%	0.96	2.48	131.37
	5.68	54.78	0.92	1.37	50.29	55.2	95.34%	0.91	2.4	120.47
	5.73	54.66	0.87	1.32	47.55	55.04	95.07%	0.86	2.31	109.96
	5.78	54.54	0.82	1.27	44.82	54.88	94.80%	0.82	2.23	99.83
Waterline	5.83	54.41	0.77	1.22	42.1	54.72	94.53%	0.77	2.14	90.1
	5.88	54.29	0.73	1.17	39.38	54.57	94.25%	0.72	2.05	80.77
	5.93	54.17	0.68	1.12	36.67	54.41	93.98%	0.67	1.96	71.85
	5.98	53.94	0.63	1.07	33.97	54.15	93.54%	0.63	1.87	63.44

6.03	53.68	0.58	1.02	31.28	53.86	93.04%	0.58	1.77	55.49
6.08	53.34	0.54	0.97	28.6	53.51	92.43%	0.53	1.68	48.01
6.13	52.87	0.49	0.92	25.94	53.03	91.60%	0.49	1.58	41.06
6.18	52.4	0.44	0.87	23.31	52.55	90.77%	0.44	1.48	34.56
6.23	51.93	0.4	0.82	20.7	52.07	89.93%	0.4	1.38	28.54
6.28	51.46	0.35	0.77	18.12	51.58	89.10%	0.35	1.27	22.99
6.33	49.39	0.32	0.72	15.58	49.5	85.50%	0.31	1.18	18.37
6.38	43.18	0.31	0.67	13.26	43.27	74.74%	0.31	1.16	15.37
6.43	39.35	0.28	0.62	11.2	39.43	68.11%	0.28	1.1	12.34
6.48	34.89	0.27	0.57	9.34	34.95	60.37%	0.27	1.06	9.87
6.53	31.42	0.25	0.52	7.7	31.47	54.35%	0.24	1.0	7.68
6.58	28.78	0.22	0.47	6.19	28.83	49.79%	0.21	0.91	5.66
6.63	26.09	0.18	0.42	4.82	26.12	45.12%	0.18	0.83	3.98
6.68	23.6	0.15	0.37	3.58	23.63	40.81%	0.15	0.72	2.6
6.73	19.29	0.13	0.32	2.48	19.31	33.35%	0.13	0.65	1.61
6.78	12.6	0.14	0.27	1.72	12.62	21.80%	0.14	0.67	1.16
6.83	10.85	0.1	0.22	1.13	10.87	18.77%	0.1	0.56	0.64
6.88	6.75	0.1	0.17	0.69	6.76	11.68%	0.1	0.56	0.39
6.93	5.29	0.07	0.12	0.39	5.3	9.16%	0.07	0.45	0.18
6.98	3.83	0.04	0.07	0.16	3.84	6.63%	0.04	0.31	0.05
7.03	1.52	0.01	0.02	0.02	1.52	2.63%	0.01	0.13	0.0
7.04	0.94	0.01	0.01	0.01	0.94	1.62%	0.01	0.1	0.0

MODEL SUMMARY

Measured Flow (Qm) = 90.7

Calculated Flow (Qc) = 90.1

(Qm-Qc)/Qm * 100 = 0.66%

Measured Waterline (WLm) = 6

Calculated Waterline (WLc) = 5.83

(WLm-WLc)/WLm * 100 = 2.91%

Max Measured Depth (Dm) = 1.25

Max Calculated Depth (Dc) = 1.22

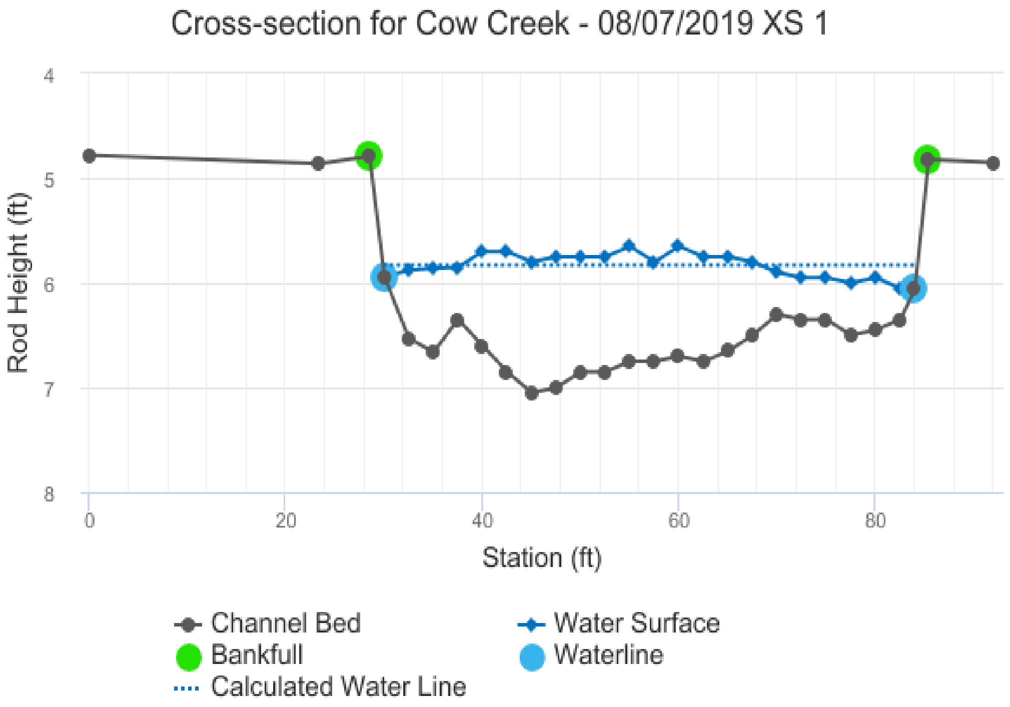
(Dm-Dc)/Dm * 100 = 2.05%

Mean Velocity = 2.14

Manning's n = 0.05

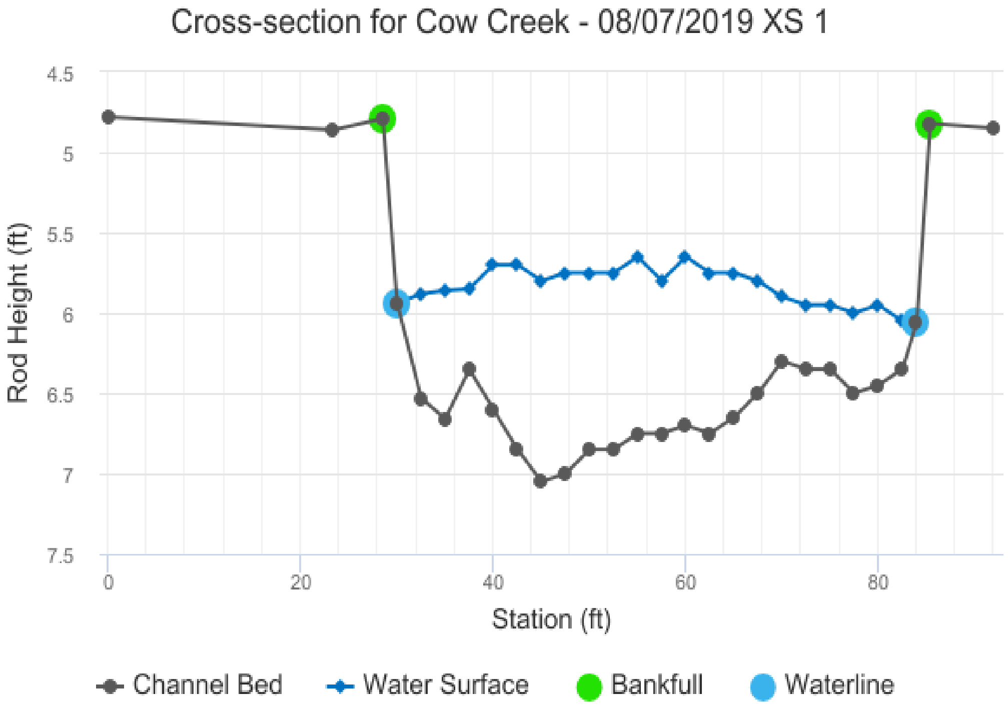
0.4 * Qm = 36.28

2.5 * Qm = 226.75



FIELD DATA

Feature	Station (ft)	Rod Height (ft)	Water depth (ft)	Velocity (ft/s)
	0	4.78		
	23.4	4.86		
Bankfull	28.5	4.79		
Waterline	30	5.94	0	
	32.5	6.53	0.65	
	35	6.66	0.8	
	37.5	6.35	0.5	
	40	6.6	0.9	
	42.5	6.85	1.15	
	45	7.05	1.25	
	47.5	7	1.25	
	50	6.85	1.1	
	52.5	6.85	1.1	
	55	6.75	1.1	
	57.5	6.75	0.95	
	60	6.7	1.05	
	62.5	6.75	1	
	65	6.65	0.9	
	67.5	6.5	0.7	
	70	6.3	0.4	
	72.5	6.35	0.4	
	75	6.35	0.4	
	77.5	6.5	0.5	
	80	6.45	0.5	
	82.5	6.35	0.3	
Waterline	84	6.06	0	
Bankfull	85.4	4.82		
	92.1	4.85		



R2Cross RESULTS: Cow Creek - 08/07/2019 XS 1, Analysis Method: [Manning's n]

COMPUTED FROM MEASURED FIELD DATA

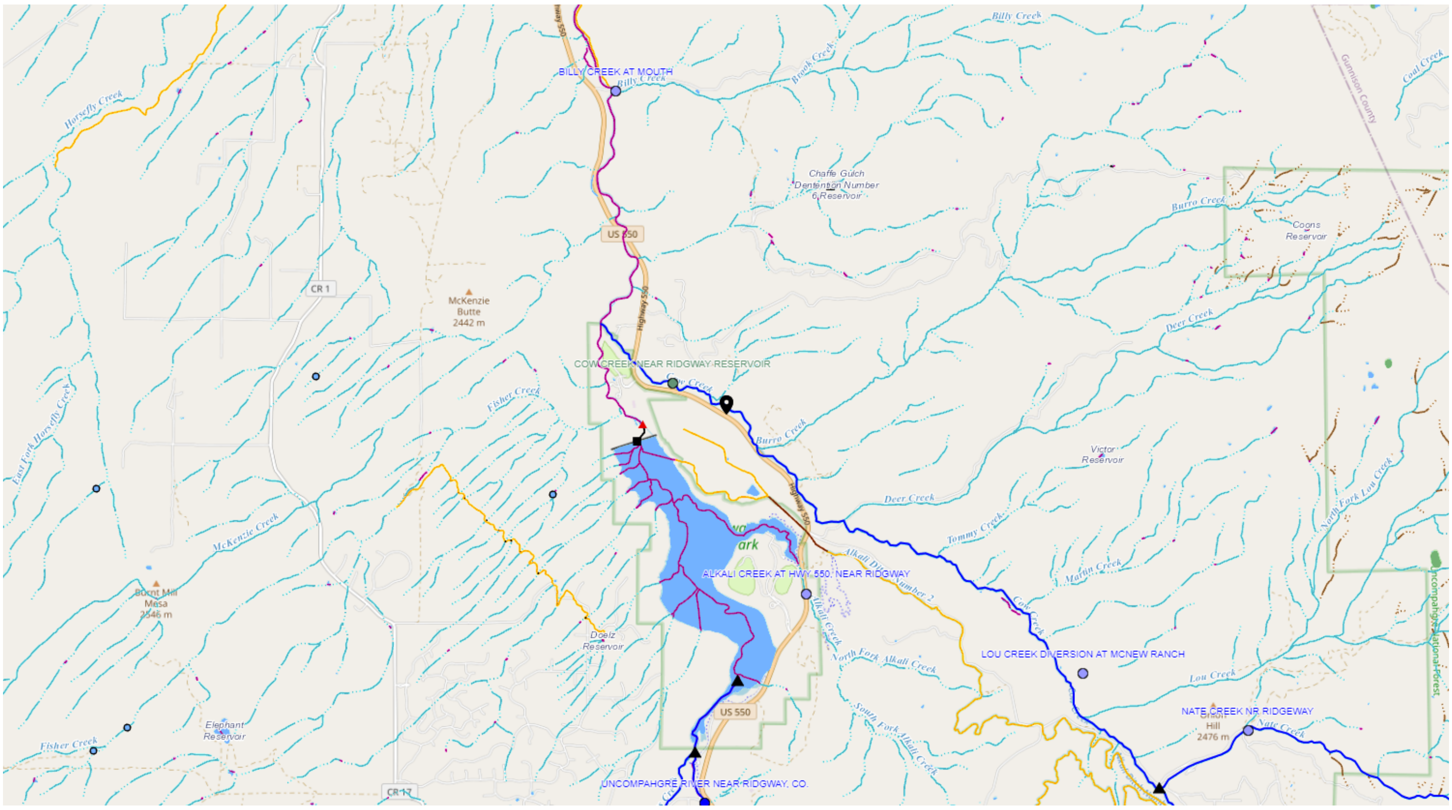
Wetted Perimeter (ft)	Water Depth (ft)	Area (SQ ft)	Discharge (cfs)	Percent Discharge
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
2.57	0.65	1.62	3.5	3.86
2.5	0.8	2	4.31	4.75
2.52	0.5	1.25	2.69	2.97
2.51	0.9	2.25	4.85	5.34
2.51	1.15	2.88	6.19	6.83
2.51	1.25	3.12	6.73	7.42
2.5	1.25	3.12	6.73	7.42
2.5	1.1	2.75	5.92	6.53
2.5	1.1	2.75	5.92	6.53
2.5	1.1	2.75	5.92	6.53
2.5	0.95	2.38	5.12	5.64
2.5	1.05	2.62	5.66	6.24
2.5	1	2.5	5.39	5.94
2.5	0.9	2.25	4.85	5.34
2.5	0.7	1.75	3.77	4.16
2.51	0.4	1	2.15	2.38
2.5	0.4	1	2.15	2.38
2.5	0.4	1	2.15	2.38
2.5	0.5	1.25	2.69	2.97
2.5	0.5	1.25	2.69	2.97
2.5	0.3	0.6	1.29	1.43
1.53	0	0	0	0
0	0	0	0	0
0	0	0	0	0

DISCLAIMER

R2Cross RESULTS

Stream Name: Cow Creek
Stream Locations: Near SWA
Fieldwork Date: 09/11/2019
Cross-section: 1
Observers: Birch, Gardunio, Anderson, Kimber
Coordinate System: UTM Zone 13
X (easting): 259988
Y (northing): 4236232
Date Processed: 12/12/2020
Slope: 0.0131
Computation method: Manning's n
R2Cross data filename: R2CrossData_Cow2_09-11-2019-Q=3.5 flowtracker.xlsx
R2Cross version: 1.1.16

LOCATION



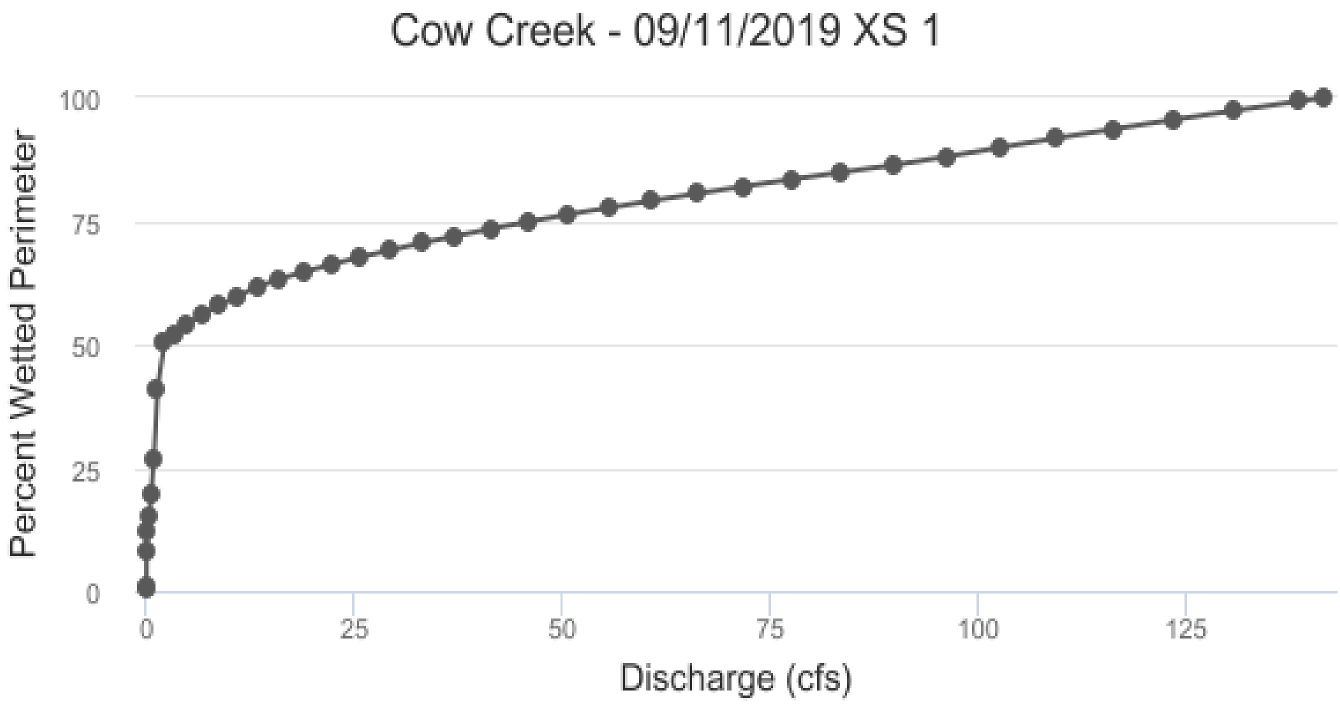
ANALYSIS RESULTS

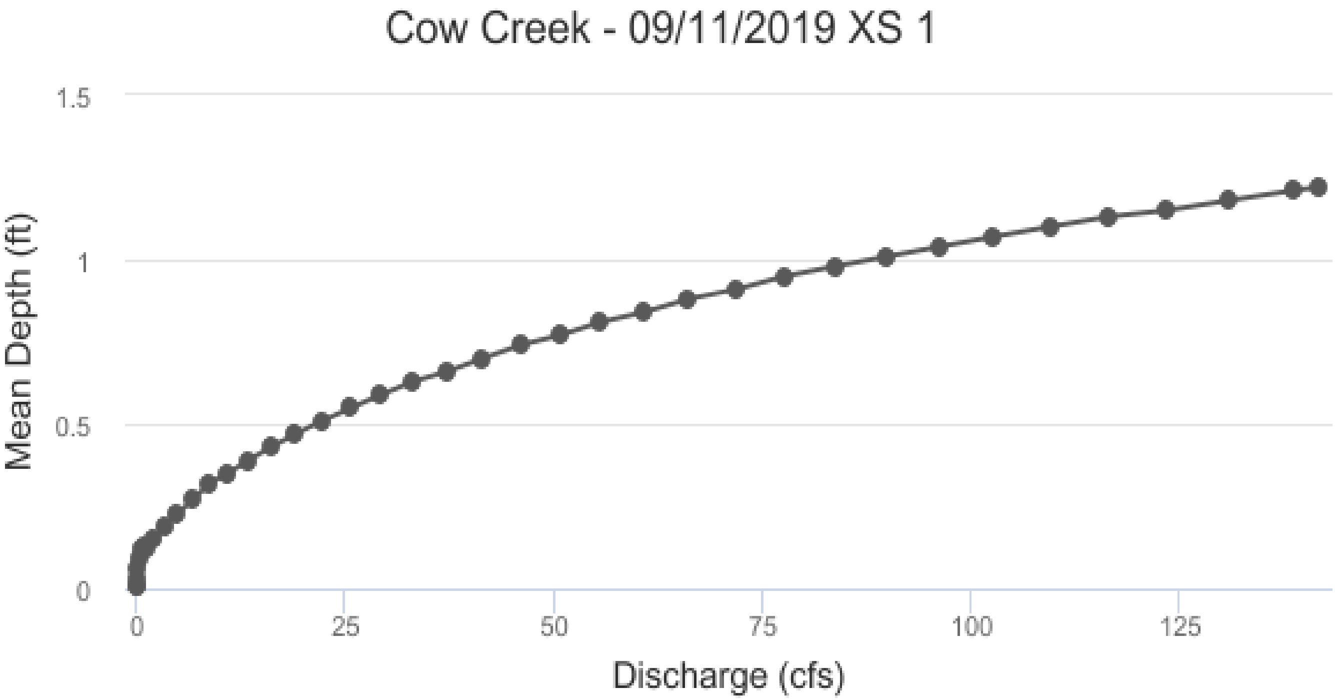
Habitat Criteria Results

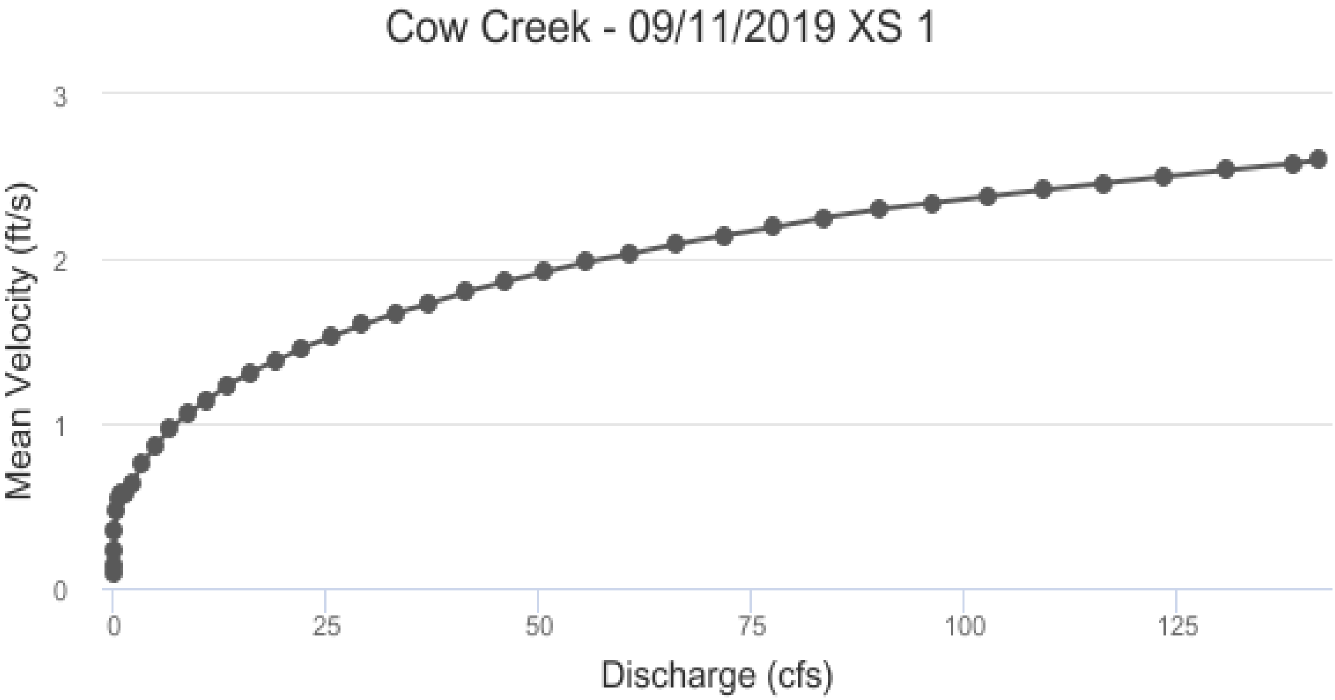
Bankfull top width (ft) = 44.71

	Habitat Criteria	Discharge (cfs) Meeting Criteria
Mean Depth (ft) **	0.45	17.19
Percent Wetted Perimeter (%)	52.36	3.53
Mean Velocity (ft/s)	1.0	7.43

**Values highlighted in yellow indicate that the discharge is less than 40% of measured Q or greater than 250% of measured Q.




Cow Creek - 09/11/2019 XS 1
Mean Depth (ft)
Discharge (cfs)
1.5
1
0.5
0
0
25
50
75
100
125


Cow Creek - 09/11/2019 XS 1
Mean Velocity (ft/s)
Discharge (cfs)
3
2
1
0
0
25
50
75
100
125

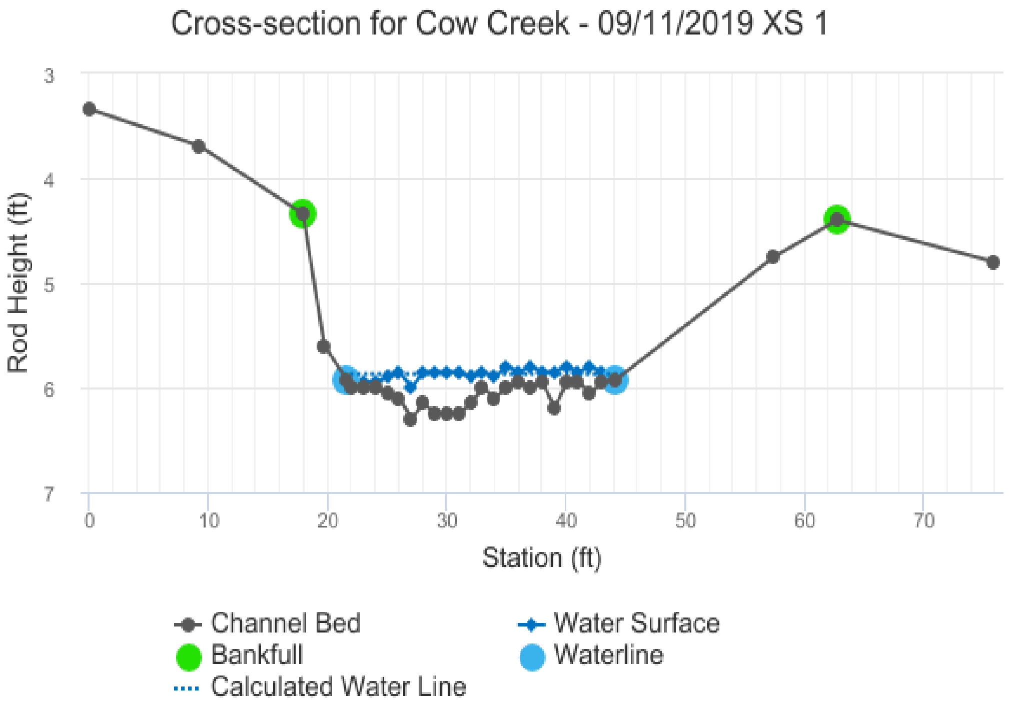
STAGING TABLE

Feature	Distance to Water (ft)	Top Width (ft)	Mean Depth (ft)	Maximum Depth (ft)	Area (SQ ft)	Wetted Perimeter (ft)	Percent Wetted Perimeter	Hydraulic Radius (ft)	Mean Velocity (ft/s)	Discharge (cfs)
Bankfull	4.4	44.71	1.22	1.9	54.58	45.33	100.00%	1.2	2.6	141.79
	4.42	44.38	1.21	1.88	53.69	44.99	99.25%	1.19	2.58	138.64
	4.47	43.55	1.18	1.83	51.49	44.15	97.39%	1.17	2.54	130.96
	4.52	42.73	1.15	1.78	49.34	43.3	95.52%	1.14	2.5	123.53
	4.57	41.9	1.13	1.73	47.22	42.45	93.65%	1.11	2.46	116.35
	4.62	41.07	1.1	1.68	45.15	41.61	91.79%	1.09	2.42	109.41
	4.67	40.24	1.07	1.63	43.12	40.76	89.92%	1.06	2.38	102.72
	4.72	39.41	1.04	1.58	41.12	39.92	88.06%	1.03	2.34	96.28
	4.77	38.66	1.01	1.53	39.17	39.15	86.36%	1.0	2.3	89.94
	4.82	38.02	0.98	1.48	37.26	38.49	84.92%	0.97	2.25	83.66
	4.87	37.39	0.95	1.43	35.37	37.84	83.48%	0.93	2.19	77.61
	4.92	36.75	0.91	1.38	33.52	37.19	82.03%	0.9	2.14	71.78
	4.97	36.12	0.88	1.33	31.7	36.53	80.59%	0.87	2.09	66.17
	5.02	35.48	0.84	1.28	29.91	35.88	79.15%	0.83	2.03	60.79
	5.07	34.85	0.81	1.23	28.15	35.23	77.71%	0.8	1.98	55.63
	5.12	34.21	0.77	1.18	26.42	34.57	76.27%	0.76	1.92	50.69
	5.17	33.58	0.74	1.13	24.73	33.92	74.83%	0.73	1.86	45.96
	5.22	32.94	0.7	1.08	23.06	33.27	73.38%	0.69	1.8	41.46
	5.27	32.3	0.66	1.03	21.43	32.61	71.94%	0.66	1.73	37.18
	5.32	31.67	0.63	0.98	19.83	31.96	70.50%	0.62	1.67	33.12
	5.37	31.03	0.59	0.93	18.27	31.31	69.06%	0.58	1.6	29.27
	5.42	30.4	0.55	0.88	16.73	30.65	67.62%	0.55	1.53	25.64
	5.47	29.76	0.51	0.83	15.23	30.0	66.18%	0.51	1.46	22.23
	5.52	29.13	0.47	0.78	13.75	29.34	64.73%	0.47	1.38	19.05
	5.57	28.49	0.43	0.73	12.31	28.69	63.29%	0.43	1.31	16.08

	5.62	27.77	0.39	0.68	10.9	27.96	61.67%	0.39	1.23	13.36
	5.67	26.92	0.35	0.63	9.54	27.1	59.78%	0.35	1.14	10.91
	5.72	26.07	0.32	0.58	8.21	26.24	57.88%	0.31	1.06	8.69
	5.77	25.21	0.27	0.53	6.93	25.38	55.99%	0.27	0.97	6.7
	5.82	24.36	0.23	0.48	5.69	24.52	54.09%	0.23	0.87	4.93
Waterline	5.87	23.51	0.19	0.43	4.5	23.66	52.20%	0.19	0.76	3.41
	5.92	22.66	0.15	0.38	3.34	22.8	50.31%	0.15	0.64	2.13
	5.97	18.41	0.12	0.33	2.29	18.54	40.91%	0.12	0.57	1.31
	6.02	12.11	0.13	0.28	1.53	12.21	26.94%	0.13	0.57	0.88
	6.07	8.77	0.12	0.23	1.01	8.86	19.53%	0.11	0.54	0.55
	6.12	6.74	0.09	0.18	0.63	6.8	15.00%	0.09	0.47	0.3
	6.17	5.36	0.06	0.13	0.33	5.39	11.90%	0.06	0.35	0.12
	6.22	3.53	0.03	0.08	0.11	3.55	7.83%	0.03	0.22	0.02
	6.27	0.35	0.01	0.03	0.01	0.36	0.78%	0.01	0.14	0.0
	6.29	0.17	0.01	0.01	0.0	0.18	0.39%	0.01	0.09	0.0

MODEL SUMMARY

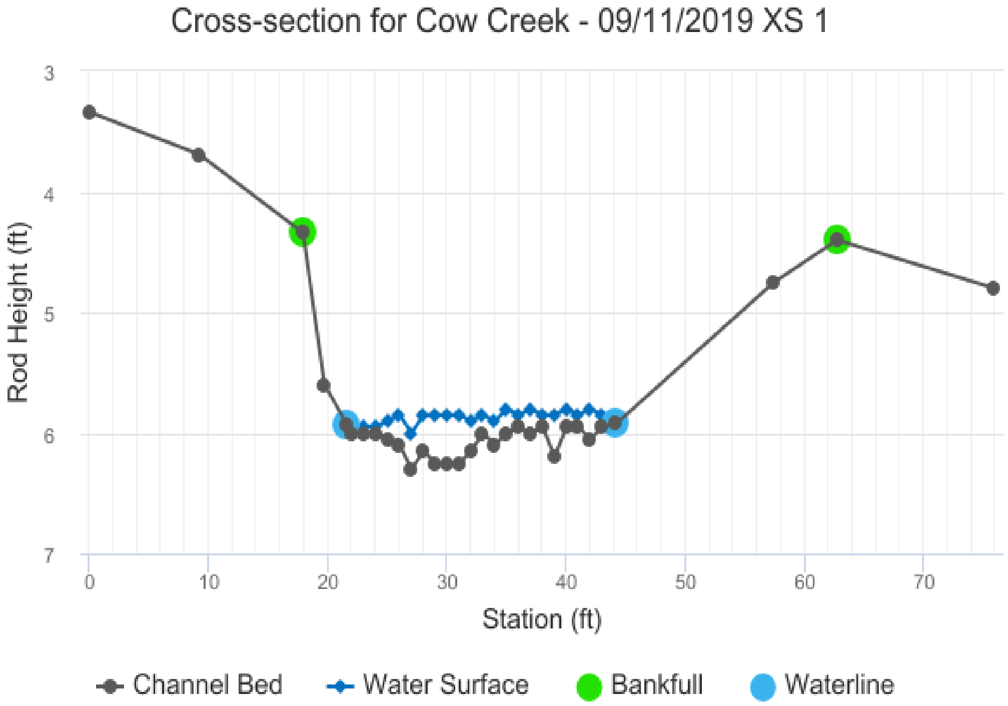
Measured Flow (Qm) = 3.5
Calculated Flow (Qc) = 3.41
(Qm-Qc)/Qm * 100 = 2.59%
Measured Waterline (WLm) = 5.92
Calculated Waterline (WLc) = 5.87
(WLm-WLc)/WLm * 100 = 0.93%
Max Measured Depth (Dm) = 0.4
Max Calculated Depth (Dc) = 0.43
(Dm-Dc)/Dm * 100 = -7.50%
Mean Velocity = 0.76
Manning's n = 0.074
0.4 * Qm = 1.4
2.5 * Qm = 8.75



FIELD DATA

Feature	Station (ft)	Rod Height (ft)	Water depth (ft)	Velocity (ft/s)
	0	3.34		
	9.2	3.69		
Bankfull	17.9	4.34		
	19.7	5.6		
Waterline	21.6	5.93		
	22	6	0.05	
	23	6	0.05	
	24	6	0.05	
	25	6.05	0.15	
	26	6.1	0.25	
	27	6.3	0.3	
	28	6.15	0.3	
	29	6.25	0.4	
	30	6.25	0.4	
	31	6.25	0.4	
	32	6.15	0.25	
	33	6	0.15	
	34	6.1	0.2	
	35	6	0.2	
	36	5.95	0.1	
	37	6	0.2	
	38	5.95	0.1	
	39	6.2	0.35	
	40	5.95	0.15	
	41	5.95	0.1	
	42	6.05	0.25	
	43	5.95	0.1	
Waterline	44.2	5.92		
	57.4	4.75		
Bankfull	62.7	4.4		

75.9	4.8


Cross-section for Cow Creek - 09/11/2019 XS 1
Rod Height (ft)
3
4
5
6
7
Station (ft)
0
10
20
30
40
50
60
70
Channel Bed
Water Surface
Bankfull
Waterline

COMPUTED FROM MEASURED FIELD DATA

Wetted Perimeter (ft)	Water Depth (ft)	Area (SQ ft)	Discharge (cfs)	Percent Discharge
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0.41	0.05	0.04	0.03	0.78
1	0.05	0.05	0.04	1.11
1	0.05	0.05	0.04	1.11
1	0.15	0.15	0.12	3.34
1	0.25	0.25	0.19	5.56
1.02	0.3	0.3	0.23	6.67
1.01	0.3	0.3	0.23	6.67
1	0.4	0.4	0.31	8.9
1	0.4	0.4	0.31	8.9
1	0.4	0.4	0.31	8.9
1	0.25	0.25	0.19	5.56
1.01	0.15	0.15	0.12	3.34
1	0.2	0.2	0.16	4.45
1	0.2	0.2	0.16	4.45
1	0.1	0.1	0.08	2.23
1	0.2	0.2	0.16	4.45
1	0.1	0.1	0.08	2.23
1.03	0.35	0.35	0.27	7.79
1.03	0.15	0.15	0.12	3.34
1	0.1	0.1	0.08	2.23
1	0.25	0.25	0.19	5.56
1	0.1	0.11	0.09	2.45
1.2	0	0	0	0
0	0	0	0	0
0	0	0	0	0

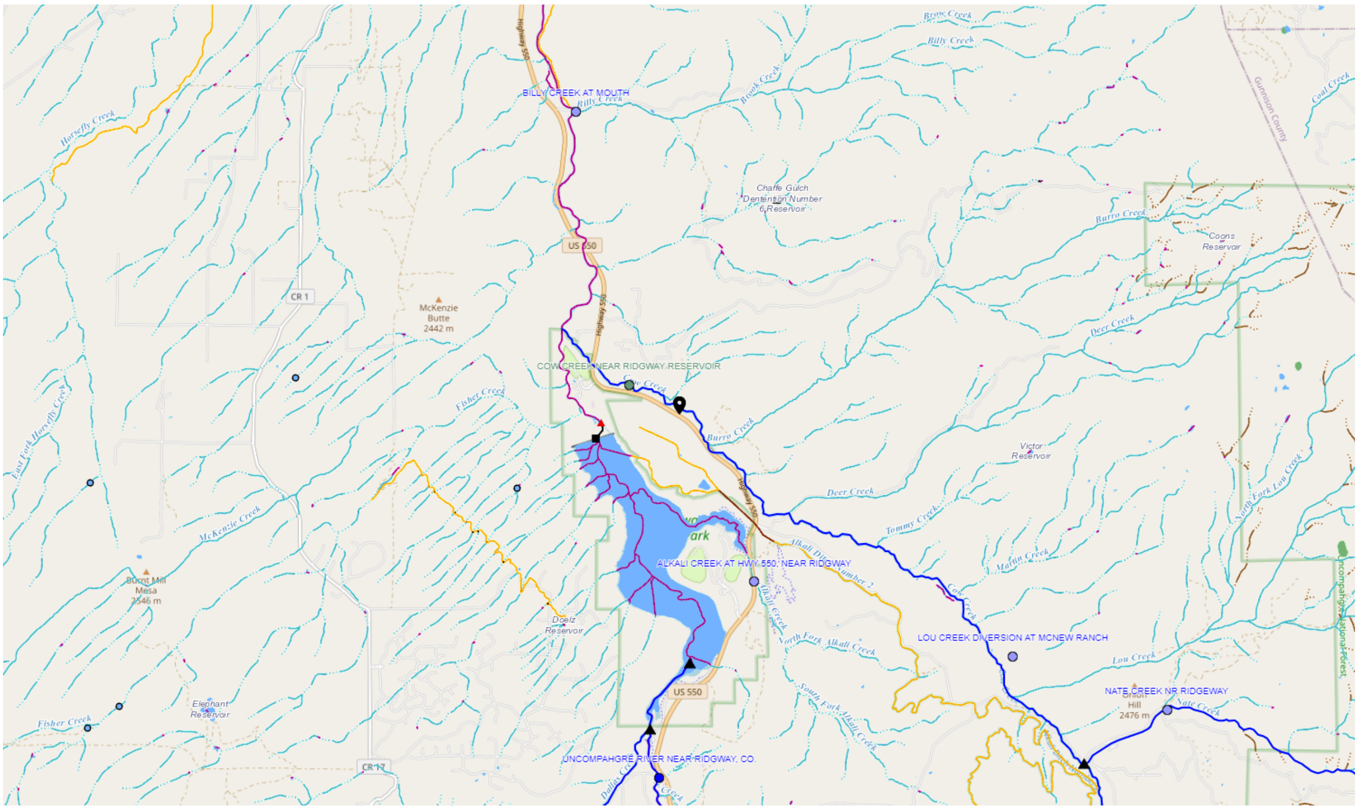
0	0	0	0	0

DISCLAIMER

R2Cross RESULTS

Stream Name: Cow Creek
Stream Locations: On Billy Creek SWA, Above Diversion
Fieldwork Date: 08/06/2020
Cross-section: 20-01
Observers: Birch, Le
Coordinate System: UTM Zone 13
X (easting): 260022
Y (northing): 4236199
Date Processed: 12/12/2020
Slope: 0.0168
Computation method: Manning's n
R2Cross data filename: CowCreek-3_8-6-2020_R2CrossData-Q=5.73 flowtracker.xlsx
R2Cross version: 1.1.16

LOCATION



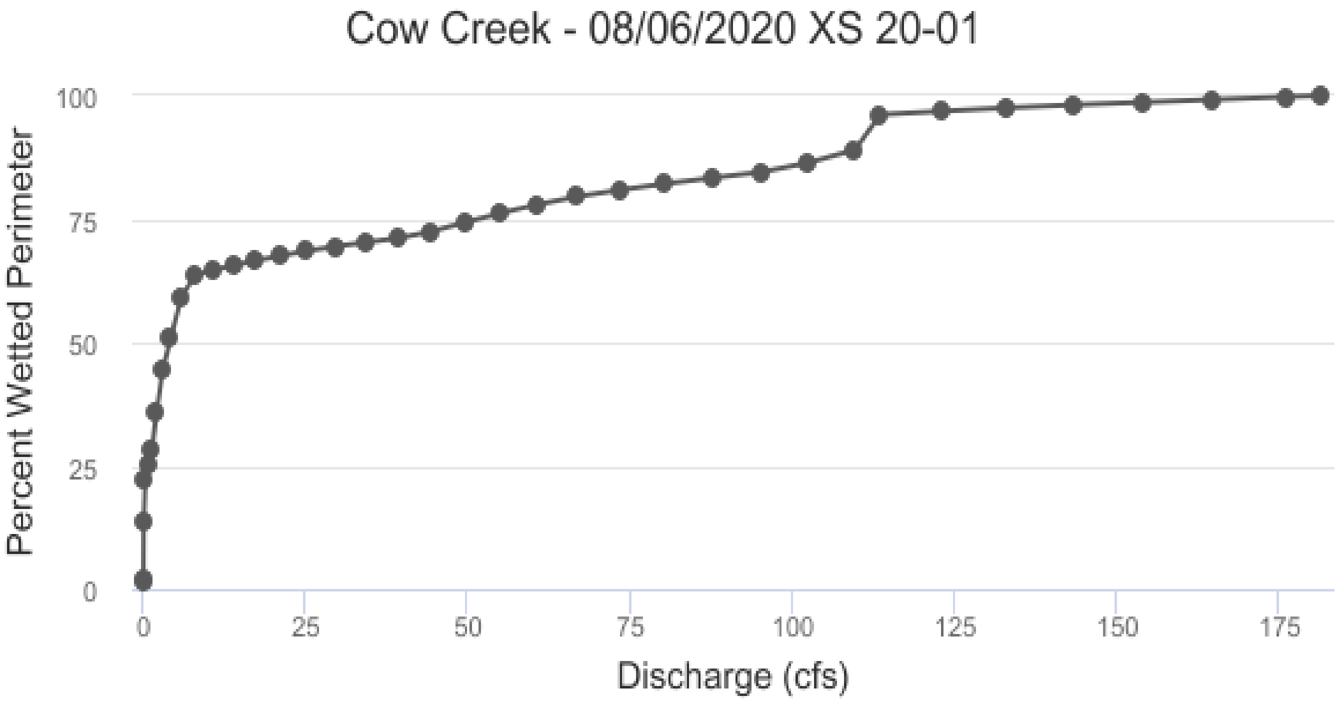
ANALYSIS RESULTS

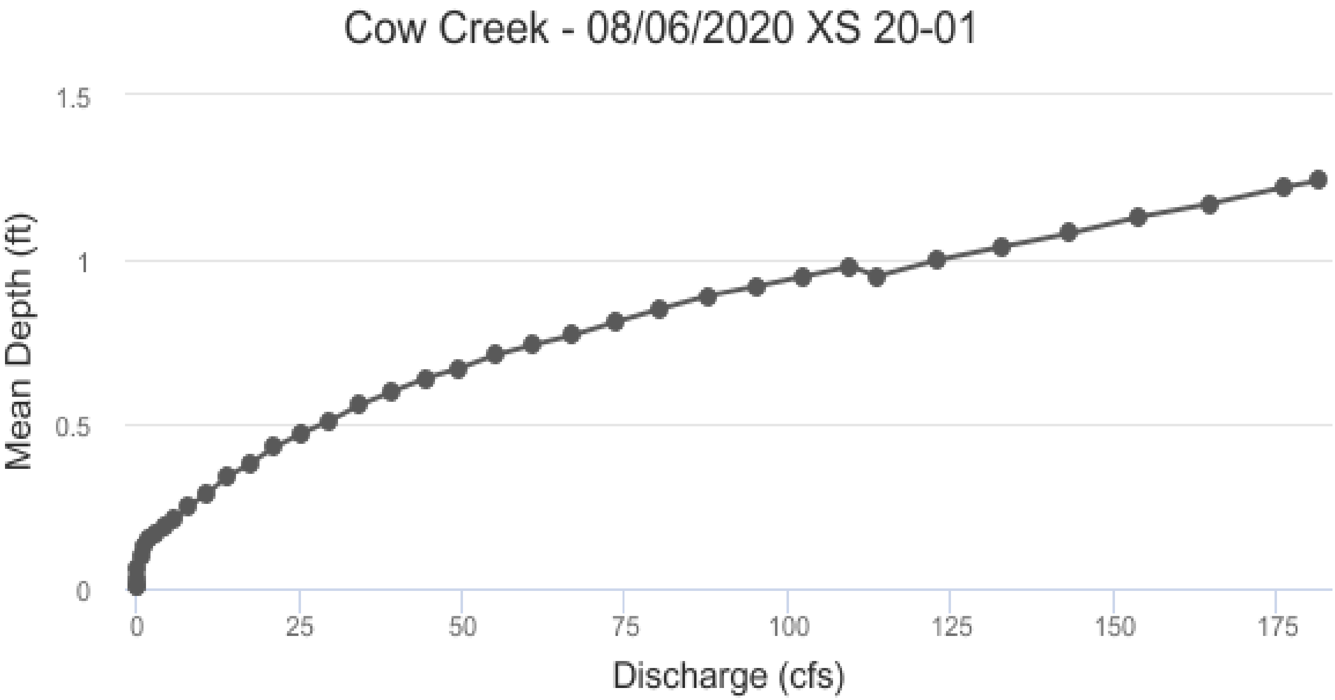
Habitat Criteria Results

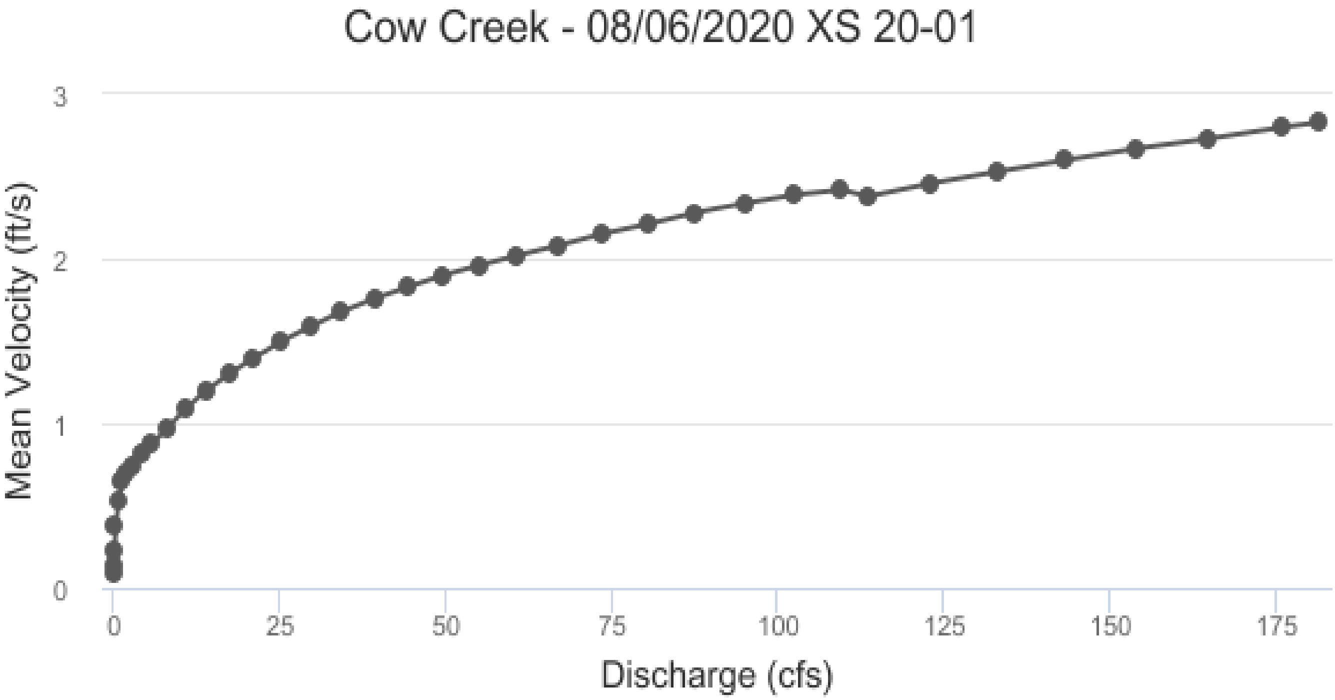
Bankfull top width (ft) = 51.8

	Habitat Criteria	Discharge (cfs) Meeting Criteria
Mean Depth (ft) **	0.52	29.97
Percent Wetted Perimeter (%)	55.9	5.16
Mean Velocity (ft/s)	1.0	8.63

**Values highlighted in yellow indicate that the discharge is less than 40% of measured Q or greater than 250% of measured Q.




Cow Creek - 08/06/2020 XS 20-01
Mean Depth (ft)
1.5
1
0.5
0
0
25
50
75
100
125
150
175
Discharge (cfs)


Cow Creek - 08/06/2020 XS 20-01
Mean Velocity (ft/s)
3
2
1
0
0
25
50
75
100
125
150
175
Discharge (cfs)

STAGING TABLE

Feature	Distance to Water (ft)	Top Width (ft)	Mean Depth (ft)	Maximum Depth (ft)	Area (SQ ft)	Wetted Perimeter (ft)	Percent Wetted Perimeter	Hydraulic Radius (ft)	Mean Velocity (ft/s)	Discharge (cfs)
Bankfull	3.5	51.8	1.24	1.8	64.1	52.47	100.00%	1.22	2.83	181.59
	3.52	51.67	1.22	1.78	62.86	52.33	99.74%	1.2	2.8	176.08
	3.57	51.41	1.17	1.73	60.28	52.04	99.18%	1.16	2.73	164.82
	3.62	51.14	1.13	1.68	57.72	51.75	98.63%	1.12	2.67	153.88
	3.67	50.89	1.08	1.63	55.17	51.47	98.11%	1.07	2.6	143.22
	3.72	50.62	1.04	1.58	52.63	51.17	97.52%	1.03	2.53	132.94
	3.77	50.3	1.0	1.53	50.11	50.81	96.84%	0.99	2.46	123.06
	3.82	49.98	0.95	1.48	47.6	50.45	96.15%	0.94	2.38	113.51
	3.87	46.28	0.98	1.43	45.18	46.71	89.03%	0.97	2.42	109.55
	3.92	44.96	0.95	1.38	42.9	45.36	86.45%	0.95	2.39	102.48
	3.97	43.99	0.92	1.33	40.68	44.36	84.54%	0.92	2.34	95.21
	4.02	43.41	0.89	1.28	38.5	43.74	83.36%	0.88	2.28	87.65
	4.07	42.82	0.85	1.23	36.34	43.12	82.19%	0.84	2.21	80.38
	4.12	42.19	0.81	1.18	34.22	42.46	80.93%	0.81	2.15	73.45
	4.17	41.49	0.77	1.13	32.12	41.76	79.59%	0.77	2.08	66.86
	4.22	40.66	0.74	1.08	30.07	40.91	77.98%	0.73	2.02	60.7
	4.27	39.69	0.71	1.03	28.06	39.94	76.11%	0.7	1.96	54.98
	4.32	38.74	0.67	0.98	26.1	38.97	74.28%	0.67	1.9	49.52
	4.37	37.79	0.64	0.93	24.19	38.01	72.44%	0.64	1.83	44.36
	4.42	37.1	0.6	0.88	22.32	37.3	71.09%	0.6	1.76	39.28
	4.47	36.68	0.56	0.83	20.47	36.86	70.25%	0.56	1.68	34.29
	4.52	36.25	0.51	0.78	18.65	36.42	69.42%	0.51	1.59	29.59
	4.57	35.79	0.47	0.73	16.85	35.95	68.52%	0.47	1.5	25.2
	4.62	35.29	0.43	0.68	15.07	35.44	67.54%	0.43	1.4	21.13
	4.67	34.79	0.38	0.63	13.32	34.93	66.57%	0.38	1.3	17.36

	4.72	34.29	0.34	0.58	11.59	34.42	65.60%	0.34	1.2	13.91
	4.77	33.8	0.29	0.53	9.89	33.91	64.62%	0.29	1.09	10.78
	4.82	33.3	0.25	0.48	8.21	33.4	63.65%	0.25	0.97	7.99
Waterline	4.87	30.98	0.21	0.43	6.59	31.08	59.23%	0.21	0.88	5.81
	4.92	26.74	0.19	0.38	5.14	26.82	51.13%	0.19	0.82	4.23
	4.97	23.14	0.17	0.33	3.89	23.22	44.25%	0.17	0.75	2.93
	5.02	18.75	0.15	0.28	2.83	18.81	35.86%	0.15	0.7	1.99
	5.07	14.9	0.13	0.23	2.0	14.94	28.47%	0.13	0.65	1.3
	5.12	13.21	0.1	0.18	1.31	13.24	25.23%	0.1	0.53	0.7
	5.17	11.53	0.06	0.13	0.68	11.55	22.02%	0.06	0.38	0.26
	5.22	7.03	0.03	0.08	0.2	7.04	13.41%	0.03	0.23	0.04
	5.27	1.17	0.01	0.03	0.02	1.17	2.24%	0.01	0.14	0.0
	5.29	0.67	0.01	0.01	0.01	0.68	1.29%	0.01	0.09	0.0

MODEL SUMMARY

Measured Flow (Qm) = 5.73

Calculated Flow (Qc) = 5.81

(Qm-Qc)/Qm * 100 = -1.32%

Measured Waterline (WLm) = 4.86

Calculated Waterline (WLc) = 4.87

(WLm-WLc)/WLm * 100 = -0.29%

Max Measured Depth (Dm) = 0.4

Max Calculated Depth (Dc) = 0.43

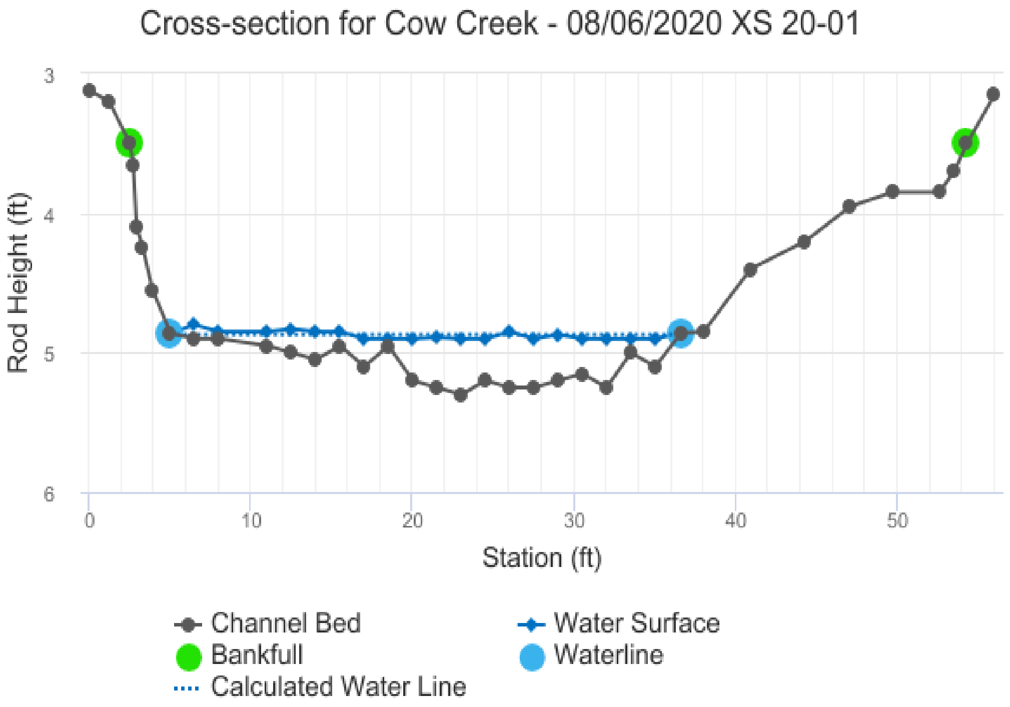
(Dm-Dc)/Dm * 100 = -6.51%

Mean Velocity = 0.88

Manning's n = 0.078

0.4 * Qm = 2.29

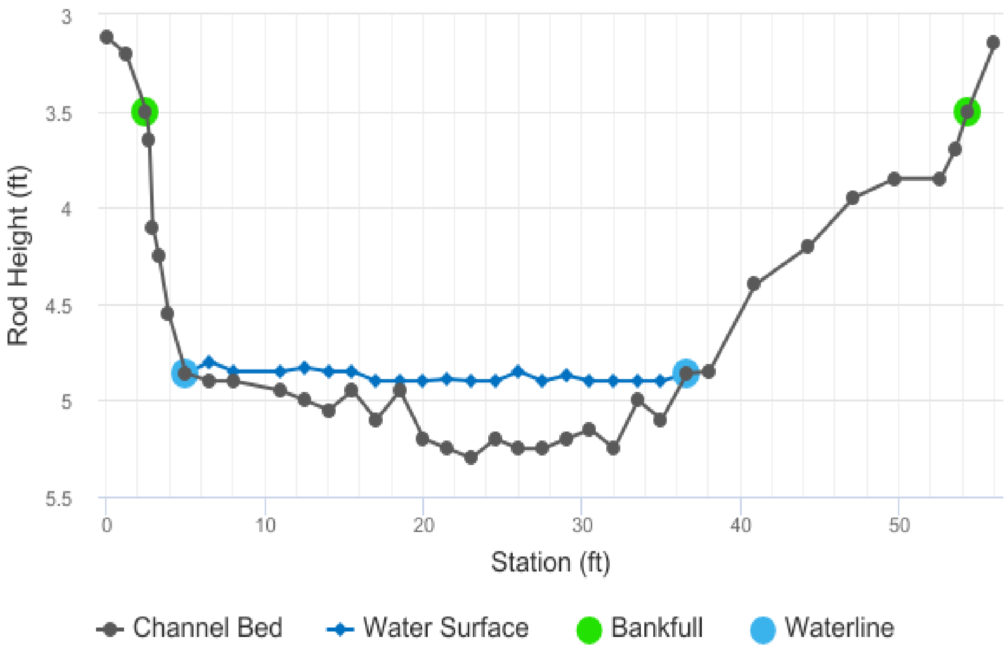
2.5 * Qm = 14.32



FIELD DATA

Feature	Station (ft)	Rod Height (ft)	Water depth (ft)	Velocity (ft/s)
	0	3.12		
	1.2	3.2		
Bankfull	2.5	3.5		
	2.7	3.65		
	2.9	4.1		
	3.3	4.25		
	3.9	4.55		
Waterline	5	4.86	0	
	6.5	4.9	0.1	
	8	4.9	0.05	
	11	4.95	0.1	
	12.5	5	0.17	
	14	5.05	0.2	
	15.5	4.95	0.1	
	17	5.1	0.2	
	18.5	4.95	0.05	
	20	5.2	0.3	
	21.5	5.25	0.36	
	23	5.3	0.4	
	24.5	5.2	0.3	
	26	5.25	0.4	
	27.5	5.25	0.35	
	29	5.2	0.33	
	30.5	5.15	0.25	
	32	5.25	0.35	
	33.5	5	0.1	
	35	5.1	0.2	
Waterline	36.6	4.86	0	
	38	4.85		
	40.9	4.4		

	44.3	4.2
	47.1	3.95
	49.7	3.85
	52.6	3.85
	53.5	3.7
Bankfull	54.3	3.5
	56	3.15


Cross-section for Cow Creek - 08/06/2020 XS 20-01

COMPUTED FROM MEASURED FIELD DATA

Wetted Perimeter (ft)	Water Depth (ft)	Area (SQ ft)	Discharge (cfs)	Percent Discharge
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
1.5	0.1	0.15	0.13	2.28
1.5	0.05	0.11	0.1	1.71
3	0.1	0.23	0.2	3.42
1.5	0.17	0.26	0.22	3.87
1.5	0.2	0.3	0.26	4.55
1.5	0.1	0.15	0.13	2.28
1.51	0.2	0.3	0.26	4.55
1.51	0.05	0.07	0.07	1.14
1.52	0.3	0.45	0.39	6.83
1.5	0.36	0.54	0.47	8.2
1.5	0.4	0.6	0.52	9.11
1.5	0.3	0.45	0.39	6.83
1.5	0.4	0.6	0.52	9.11
1.5	0.35	0.53	0.46	7.97
1.5	0.33	0.49	0.43	7.51
1.5	0.25	0.38	0.33	5.69
1.5	0.35	0.53	0.46	7.97
1.52	0.1	0.15	0.13	2.28
1.5	0.2	0.31	0.27	4.71
1.62	0	0	0	0
0	0	0	0	0
0	0	0	0	0

0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

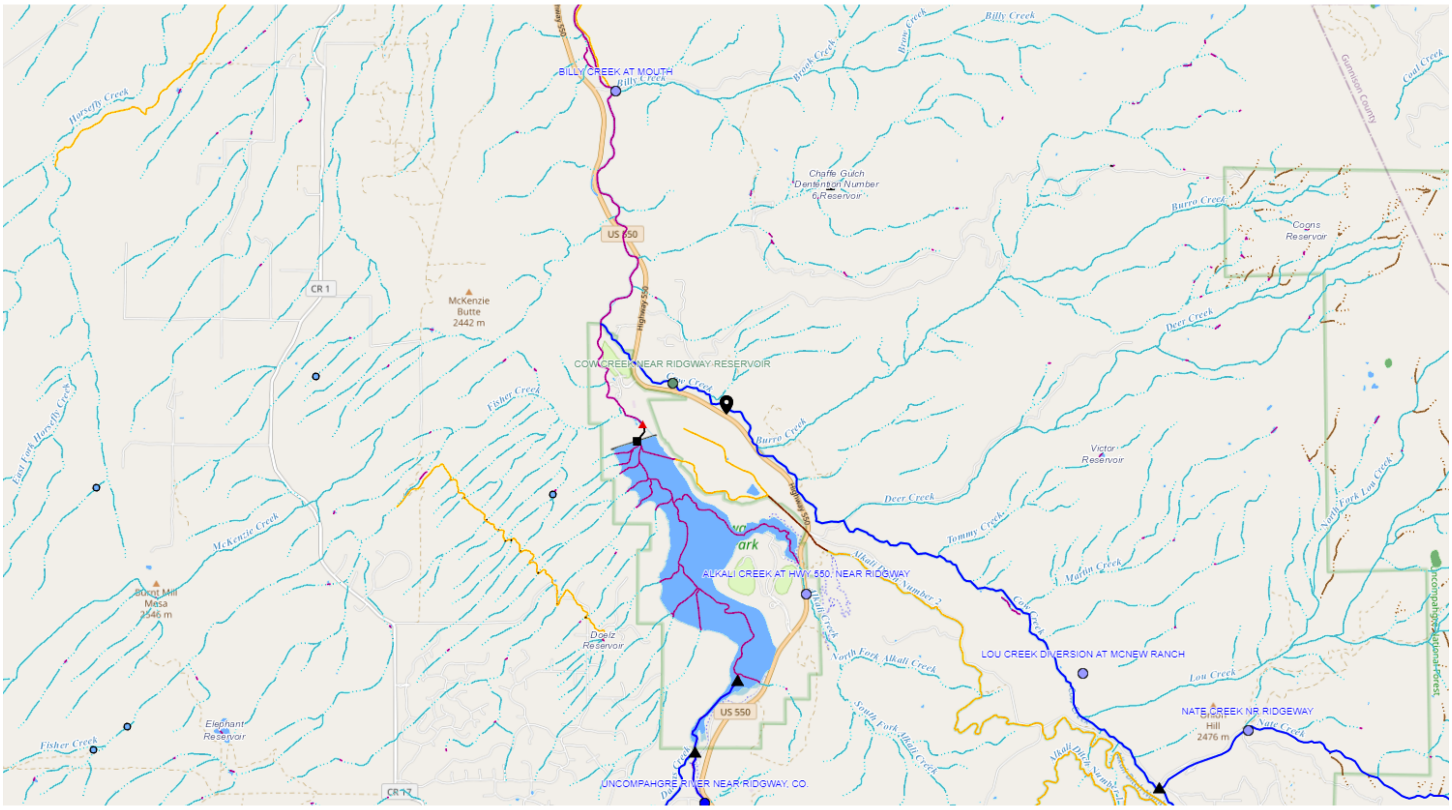
DISCLAIMER

"The Colorado Water Conservation Board makes no representations about the use of the software contained in the R2Cross platform for any purpose besides that for which it was designed. To the maximum extent permitted by applicable law, all information, modeling results, and software are provided “as is” without warranty or condition of any kind, including all implied warranties or conditions of merchantability, or fitness for a particular purpose. The user assumes all responsibility for the accuracy and suitability of this program for a specific application. In no event shall the Colorado Water Conservation Board or any state agency, official or employee be liable for any direct, indirect, punitive, incidental, special, consequential damages or any damages whatsoever including, without limitation, damages for loss of use, data, profits, or savings arising from the implementation, reliance on, or use of or inability to use the R2Cross platform.

R2Cross RESULTS

Stream Name: Cow Creek
Stream Locations: Billy Creek SWA
Fieldwork Date: 08/06/2020
Cross-section: 20-02
Observers: Birch, Le
Coordinate System: UTM Zone 13
X (easting): 260020
Y (northing): 4236172
Date Processed: 12/12/2020
Slope: 0.013
Computation method: Manning's n
R2Cross data filename: CowCreek-4_8-6-2020_R2CrossData-Q=5.95 flowtracker.xlsx
R2Cross version: 1.1.16

LOCATION



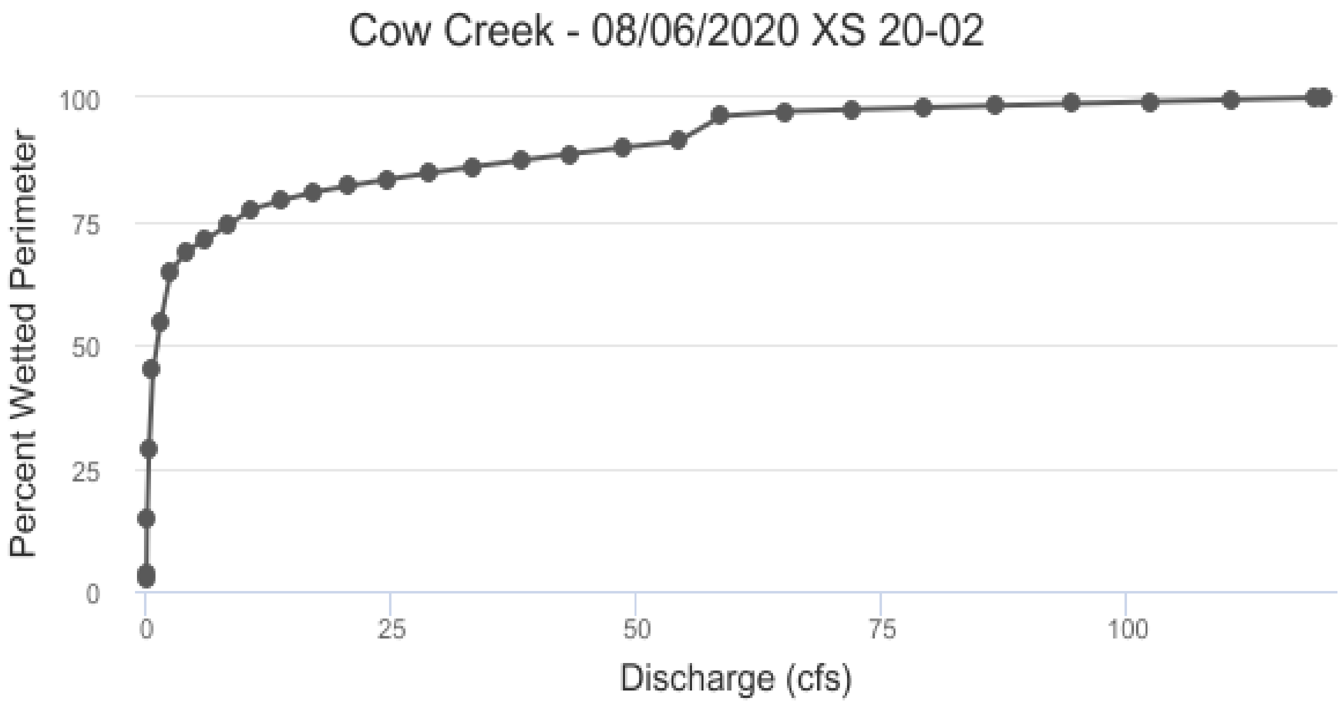
ANALYSIS RESULTS

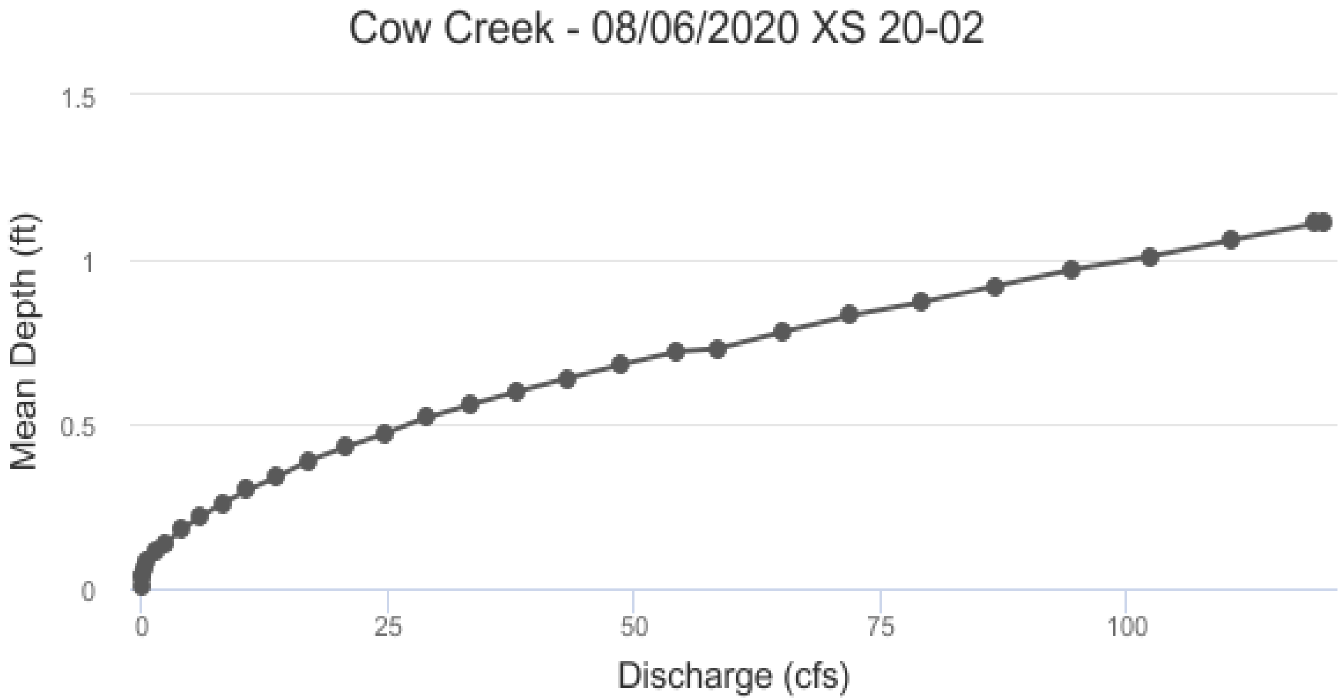
Habitat Criteria Results

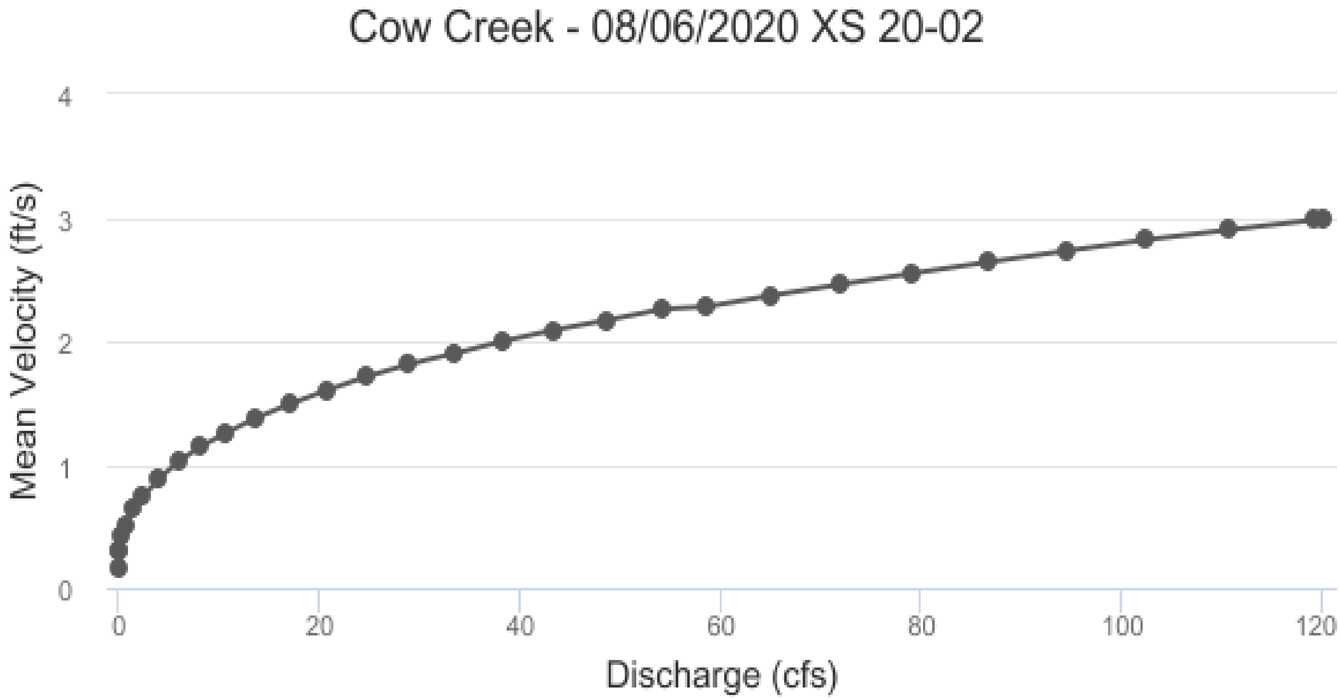
Bankfull top width (ft) = 36.04

	Habitat Criteria	Discharge (cfs) Meeting Criteria
Mean Depth (ft) **	0.36	15.13
Percent Wetted Perimeter (%) **	50.0	1.06
Mean Velocity (ft/s)	1.0	5.52

**Values highlighted in yellow indicate that the discharge is less than 40% of measured Q or greater than 250% of measured Q.







R2Cross RESULTS: Cow Creek - 08/06/2020 XS 20-02, Analysis Method: [Manning's n]

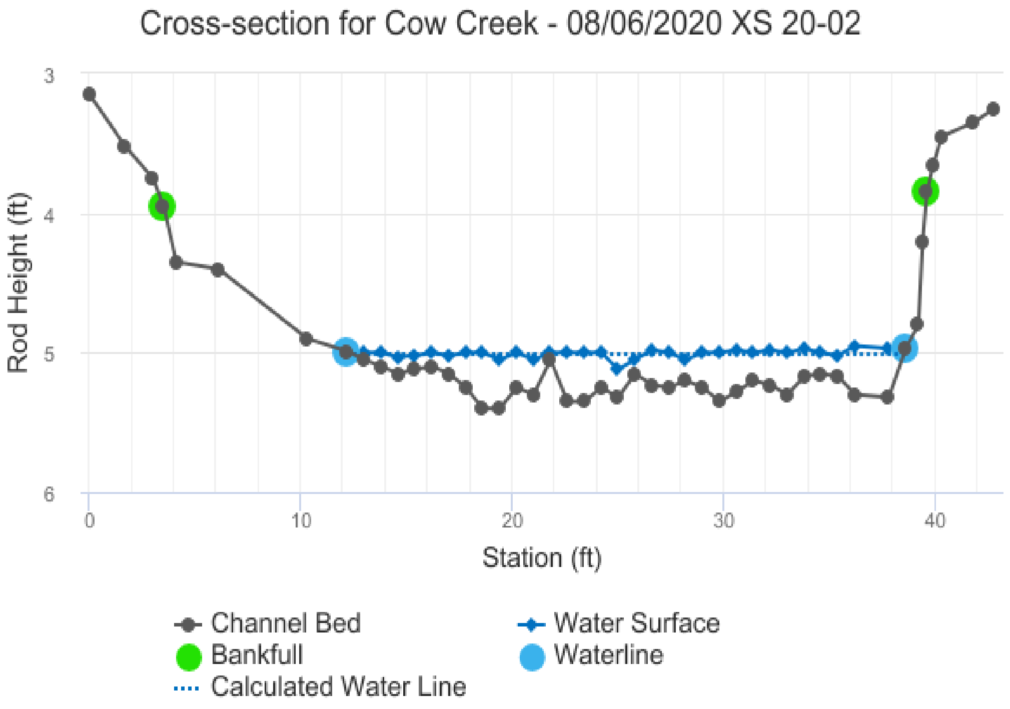
STAGING TABLE

Feature	Distance to Water (ft)	Top Width (ft)	Mean Depth (ft)	Maximum Depth (ft)	Area (SQ ft)	Wetted Perimeter (ft)	Percent Wetted Perimeter	Hydraulic Radius (ft)	Mean Velocity (ft/s)	Discharge (cfs)
Bankfull	3.95	36.04	1.11	1.45	40.15	37.08	100.00%	1.08	2.99	120.15
	3.96	36.03	1.11	1.44	39.95	37.06	99.96%	1.08	2.98	119.19
	4.01	35.93	1.06	1.39	38.15	36.92	99.56%	1.03	2.9	110.67
	4.06	35.82	1.01	1.34	36.36	36.77	99.16%	0.99	2.82	102.41
	4.11	35.72	0.97	1.29	34.57	36.62	98.76%	0.94	2.73	94.41
	4.16	35.62	0.92	1.24	32.79	36.47	98.36%	0.9	2.64	86.66
	4.21	35.51	0.87	1.19	31.01	36.33	97.97%	0.85	2.55	79.18
	4.26	35.42	0.83	1.14	29.24	36.18	97.58%	0.81	2.46	71.97
	4.31	35.33	0.78	1.09	27.47	36.04	97.19%	0.76	2.37	65.03
	4.36	35.03	0.73	1.04	25.7	35.68	96.24%	0.72	2.28	58.61
	4.41	33.18	0.72	0.99	24.0	33.81	91.17%	0.71	2.26	54.21
	4.46	32.75	0.68	0.94	22.35	33.33	89.89%	0.67	2.17	48.6
	4.51	32.31	0.64	0.89	20.73	32.85	88.61%	0.63	2.09	43.26
	4.56	31.87	0.6	0.84	19.12	32.38	87.32%	0.59	2.0	38.2
	4.61	31.44	0.56	0.79	17.54	31.9	86.04%	0.55	1.9	33.4
	4.66	31.0	0.52	0.74	15.98	31.43	84.76%	0.51	1.81	28.88
	4.71	30.56	0.47	0.69	14.44	30.95	83.47%	0.47	1.71	24.65
	4.76	30.13	0.43	0.64	12.92	30.48	82.19%	0.42	1.6	20.7
	4.81	29.67	0.39	0.59	11.43	29.99	80.87%	0.38	1.49	17.04
	4.86	29.08	0.34	0.54	9.96	29.38	79.23%	0.34	1.38	13.74
	4.91	28.41	0.3	0.49	8.52	28.7	77.41%	0.3	1.26	10.76
	4.96	27.18	0.26	0.44	7.13	27.46	74.06%	0.26	1.15	8.23
Waterline	5.01	26.11	0.22	0.39	5.8	26.39	71.16%	0.22	1.03	5.99
	5.06	25.28	0.18	0.34	4.51	25.54	68.89%	0.18	0.89	4.03
	5.11	23.76	0.14	0.29	3.28	23.99	64.71%	0.14	0.75	2.47

	5.16	19.98	0.11	0.24	2.19	20.18	54.43%	0.11	0.64	1.41
	5.21	16.47	0.08	0.19	1.28	16.62	44.83%	0.08	0.51	0.66
	5.26	10.64	0.06	0.14	0.6	10.74	28.97%	0.06	0.42	0.25
	5.31	5.37	0.04	0.09	0.2	5.4	14.57%	0.04	0.31	0.06
	5.36	1.27	0.04	0.04	0.05	1.28	3.46%	0.04	0.31	0.01
	5.38	0.96	0.01	0.01	0.01	0.96	2.60%	0.01	0.16	0.0

MODEL SUMMARY

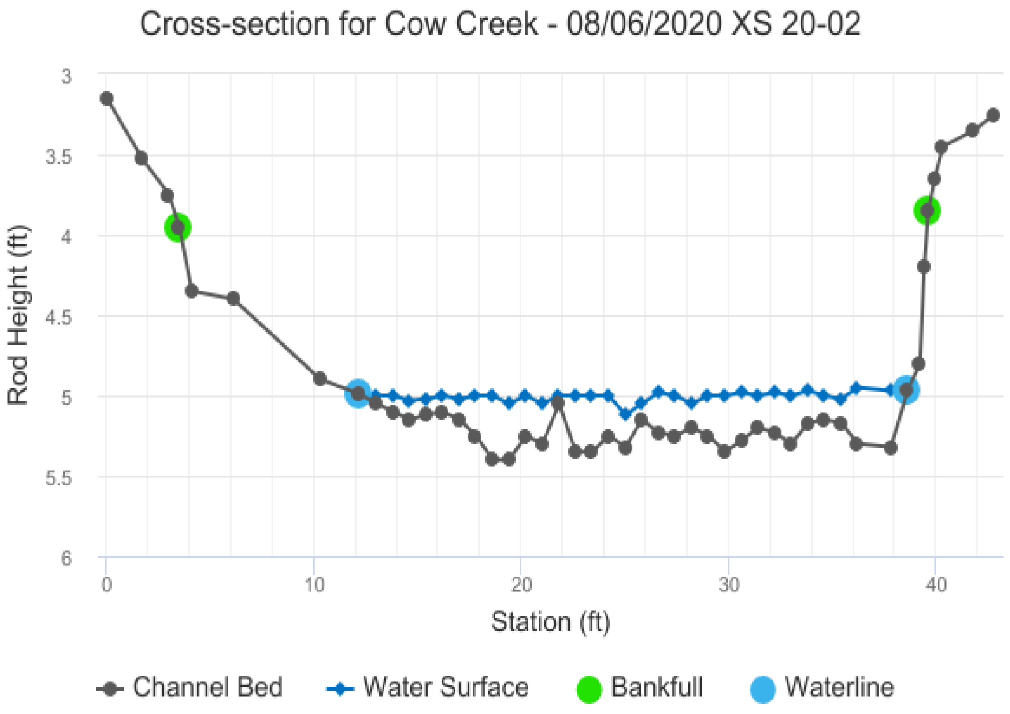
Measured Flow (Qm) =	5.95
Calculated Flow (Qc) =	5.99
(Qm-Qc)/Qm * 100 =	-0.75%
Measured Waterline (WLm) =	4.98
Calculated Waterline (WLc) =	5.01
(WLm-WLc)/WLm * 100 =	-0.51%
Max Measured Depth (Dm) =	0.4
Max Calculated Depth (Dc) =	0.39
(Dm-Dc)/Dm * 100 =	1.39%
Mean Velocity =	1.03
Manning's n =	0.06
0.4 * Qm =	2.38
2.5 * Qm =	14.88



FIELD DATA

Feature	Station (ft)	Rod Height (ft)	Water depth (ft)	Velocity (ft/s)
	0	3.15		
	1.7	3.525		
	3	3.75		
Bankfull	3.5	3.95		
	4.1	4.35		
	6.1	4.4		
	10.3	4.9		
Waterline	12.2	4.99	0	
	13	5.05	0.05	
	13.8	5.1	0.1	
	14.6	5.15	0.12	
	15.4	5.12	0.1	
	16.2	5.1	0.1	
	17	5.15	0.13	
	17.8	5.25	0.25	
	18.6	5.4	0.4	
	19.4	5.4	0.35	
	20.2	5.25	0.25	
	21	5.3	0.25	
	21.8	5.05	0.05	
	22.6	5.35	0.35	
	23.4	5.35	0.35	
	24.2	5.25	0.25	
	25	5.32	0.2	
	25.8	5.15	0.1	
	26.6	5.23	0.25	
	27.4	5.25	0.25	
	28.2	5.2	0.15	
	29	5.25	0.25	
	29.8	5.35	0.35	

	30.6	5.28	0.3
	31.4	5.2	0.2
	32.2	5.23	0.25
	33	5.3	0.3
	33.8	5.17	0.2
	34.6	5.15	0.15
	35.4	5.17	0.15
	36.2	5.3	0.35
	37.8	5.32	0.35
Waterline	38.6	4.97	0
	39.2	4.8	
	39.4	4.2	
Bankfull	39.6	3.85	
	39.9	3.65	
	40.3	3.45	
	41.8	3.35	
	42.8	3.25	



COMPUTED FROM MEASURED FIELD DATA

Wetted Perimeter (ft)	Water Depth (ft)	Area (SQ ft)	Discharge (cfs)	Percent Discharge
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0.8	0.05	0.04	0.04	0.69
0.8	0.1	0.08	0.08	1.38
0.8	0.12	0.1	0.1	1.66
0.8	0.1	0.08	0.08	1.38
0.8	0.1	0.08	0.08	1.38
0.8	0.13	0.1	0.11	1.79
0.81	0.25	0.2	0.21	3.45
0.81	0.4	0.32	0.33	5.52
0.8	0.35	0.28	0.29	4.83
0.81	0.25	0.2	0.21	3.45
0.8	0.25	0.2	0.21	3.45
0.84	0.05	0.04	0.04	0.69
0.85	0.35	0.28	0.29	4.83
0.8	0.35	0.28	0.29	4.83
0.81	0.25	0.2	0.21	3.45
0.8	0.2	0.16	0.16	2.76
0.82	0.1	0.08	0.08	1.38
0.8	0.25	0.2	0.21	3.45
0.8	0.25	0.2	0.21	3.45
0.8	0.15	0.12	0.12	2.07
0.8	0.25	0.2	0.21	3.45
0.81	0.35	0.28	0.29	4.83

0.8	0.3	0.24	0.25	4.14
0.8	0.2	0.16	0.16	2.76
0.8	0.25	0.2	0.21	3.45
0.8	0.3	0.24	0.25	4.14
0.81	0.2	0.16	0.16	2.76
0.8	0.15	0.12	0.12	2.07
0.8	0.15	0.12	0.12	2.07
0.81	0.35	0.42	0.43	7.24
1.6	0.35	0.42	0.43	7.24
0.87	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

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CWCB Staff Cow Creek Point Flow Model Notes

Approach

The proposed ISF reach on Cow Creek is fairly complex due to the number of mainstem diversion structures and return flows from adjacent irrigated lands. The availability of diversion records, previous modeling efforts, and the existence of the Cow Creek gage at the bottom of the reach made it possible for staff to develop a point flow model to better understand streamflow throughout the reach. The point flow model estimates daily streamflow at a number of locations along Cow Creek between the Martin Ditch and the Cow Creek gage near the confluence with the Uncompahgre River. Return flows from irrigated lands are estimated using system efficiency numbers derived from StateCU and StateMod documentation. The stream gage records, estimated return flows, lagged return flows, and diversion records are derived from HydroBase and are used to estimate streamflow.

Model

A spreadsheet model was created in Microsoft Excel to organize the daily average streamflow data from the Cow Creek near Ridgway, CO gage (DWR COWCRKCO) and diversion record information, and to perform the calculations for unlagged return flows, lagged return flows, and streamflow at a number of locations, or nodes. The model operated on a daily time step to estimate flow at locations between the Martin Ditch and the Cow Creek near Ridgway, CO gage (DWR COWCRKCO). Due to the short length of the reach, transit timing was not incorporated into the modeling.

The Cow Creek gage and diversion record data were collected from HydroBase through a local connection to the production server in TSTool on January 31, 2020. The monthly irrigation efficiency and return flow patterns were obtained from the Gunnison River StateMod model released on 8/2/2016, which relied on calculations performed in StateCU. The Cow Creek point flow model is run from 4/24/2008 to 10/31/2019. This timeframe corresponds to operation of the Cow Creek gage and the availability of diversion records at the time the data was retrieved.

Modeled Nodes

Streamflow was modeled at the primary diversion structures on the mainstem of Cow Creek that were located upstream of the Cow Creek gage and below Nate Creek and had more than 1 cfs in decreed surface water diversions (see table below). In addition, the model included nodes at the confluence with Lou Creek, Deer Creek, and Burro Creek. A number of smaller water rights (generally less than 0.75 cfs) for ponds or springs were not simulated. Most of these smaller diversions did not have diversion records. The Island Pond Ditch (WDID 6800616, decreed for 1 cfs), which is used to fill and refresh ponds and is not used for irrigation was also not modeled. The term “inflow” in the model signifies the amount of water coming to a node, “outflow” means the amount of water leaving a node (see list of nodes).

Mainstem Diversion Structures Modeled.

WDID	Structure Name	Decreed Flow Rate, cfs	Location
6800523	Chaffee Ditch	4.934	Between Burro Creek & gage
6800601	Hayes Teague Ditch	3.667	Between Burro Creek & gage

6800565	East Side Ditch	7. 0	Between Martin & Deer Creek
6800729	Shortline D Ditch	14.0	Between Martin & Deer Creek
6800624	Jolly Ditch	4.0	Between Lou & Martin Creek
6800647	Martin Ditch	8.0	Between Nate Creek & Lou Creek

List of Modeled Locations

1. Martin Inflow
2. Martin Outflow (same as Lou Creek Inflow/Outflow which are equal assuming no tributary contributions)
3. Jolly Outflow
4. Shortline D Outflow
5. East Side D Outflow
6. Deer Creek Inflow/Outflow (these are equal assuming no tributary contributions)
7. Burro Creek Inflow/Outflow (these are equal assuming no tributary contributions)
8. Hayes Teague Outflow
9. Chaffee Outflow (same as Cow Creek gage)

Return Flows

Return flows were simulated for irrigated parcels that accrue to Cow Creek. This included lands irrigated by diversion structures from the mainstem of Cow Creek as well as diversion structures located on tributaries to Cow Creek. The Full CDSS Map Viewer (https://gis.colorado.gov/dnrviewer/Index.html?viewer=mapviewer) was used to determine which structures irrigate each field based on the 2015 Irrigated Lands Coverage. Some structures had diversion records but were not assigned to any irrigated lands. Staff worked with the Water Commissioner to determine where water from these structures is used (Eric Weig, personal communication November 2020 through February 2021). The Water Commissioner believed that the Map Viewer information was overall fairly accurate. In some cases, multiple structures were used to irrigate the same lands (see line diagram of the modeled system).

Return flows were simulated using information about monthly system efficiency from Gunnison StateMod Model. The Martin Ditch and the Shortline D Ditch had structure specific efficiency factors that were obtained from the StateMod gm2015.dds file. Return flows for all other diversions in the modeled area were simulated using District 68 monthly average efficiencies from Table 11 in the StateCU documentation for the Gunnison basin (Historical Crop Consumptive Use Analysis, Gunnison River Basin, Colorado Decision Support System, 2015). In the spreadsheet model, monthly system efficiencies were applied to the daily diversion records to determine the unlagged return flows on a daily basis. An Excel Macro was used to lag the return flows back to the river on a daily basis. Fifty percent of the return flows were assumed to be surface water that returned on the first day. The remaining return flows were lagged using the delay tables developed for the west slope Statemod models; pattern 1 was used based on documentation in the Gunnison Model. The first month was adjusted to account for 3% loss of returns due to non-crop consumption or "incidental" system losses.

Return flows were generally simulated based on the assumption that returns accrue to the next downstream node below the location of the irrigated acres. In some cases, diversion structures irrigate multiple fields (Martin Ditch, Shortline D Ditch, and East Side Ditch). The return flows from these fields can accrue to locations both above and below other modeled nodes. Google Earth imagery was checked for return flow channels or waste water ditches, which were not observed. The amount of return flows accruing above or below the next modeled node was prorated based on the percent of irrigated land occurring above or below the node. This was assessed using Map Viewer to determine the parcel acreage and measure irrigated lands above each node. Approximately 23% of the land irrigated by the Martin Ditch is located upstream from the Shortline D Ditch. Approximately 43% of the land irrigated by the Shortline D Ditch is upstream from the confluence with Deer Creek. The East Side Ditch irrigates mainly downstream from Deer Creek but also a small parcel below Burro Creek. All return flows for the East Side Ditch were assumed to accrue below Burro Creek at the Hayes Teague Ditch node. This likely underestimates the amount of flow at the Burro Creek node.

Tributary Contributions

Based on correspondence with the Water Commissioner, Lou Creek, Deer Creek, and Burro Creek flow seasonally and the Babb Ditch diverts the entire flow from Deer Creek year-round (Eric Weig, personal communication November 2020 through February 2021). Martin Creek and Tommy Creeks appear to be smaller than the other tributaries and are also assumed to have seasonal flow. Based on this information, the model does not simulate tributary inflows. This is a reasonable and conservative assumption, particularly in late summer and early fall when tributary inflow is unlikely and when water availability is lowest.

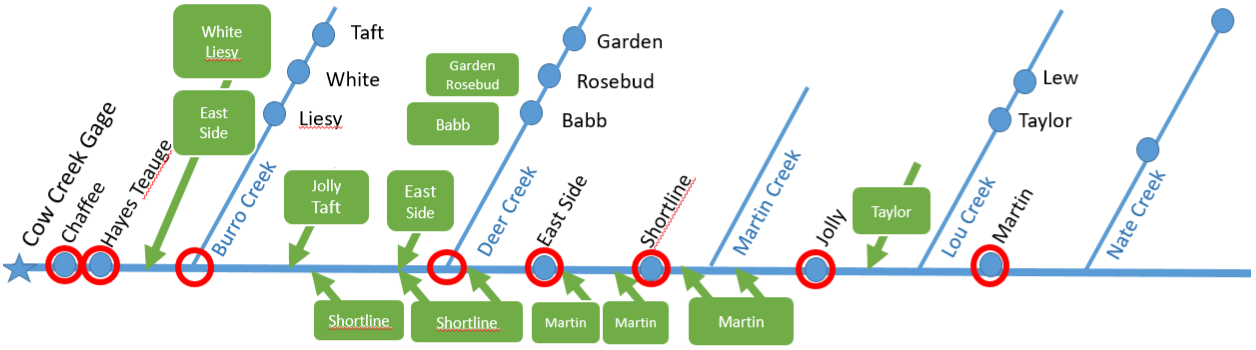
Results

Daily median streamflow was calculated at each node over the model period. This information is summarized in the Cow Creek Executive Summary.

Summary of Assumptions

1. Return Flows were estimated using StateMod monthly average system efficiencies for the Martin Ditch and Shortline D Ditch and StateCU monthly average system efficiencies for District 68 for all other structures. This relies on underlying assumptions in StateCU and StateMod regarding historical acreage, climate data, equal sharing of ditches, etc.
2. 50% of return flows were assumed to return immediately, 3% were assumed to not return (incidental system losses), and the remaining return flows were lagged based on the delay table used in the Gunnison StateMod Model.
3. No gains due to tributary inflows. This aligns with information provided by the Water Commissioner that Burro, Deer, and Martin Creeks provide little or no streamflow to Cow Creek except during high runoff (note during this period streamflows are well above proposed ISF rate).
4. No gains or losses due to bank storage/seepage.
5. Transit time was not accounted for by the model. Transit times are likely short given the reach length.
6. Small water rights for ponds and springs were not explicitly accounted for by the model.

Line Diagram of the Cow Creek Point Flow Model



Discharge Measurment Field Visit Data Report *(Filters: Name begins with Cow Creek; Division = 4;)*

Div	Name	CWCB Case Number	Segment ID	Meas. Date	UTM	Location	Flow Amount (cfs)	Meas #	Rating	Station ID
4	Cow Creek		16/4/A-001	05/20/2015	UTMx: 268251 UTMy: 4225778	Cow Creek upstream of JbarMRanch Bridge.	96.99	1	Good	

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Discharge Measurement Summary

Date Generated: Wed Jun 3 2015

File Information

File Name	COWCRAFC.001.WAD
Start Date and Time	2015/05/20 13:39:23

Site Details

Site Name	COW CR ABV FLUME CR
Operator(s)	BRIAN EPSTEIN

System Information

Sensor Type	FlowTracker
Serial #	P2354
CPU Firmware Version	3.9
Software Ver	2.30
Mounting Correction	0.0%

Units (English Units)

Distance	ft
Velocity	ft/s
Area	ft^2
Discharge	cfs

Discharge Uncertainty

Category	ISO	Stats
Accuracy	1.0%	1.0%
Depth	0.1%	1.6%
Velocity	0.6%	2.1%
Width	0.1%	0.1%
Method	1.3%	-
# Stations	1.3%	-
Overall	**2.2%**	**2.8%**

Summary

Averaging Int.	40	# Stations	40
Start Edge	REW	Total Width	28.000
Mean SNR	45.8 dB	Total Area	25.526
Mean Temp	45.98 °F	Mean Depth	0.912
Disch. Equation	Mid-Section	Mean Velocity	3.7996
		Total Discharge	**96.9872**

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Site Details	
Site Name	COW CR ABV FLUME CR
Operator(s)	BRIAN EPSTEIN

Measurement Results

St	Clock	Loc	Method	Depth	%Dep	MeasD	Vel	CorrFact	MeanV	Area	Flow	%Q
0	13:39	10.00	None	0.000	0.0	0.0	0.0000	1.00	0.0000	0.000	0.0000	0.0
1	*13:39*	*11.00*	*0.6*	*0.400*	*0.6*	*0.160*	*0.6512*	*1.00*	*0.6512*	*0.400*	*0.2605*	*0.3*
2	13:40	12.00	0.6	0.450	0.6	0.180	1.9199	1.00	1.9199	0.450	0.8642	0.9
3	13:41	13.00	0.6	0.680	0.6	0.272	1.7618	1.00	1.7618	0.680	1.1982	1.2
4	13:42	14.00	0.6	0.500	0.6	0.200	2.6778	1.00	2.6778	0.500	1.3389	1.4
5	13:43	15.00	0.6	0.850	0.6	0.340	3.1220	1.00	3.1220	0.850	2.6539	2.7
6	13:44	16.00	0.6	0.950	0.6	0.380	3.4652	1.00	3.4652	0.950	3.2924	3.4
7	13:46	17.00	0.6	1.200	0.6	0.480	3.5246	1.00	3.5246	0.900	3.1725	3.3
8	13:48	17.50	0.6	1.250	0.6	0.500	3.4820	1.00	3.4820	0.625	2.1762	2.2
9	13:49	18.00	0.6	1.300	0.6	0.520	4.0272	1.00	4.0272	0.650	2.6174	2.7
10	13:50	18.50	0.6	1.250	0.6	0.500	4.7900	1.00	4.7900	0.625	2.9938	3.1
11	13:52	19.00	0.6	1.300	0.6	0.520	4.8012	1.00	4.8012	0.650	3.1205	3.2
12	13:53	19.50	0.6	1.200	0.6	0.480	4.6345	1.00	4.6345	0.600	2.7810	2.9
13	13:55	20.00	0.6	1.350	0.6	0.540	4.1480	1.00	4.1480	0.675	2.8000	2.9
14	13:56	20.50	0.6	1.400	0.6	0.560	4.6673	1.00	4.6673	0.700	3.2670	3.4
15	13:57	21.00	0.6	1.400	0.6	0.560	5.4728	1.00	5.4728	0.700	3.8308	3.9
16	13:58	21.50	0.6	1.450	0.6	0.580	4.4547	1.00	4.4547	0.725	3.2300	3.3
17	*14:02*	*22.00*	*0.6*	*1.400*	*0.6*	*0.560*	*5.1204*	*1.00*	*5.1204*	*0.700*	*3.5841*	*3.7*
18	*14:05*	*22.50*	*0.6*	*1.450*	*0.6*	*0.580*	*3.3018*	*1.00*	*3.3018*	*0.725*	*2.3940*	*2.5*
19	*14:07*	*23.00*	*0.6*	*1.350*	*0.6*	*0.540*	*5.2431*	*1.00*	*5.2431*	*0.675*	*3.5393*	*3.6*
20	14:09	23.50	0.6	1.350	0.6	0.540	6.3963	1.00	6.3963	0.675	4.3177	4.5
21	14:10	24.00	0.6	1.250	0.6	0.500	5.7339	1.00	5.7339	0.625	3.5837	3.7
22	14:11	24.50	0.6	1.400	0.6	0.560	5.1522	1.00	5.1522	0.700	3.6064	3.7
23	14:12	25.00	0.6	1.500	0.6	0.600	4.4590	1.00	4.4590	0.750	3.3442	3.4
24	14:13	25.50	0.6	1.450	0.6	0.580	4.3320	1.00	4.3320	0.725	3.1410	3.2
25	14:15	26.00	0.6	1.350	0.6	0.540	4.8891	1.00	4.8891	0.675	3.3003	3.4
26	14:18	26.50	0.6	1.050	0.6	0.420	5.6388	1.00	5.6388	0.525	2.9600	3.1
27	14:19	27.00	0.6	1.100	0.6	0.440	4.7848	1.00	4.7848	0.550	2.6318	2.7
28	14:20	27.50	0.6	1.150	0.6	0.460	4.3025	1.00	4.3025	0.575	2.4738	2.6
29	14:22	28.00	0.6	1.200	0.6	0.480	4.1506	1.00	4.1506	0.600	2.4906	2.6
30	14:23	28.50	0.6	1.200	0.6	0.480	4.1565	1.00	4.1565	0.600	2.4942	2.6
31	14:24	29.00	0.6	0.800	0.6	0.320	3.8940	1.00	3.8940	0.600	2.3360	2.4
32	14:26	30.00	0.6	0.700	0.6	0.280	4.0308	1.00	4.0308	0.700	2.8221	2.9
33	14:27	31.00	0.6	0.900	0.6	0.360	2.9898	1.00	2.9898	0.900	2.6907	2.8
34	14:28	32.00	0.6	0.620	0.6	0.248	2.0266	1.00	2.0266	0.620	1.2566	1.3
35	*14:29*	*33.00*	*0.6*	*0.350*	*0.6*	*0.140*	*1.8819*	*1.00*	*1.8819*	*0.350*	*0.6588*	*0.7*
36	*14:31*	*34.00*	*0.6*	*0.700*	*0.6*	*0.280*	*0.7487*	*1.00*	*0.7487*	*0.700*	*0.5242*	*0.5*
37	14:32	35.00	0.6	0.750	0.6	0.300	2.0315	1.00	2.0315	0.750	1.5236	1.6
38	14:33	36.00	0.6	0.750	0.6	0.300	1.5259	1.00	1.5259	1.125	1.7167	1.8
39	14:33	38.00	None	0.000	0.0	0.0	0.0000	1.00	0.0000	0.000	0.0000	0.0

Rows in italics indicate a QC warning. See the Quality Control page of this report for more information.

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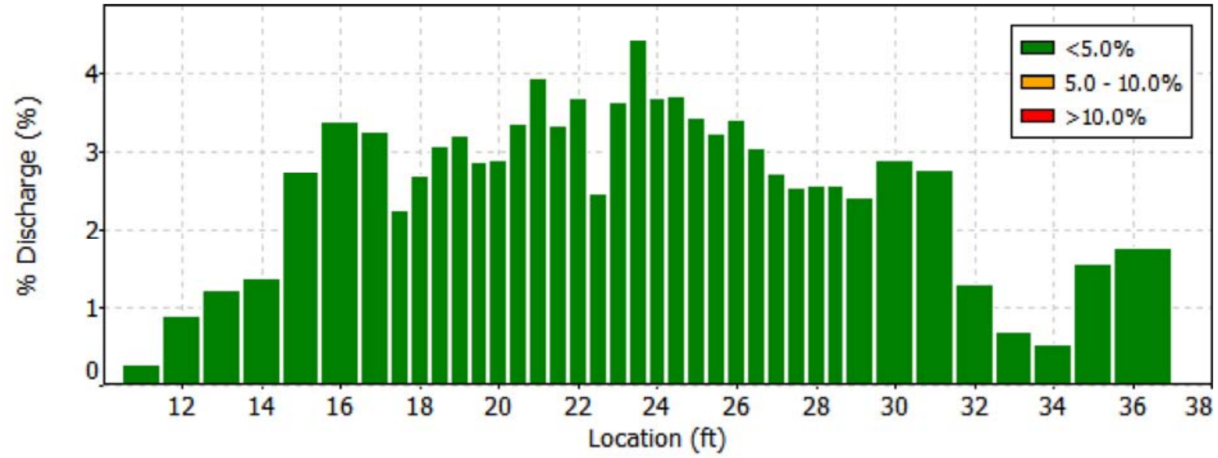
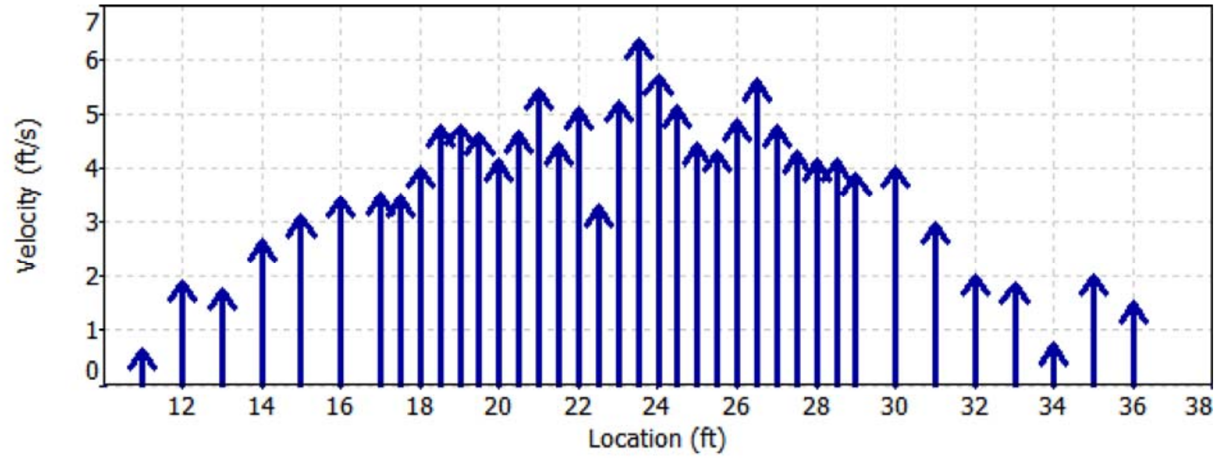
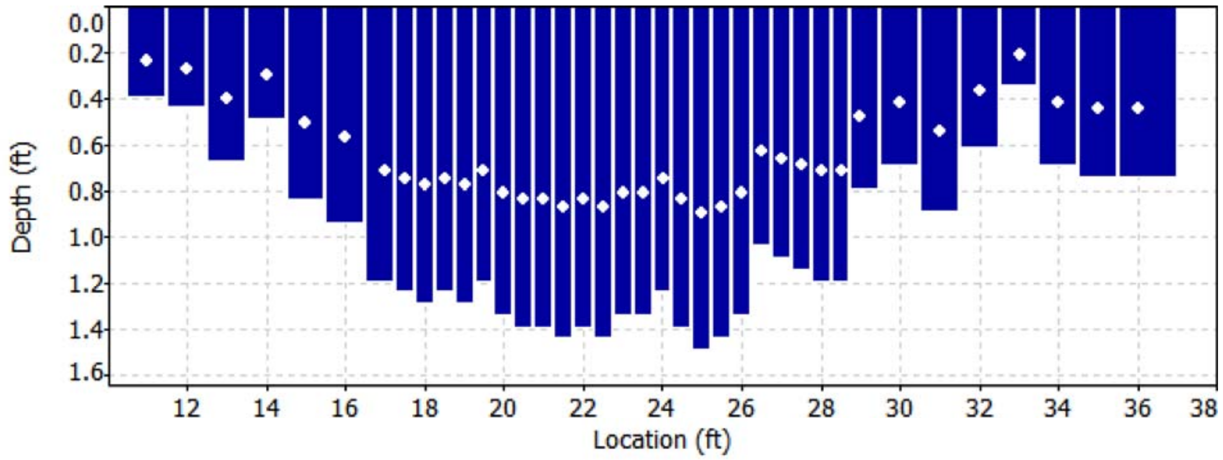
Discharge Measurement Summary

Date Generated: Wed Jun 3 2015

File Information		**Site Details**	
File Name	COWCRAFC.001.WAD	Site Name	COW CR ABV FLUME CR
Start Date and Time	2015/05/20 13:39:23	Operator(s)	BRIAN EPSTEIN







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Start Date and Time	2015/05/20 13:39:23

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Operator(s)	BRIAN EPSTEIN

Quality Control

St	Loc	%Dep	Message
1	11.00	0.6	High number of spikes: 5
17	22.00	0.6	High number of spikes: 6
18	22.50	0.6	High standard error: 0.195
19	23.00	0.6	High standard error: 0.276
35	33.00	0.6	High angle: 23
36	34.00	0.6	High angle: 27

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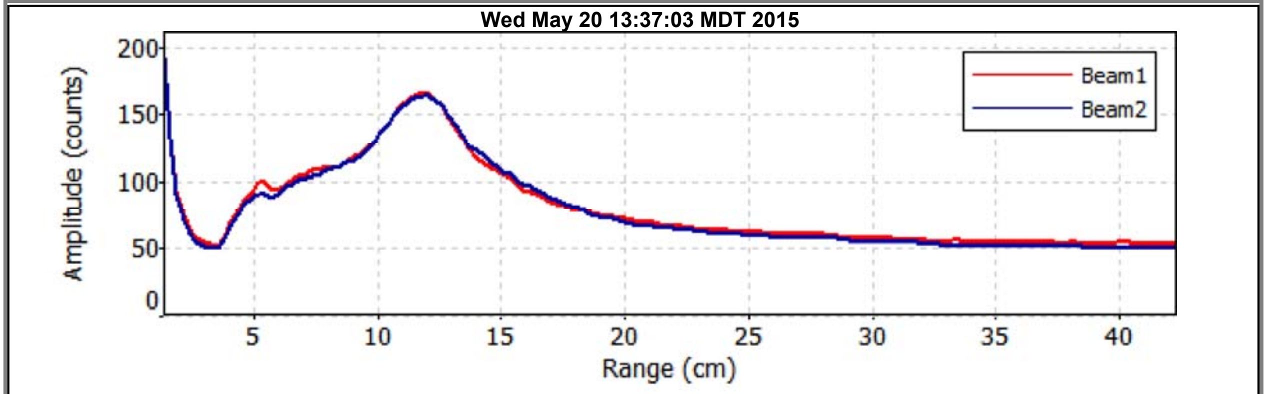
Automatic Quality Control Test (BeamCheck)



- ✓ Noise level check - Pass
- ✓ SNR check - Pass
- ✓ Peak location check - Pass
- ✓ Peak shape check - Pass




































Uncompahgre River
Water Quality Report
2012

Written by John Woodling
On behalf of the
Uncompahgre Watershed Partnership
http://www.uncompahgrewatershed.org/

Acknowledgments

This water quality report was competed by the Uncompahgre Watershed Partnership (UWP). It was supported by grants from the Colorado Nonpoint Source Pollution Program and the Colorado Water Conservation Board's Healthy Rivers Program. Bonie Pate was project coordinator for the Water Quality Control Division; Chris Sturm was project coordinator for the Healthy Rivers Fund. Sarah Sauter was the coordinator for the UWP. John Woodling, PhD, as a consultant to the UWP, was the document's primary author.

Others contributed materially to the success and completion of this update. Andrew Madison, Rachel Boothby and Mathew Jurjonas working for the UWP assisted with data analysis. Our thanks go also to the following individuals who rendered valuable advice to the UWP and commented on draft versions of this plan:

Bonie Pate, Phil Hegeman, and Rebecca Anthony Water Quality Control Division, Colorado Department of Public Health and Environment

Dan Kowalski, Division of Wildlife, Colorado Department of Natural Resources

Jeff Litteral, Division of Reclamation, Mining and Safety, Colorado Department of Natural Resources

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Additionally, we wish to thank the UWP stakeholders and supports who provided the organization and Uncompahgre River Valley community with the necessary energy and encouragement to engage in this planning process.

Executive Summary

This comprehensive assessment of water quality in the Uncompahgre River was produced for the Uncompahgre Watershed Partnership (UWP) to serve as the scientific foundation for the Uncompahgre Watershed Plan.

The Uncompahgre River arises near the aptly named Red Mountain massive south of Ouray, Colorado and flows in a generally northern direction approximately 77 miles to a confluence with the Gunnison River in Delta, Colorado. The word Uncompahgre is an English pronunciation of a Ute Indian word roughly meaning "red water spring" or “dirty water” and may be a reference to the abundant series of hot springs and iron rich water in the vicinity of Ouray, Colorado (Rockwell 1965).

Influences on Water Quality

As the name implies, the Uncompahgre River probably was never thought of as pristine water from the time when humans first appeared in the valley to the modern era. Naturally exposed ore bodies in the headwaters of the Uncompahgre River have been a source of metals to the system for millennia. The Red Mountains derive their red color from iron. Iron and other associated metals have been carried by streams draining the flanks of these and other mountains since their formation. The hot springs found along the mainstem (notably in Ouray and Ridgway) have probably been used therapeutically since humans first found the valley and have been a source of dissolved salts for uncounted millennia. In addition, the shale formations extending throughout the Uncompahgre Basin are sources of salts and selenium that enter the river from natural erosion. Many of the natural processes negatively impacting water quality have been exacerbated by human actions including urbanization of the river corridor and non-point contamination from roads, ranching, and farming.

The water quality in the Uncompahgre River varies due to five principal influences including:

1. Geology
2. Input from Red Mountain Creek,
3. Input from many types and numbers of tributaries,
4. The presence and operation of Ridgway Reservoir
5. Agricultural practices in the basin from Montrose to Delta, Colorado.

Geology

The sedimentary deposits and igneous intrusions in the basin influence water quality. Mineral-rich volcanic materials in the mountains led to naturally elevated levels of metals like iron, zinc and aluminum in headwater tributaries. The geology in the lower portion of the watershed is dominated by Mancos shale deposits, a primary contributor of dissolved mineral salts (hardness) and selenium to the Uncompahgre River downstream of Ouray. Elevated hardness levels in the Uncompahgre River upstream of Ridgway Reservoir mitigate metal toxicity but elevated salt levels in the river downstream of Montrose may well limit human use of the waters.

Red Mountain Creek

Red Mountain Creek drains water from the Red Mountain Massive is rich in minerals and acid-producing pyrite and flows through the Red Mountain mining district which has an extensive network of abandoned and inactive mines, adits, tunnels, and waste rock piles. The acidic, metal-laden water in Red Mountain Creek is derived from both natural and man-made sources. Dissolved aluminum, cadmium, copper, iron, lead, zinc and acid levels are each toxic to a wide variety of aquatic life.

Tributary waters

Inputs from tributary water have a dynamic effect on water quality in the Uncompahgre River. In numerous instances, tributaries provide relatively clean water to the Uncompahgre River, diluting the overall concentration of pollutions. Despite carrying a measurable metals load, Canyon and Oak Creeks provide much needed dilution water to the Upper Uncompahgre River in Ouray. Below the Ridgway Reservoir, water diverted into the basin from the Gunnison River via the Gunnison Tunnel and South Canal provides relatively clean flows to the Uncompahgre River during irrigation season. The clean Gunnison River water is quickly contaminated by selenium, iron, aluminum, nitrogen and phosphorus loads from Cedar Creek, Dry Cedar Creek, Dry Creek, the Loutsenhizer Arroyo and a host of smaller tributaries and irrigation ditches.

Ridgway Reservoir

Ridgway Reservoir functions as a metals sink for the Uncompahgre River, trapping more than 90% (1.4 million pounds) of the annual metals load from the upper watershed. As a result, the Uncompahgre River from Ridgway Reservoir to Montrose had the best water quality in the entire basin. While Ridgway Reservoir is responsible for the pristine water quality in the Uncompahgre River immediately downstream, the Reservoir also responsible for negative impacts to aquatic life. When the spillway is shut, reservoir operations require that water be released from a release structure at the bottom of the dam, resulting in severe gas bubble trauma in trout. Temperature fluctuations and low winter flows due to storage obligations may also be impacting the fitness of trout populations below the reservoir.

Agriculture

For over a century, farmers have irrigated the Uncompahgre Valley for agricultural purposes. About 65,000 acres are irrigated and there are numerous animal feeding operations. Between Montrose and Delta, the Uncompahgre River gains an additional 1,065,673 lbs/yr of nitrogen as N from non-point sources. Possible sources of the 1,065,673 lbs/yr of nitrogen as N to the Uncompahgre River at Delta include urban runoff from municipalities, agricultural runoff from farms and feeding operations, and irrigation return flows.

Water Quality Summary by river reach

The mainstem Uncompahgre River seems to always be dismissed as a naturally degraded waterway. Indeed, this very report begins in the same manner. The idea is however false. The Uncompahgre River downstream of Ridgway Reservoir is a “gem” of a stream supporting a naturally reproducing brown trout population to a point downstream of Montrose, belaying the idea that the Uncompahgre River is somehow a degraded system from source to mouth. Some segments are severely degraded while others are remarkably healthy. These issues are summarized in the following paragraphs.

Uncompahgre River source to Red Mountain Creek

The Uncompahgre River is significantly impacted by heavy metals contamination. Concentrations cadmium, copper, lead and zinc exceeded chronic Colorado Table Value Standards (TVS) in headwaters of the Uncompahgre River, above Red Mountain Creek. Concentrations are not high enough to prohibit aquatic life. A naturally reproducing trout population inhabits the Uncompahgre River just upstream of the river’s confluence with Red Mountain Creek.

Upper Red Mountain Creek

Red Mountain Creek from the source to the confluence with East Fork Red Mountain Creek is a headwater Rocky Mountain stream system. Zinc and pH did not attain chronic Table Value Stream Standards for aquatic life and would be expected to induce some degree of toxic impact to a wide variety of aquatic biota. Small stream channel size and low temperature regimes probably precluded natural colonization by fish. The zinc in upper Red Mountain Creek was considered to be either natural background or the result of non-point source loading.

Red Mountain Creek from the East Fork of Red Mountain Creek to the confluence with the Uncompahgre River

Metal concentrations and acidity make Red Mountain Creek one of the most contaminated waters in Colorado. Nearly 100 years of mining activity with natural contamination and poor habitat result in a stream nearly devoid of aquatic life. The stream acidity along with dissolved aluminum, cadmium, copper, iron, lead and zinc all were at levels acutely lethal to aquatic life.

Uncompahgre River from Red Mountain Creek to Canyon Creek in Ouray

Water quality was extremely poor in this section. Aluminum, copper and iron concentrations were acutely toxic to brook trout and brown trout and pH was low enough to eliminate trout reproduction. The periodic flushing of sediment from the in-channel Ouray Hydropower dam seems to result in instantaneous, acutely toxic concentrations of copper and lead. The Uncompahgre River from Red Mountain Creek to Canyon Creek could be considered for inclusion on the WQCC 303d list for a wide variety of constituents including pH, aluminum, cadmium, copper, iron, lead and zinc.

Canyon Creek and Oak Creek

Canyon Creek and Oak Creek enter the Uncompahgre River in Ouray. Both tributaries support naturally producing brook trout populations. Metals concentrations in both streams were detectable, but less than the metals concentration in the mainstem Uncompahgre River. As a result, their flows provided dilution water to the Uncompahgre River.

Uncompahgre River from Canyon Creek to Ouray USGS gage station

The Uncompahgre River is not likely to support metals-sensitive aquatic life in Ouray. Copper, iron and aluminum concentrations have likely reduced both numbers and kinds of aquatic species present in the river through Ouray. There was a measurable difference in water quality in the Uncompahgre River above and below Ouray. Metal concentrations were often higher at the USGS station below Ouray compared to upstream at the site near Oak and Canyon Creeks. The low metal concentrations above Ouray were attributed to the location of the outlet works of the Ouray Hydropower Station.

Uncompahgre River from USGS Ouray Gage to Ridgway Reservoir

Metals normally associated with metal contaminated streams decreased to concentrations lower than chronic Table Value Standards in most samples upstream of Ridgway Reservoir. Total iron precipitation smothered the stream substrate and was likely indirectly toxic to aquatic life. Concentrations of all metals except aluminum decreased in spring months due to the dilution effects of snow melt waters. In contrast, aluminum concentrations increased during spring snowmelt months as the metal appeared to re-suspend and flow towards Ridgway Reservoir during periods of elevated stream flows in the months of May and June each year. Much of the stream substrate in this section is deeply covered with fine black sediments in low velocity areas. These sediments fill the interstitial spaces of the gravel and cobble thus eliminating the physical habitat needed by aquatic invertebrates and the areas where trout eggs could incubate.

The Uncompahgre River from Colona to Montrose

The Uncompahgre River from Ridgway Reservoir to Montrose transitioned from a forested mountain stream to one where agriculture and increasing urban development fill an ever-widening river valley. Stream temperatures were appropriate to support trout populations. The concentrations of dissolved cadmium, copper, lead and zinc were far less than the existing chronic Table Value Standards and in many cases, less than detection limits. In general the water quality was better in this segment than in any other mainstem river reach from the source to the confluence with the Gunnison River. The site-specific total iron standard and existing iron temporary modification are not appropriate for this stream reach and should be removed by the WQCC.

The Uncompahgre River in Montrose, Highway 90 Bridge to LaSalle Road

Agriculture and increasing urban development begin to exert a larger influence on the Uncompahgre River in Montrose. The dissolved solids increase as the stream flows downstream towards LaSalle Road. High dissolved solids concentrations can diminish the economic and ecological value of the Uncompahgre River. In general the water quality was still better than standards applied to this segment. Stream temperatures are low enough to support a reproducing brown trout population this stream reach. This segment warrants a change in designation from a class 2 warm to a class 1 cold water stream with Tier 2 temperature standards.

Tributaries to the Uncompahgre River from Montrose to Delta

The water chemistry of the Uncompahgre River between Montrose and Delta is degraded by the poor water quality in Cedar Creek, Loutsenhizer Arroyo, Dry Creek and other small tributaries as exemplified by the Fifth Street Ditch in Delta. Dissolved solids, nutrients, selenium, iron and aluminum concentrations were higher in Dry Cedar Creek (dissolved solids only), Cedar Creek, Loutsenhizer Arroyo and Dry Creek than in the Uncompahgre River. The relatively high water temperature and dissolved solids, in these tributaries was in-part attributable to naturally arid, salt-laden, erodible lands in the lower basin. Nonpoint source pollution from agriculture and urban runoff is also a likely source of selenium, nutrients and dissolved solids.

Uncompahgre River in from Montrose to Delta

The Uncompahgre River from Montrose to Delta is an active part of the irrigation system. Whereas irrigation withdrawals suck nearby streams dry during the growing season, the Uncompahgre River flows year round. The Uncompahgre River is enriched with solids, nutrients, calcium, manganese, sulfate, iron, aluminum and selenium from urban runoff, irrigation return flows, agricultural runoff, and natural erosion of the Mancos shale. The winter water program, started in 1991, has resulted in a significant reduction of winter time total dissolved solids and total suspended solids.

Recommendations

The Uncompahgre River water quality varies throughout the watershed. A variety of steps could be instituted to improve water quality along the length of the basin.

1) Changes to WQCC segmentation, classifications, water quality standards and 303d listings.

   - Re-segmentation of Uncompahgre River segment COGUUR3a
   - Reclassification of Uncompahgre River segment COGUUR4a
   - Reclassification of Uncompahgre River segment COGUUR5
   - Reclassification of Uncompahgre River Segment GOGUUR10
   - Reclassification of Uncompahgre River Segment COGUUR12
   - Adoption of Aluminum Standards
   - Elimination of temporary modification from stream reaches where existing water quality meets Colorado WQCC Table Value Standards.

2) Filling Data Gaps

   - A more intense sampling program is needed in Red Mountain Creek.
   - A special study to document the influence of the Ouray Hydropower Station flushing events
   - Documentation of the episodic metal and sediment loads associated with summer storm events between Ouray and Ridgway.
   - A fall and winter stream substrate sampling program is needed in the mainstem Uncompahgre River from Ouray to Ridgway to determine the source of fine sediments that may be limiting aquatic macroinvertebrates and fish populations in that stream reach.
   - Temperatures regimes need to be clarified for the Uncompahgre River in Montrose to assure that temperature standards and the aquatic life classification protect the existing aquatic assemblage.
   - A sampling program designed to better understand the influence of confined feedlots on nutrient loadings to the Uncompahgre Basin would allow for design of appropriate control measures to reduce nutrient loads into the mainstem Uncompahgre River.

3) Next Steps

   - Amend reclamation goals from zinc-based in Red Mountain Creek to Brown and Brook trout colonization of the Uncompahgre River.
   - Increased participation in best management practices that contribute to soil health. Improved soil health will decrease soil erosion and the need for fertilizer.
   - Increased participation in water conservation efforts like ditch lining, overhead irrigation, xeriscaping, and limited development on previously non-irrigated lands to minimize deep percolation of groundwater into the Mancos shale.

Table of Contents

1.0 Introduction

The Uncompahgre River arises near the aptly named Red Mountain massive south of Ouray, Colorado and flows in a generally northern direction approximately 77 miles to a confluence with the Gunnison River in Delta, Colorado. The word Uncompahgre is an English pronunciation of a Ute Indian word roughly meaning "red water spring" or “dirty water” and may be a reference to the abundant series of hot springs and iron rich water in the vicinity of Ouray, Colorado (Rockwell 1965).

As the name implies, the Uncompahgre River probably was never thought of as pristine water from the time when humans first appeared in the valley to the modern era. Naturally exposed ore bodies in the headwaters of the Uncompahgre River have been a source of metals to the system for millennia. The Red Mountains derive their red color from iron. Iron and other associated metals have been carried by streams draining the flanks of these and other mountains since their formation and subsequent erosion. The hot springs found along the mainstem (notably in Ouray and Ridgway) have probably been used therapeutically since humans first found the valley and have been a source of dissolved salts for uncounted millennia. In addition, the shale formations extending throughout the Uncompahgre Basin are sources of salts and selenium that enter the river from natural erosion. Many of the natural processes negatively impacting water quality have been exacerbated by human actions including urbanization of the river corridor and non-point contamination from roads, ranching, farming and the mining boom that started the area’s civilization.

Red Mountains derive their red color from natural iron deposits

Discovery of rich ore bodies in the late 1880’s resulted in a mining explosion that continued through most of the twentieth century in much of southwest Colorado including portions of the Uncompahgre River headwaters. The Idarado Mine in the headwaters of Red Mountain Creek continued operations until 1979 although most mines and mining related industry had closed down by the early twentieth century. Water contamination from active, inactive and abandoned mining facilities including mine adits, waste rock piles, tailing piles, etc. resulted in the State of Colorado filing a lawsuit[1] against the Idarado Mining Company (now part of Newmont Gold Company) in 1984 using the Comprehensive Environmental Compensation and Litigation Act (CERCLA). The lawsuit was settled in 1992. As of 2011 Idarado has not met the terms of the settlement pertaining to water quality in the Uncompahgre River.

Other sources of nonpoint source pollution exist in the Uncompahgre River basin. Ranching and farming led to the development in the lower portions of the valley. Farms, ranches, and urban areas contribute sediment, nutrients and bacteria to the Uncompahgre River via irrigation return flows or storm water discharges. Deep

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[1] 916 F2d 1486 State of Colorado v. Idarado Mining Company

groundwater percolation from irrigation, ponds and septic systems are known sources of salt and selenium.

Ouray, Ridgway, Montrose and Delta are thriving and growing communities located along the mainstem Uncompahgre River. These four municipalities operate domestic wastewater treatment plants that discharge directly to the Uncompahgre River. Two recreational hot springs have been developed, Ouray Hot Springs in the City of Ouray and Orvis Hot Springs near the Town of Ridgway. The mineralized, warm water from these two hot springs facilities is also discharged to the mainstem Uncompahgre River.

Transmountain diversions of water also influence water quality in the Uncompahgre River. A large amount of water enters the Uncompahgre Watershed from the Gunnison River via the Gunnison Tunnel and South Canal located east of Montrose. The transmountain diversion increases the amount of water flowing through the Uncompahgre River Basin for the majority of each year (March through November).

Water quality of the Uncompahgre River and the river's tributaries is important for several reasons. Municipalities depend on clean water for domestic use including drinking water and the agricultural community depends on the clean water for irrigation and stock water. The river also helps support businesses associated with fishing, rafting and kayaking. The Uncompahgre River also provides needed water and habitat for wildlife.

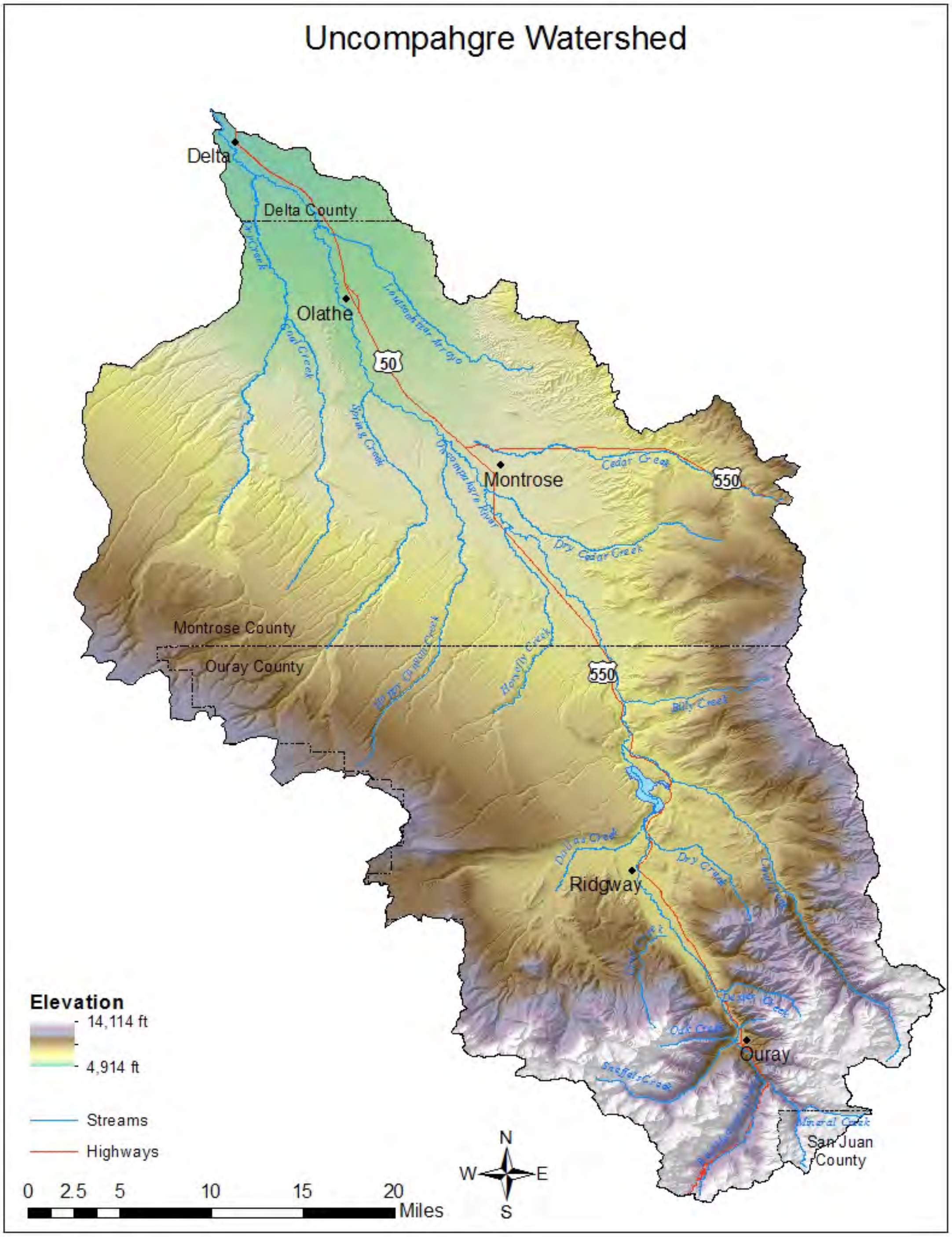
The Uncompahgre Watershed Partnership (UWP) needed a comprehensive assessment of water quality in the Uncompahgre River. This water quality report is intended to serve as the scientific foundation for the Uncompahgre Watershed Plan. To that end the UWP, this report was funded by support from the Colorado Nonpoint Source Pollution Program, Colorado Healthy Rivers Fund, and the Colorado Division of Wildlife.

The objectives of this analysis and report were to:

1. Compare current and historic water quality data to determine any trends that may have occurred since the 1990's.
2. Compare current and historic water quality from the Uncompahgre River to current stream standards applied by the Colorado Water Quality Control Commission (WQCC) to stream segments within the Uncompahgre River.
3. Compare current and historic water quality data to current "Table Value" standards as adopted by the WQCC.
4. Compare current and historic water quality data to levels needed to support brown trout and brook trout in the Uncompahgre River basin. Site-specific stream standards approved by the WQCC at another CERCLA site will be the levels assumed to be at least partially protective of some brown trout.
5. Where possible compare current and historic water quality to data to levels needed to support various aquatic macroinvertebrate species.
6. Develop a set of recommendations that could be implemented to improve water quality in the Uncompahgre River Basin.

2.0 Site Description

The headwaters of the Uncompahgre River are located in the San Juan Mountains in San Juan County, Colorado at an elevation of about 12,000 feet. The river flows from Como Lake in a northern direction for about 77 miles to a confluence with the Gunnison River in Delta.



3.0 Data Sources

All data used in this analysis were obtained from existing data sets. No additional field sampling was performed. Data from multiple agencies and entities were obtained and utilized in this water quality assessment. Few of these sites have been sampled for an extended period of time, despite the importance of water quality to the economy of the Uncompahgre Valley. Not all water quality data were used in the preparation of this report. Single samples collected in various scattered locals or smaller tributaries could not be included in order to maintain a manageable size for this report.

Water Quality Data Sources

Agency	Description / Citation
WQCD	Sites 55 and 79, data from 1968 to 2007 depending on parameter.
	WQCD, 2009. Use Attainability analysis Uncompahgre River.
	WQCD, 2009. Total Maximum Daily Load Assessment Red Mountain Creek/Uncompahgre River, San Juan/Ouray/Montrose County, Colorado. Final Draft.
	WQCD, 2009. Total Maximum Daily Load Assessment Gunnison River and Tributaries Uncompahgre River and Tributaries, Delta/Mesa/Montrose Counties, Colorado. Public Notice Draft.
CDPHE/ HAZMAT	O'Grady, M. 2005. Combined assessment analytical results report upper Uncompahgre River watershed Ouray and San Juan Counties, Colorado. Colorado Department of Public Health and the Environment, Hazardous Materials and Waste Management Division. Denver, Colorado
	Mackey, Kevin. 2000. Analytical Results Report, Canyon Creek Watershed, Ouray, CO.
	Price, Camille. 2001.May sediment release study from Ouray Hydro dam
DOW	River Watch Program (Mid 1990's to 2007)
	Martin, Lori. 2003-2004. CDOW. Delta irrigation ditches
	Kowalski, Dan. 2009. Macroinvertebrate samples
MFG	MFG. 1991. Technical Memorandum Red Mountain Creek Basin Study Flow Spring 1990 High Flow Conditions Volume I.
USGS	Four USGS sites (9146020 at Ouray, 9146200 above Ridgway Reservoir, 9147025 below Ridgway Reservoir and 9147500 at Colona)
	Thomas, J.C., K.J. Leib, and J.W. Mayo. 2008. Analysis of dissolved selenium loading for selected sits in the lower Gunnison River Basin, Colorado. 1978-2005.
	Runkel, Robert L., Kimball, Briant A., Walton-Day, Katherine, and Verplanck, Philip L., 2005, Geochemistry of Red Mountain Creek, Colorado, under low-flow conditions, August 2002: U.S. Geological Survey Scientific Investigations Report 2005–5101, 78 p.

4.0 Methods

Data found in a non-electronic format were entered into the Microsoft Excel spreadsheet format used by the River Watch program. Electronic data sets from other sources were structurally modified to conform to the spreadsheet format used by River Watch with one exception. Data from WQCD Sites 55 and Site 79 were obtained in an Excel spreadsheet that was not readily amenable to analysis or restructuring. Data from WQCD Site 55 and 79 were transferred as needed to the statistical software “Statistica” and analyzed.

4.1 Metals data

Metals data were collated chronologically by site and analyzed five different ways.

1. Metals data were compared to current state stream standards as promulgated by the Water Quality Control Commission (WQCC) using sample events where both metals and hardness concentrations were determined
2. Metals data were compared to current Table Value Standards (TVS) as adopted by the WQCC.
3. Metals data were compared to “Recalculated” stream standards adopted on a case-by-case basis by the WQCC where metal concentrations exceeded Table Value Standards due to contamination from natural sources or contamination deemed irreversible based on existing treatment technologies. These recalculated standards were developed by various proponents using an EPA procedure that allows for the standards to be based on toxicity data for species actually found in a given stream reach and not the entire list of taxa for which toxicity data exist. This approach may be used on a case-by-case basis if toxicity data for a designated number of existing species exists. The result of most recalculation procedures involves relaxation of stream standards compared to Table Value Standards where the entire toxicity data set is used in standards calculations.
4. Metals data were compared to a calculated hazard quotient. A hazard quotient (HQ) is a summation that can estimate if risk to harmful effects is likely due to the totality of metals at a sampling site. HQs were calculated by dividing actual metals concentrations by hardness-based chronic metals standards for cadmium, copper, and zinc to produce a “toxic unit” for each metal in a sample. The resulting “toxic units” were added together to create a cumulative hazard quotient. Hazard quotients estimate the additive toxicity attributable to metals interacting as a group and not acting as a single agent.

Hazard Quotient Interpretation	
If…	**Then…**
HQ > 1.0	Harmful effects are likely due to the contaminant in question
HQ = 1.0	Contaminant ***alone*** is not likely to cause ecological risk
HQ < 1.0	Harmful effects are NOT likely
USEPA R5, Ecological Risk Assessment: http://www.epa.gov/R5Super/ecology/html/erasteps/erastep2.html	

5. Chronological and seasonal trends were determined at sites where adequate numbers of samples had been collected.

4.2 Metal Loading at Ridgway Reservoir

Annual metal loads entering and leaving Ridgway Reservoir were determined using River Watch metals data and USGS flow data for sampling events where water samples were collected upstream (Gage 09146200) and downstream (Gage 09147025) of Ridgway Reservoir on the same day for the period of record, 2002-2006. River Watch sampling sites are generally located adjacent to the USGS gage sample sites thus allowing flow data to be paired with water quality data.

Reservoir loading was expressed in pounds per day (lbs/day). Pounds per day can be determined using the concentration of a pollutant (mg/L) and the flow rate of water (cfs) based on the formula:

Concentration (mg/L) x flow (cfs) x 5.39 = pounds per day (lbs/day).

Aluminum loads were determined in part using linear regression. Total aluminum concentrations were significantly correlated to river flows at the USGS gage site upstream of Ridgway Reservoir:

Total aluminum ug/L = 1353 + 5.337(Flow in cfs), p=.0004, adj* $r^2 = 0.24$.

This regression equation was used to predict mean monthly concentrations for total aluminum concentration based on mean monthly flows for the period of record at the USGS site upstream of Ridgway Reservoir. These mean monthly total aluminum concentrations were utilized to determine mean daily loading (pounds/day) for each month as follows:

Mean daily loading = Monthly mean flow (cfs) x (mean monthly total Al, ug/L)/1,000 x 5.39

The mean daily loads were converted to total monthly loads by multiplying the daily load by the number of days in the month. Loadings for all 12 months were added together to determine the annual total aluminum loading to Ridgway Reservoir.

Regression analyses were not significant for metals other than aluminum compared to flow data. Monthly mean concentrations were used to determine total iron loading to the Reservoir, as graphic representations indicated total iron concentrations increased somewhat in the last six months of the year compared to the first six months of the year. Monthly total iron loadings were determined by the following:

(Monthly mean iron concentration in ug/L)/1,000 x monthly daily flow (cfs) x 5.39

Total cadmium, total copper and total lead concentrations into Ridgway Reservoir did not appear to vary on a seasonal basis. A mean concentration of all data was calculated for each dissolved metal data set. The means of all measurements for each metal were used to determine the monthly loads based on mean monthly flows, the conversion factor of 5.39 and converting ug/L to mg/L for total cadmium, total copper and total iron.

Total metals loading leaving Ridgway Reservoir were determined in much the same manner. Mean monthly concentrations were used to calculate total aluminum and total iron concentrations leaving Ridgway Reservoir. The linear relationship of total aluminum to flow was not significant although average concentrations in some months appeared different. The total cadmium, total copper, total lead and total zinc loads leaving Ridgway Reservoir were determined using the overall mean of each of the metal and the average monthly flows at the USGS flow station downstream of the Reservoir as well as the same two correction factors. These loading analyses are not completely precise. Use of monthly means is not the preferred method of analysis and in some cases few samples were collected in a given month. However, this analysis demonstrated that metal loading to the Reservoir substrate is an indeed an impressive figure.

4.3 Other Analyses

Linear regressions were used in some cases to determine trends through time for some parameters. The Mann Whitney U test was utilized to compare medians of various parameters at various sites and for different time periods. The Student’s t-test was utilized to compare the means of some parameters.

5.0 Primer on Metals Toxicity and Water Quality Standards

5.1 Metals Toxicity

Any analysis of the Uncompahgre River Basin water quality must begin with a discussion of the impact of metals on aquatic life. The following information does not represent a complete discussion of metal toxicity to aquatic life. The objective is to provide information that aids in the interpretation of the metals and metal regime found in the Uncompahgre River Basin.

The toxicity of a metal to an aquatic organism can vary on many different factors. Factors influencing metal toxicity include; the characteristics of an individual organism, the route of exposure to the metal, the type and form of the metal and the physical and chemical characteristics of the water where the exposure takes place.

Some metals such as aluminum, copper, iron, selenium and zinc are essential to life but may become toxic at higher concentrations. Other metals, such as mercury and cadmium, are non-essential and have no known function in either plants or animals. Other metals can bioaccumulate in the tissues of aquatic animals and can cause toxic impacts when these animals are consumed (mercury) or toxic impacts to the animal itself and its offspring (selenium).

The availability and toxicity of metals depend on the form of the metal in water. Metals can either be dissolved in solution or present in a “total” or suspended fraction. The dissolved fraction, is usually considered to be the most bioavailable and hence the most toxic. Iron and aluminum can be indirectly toxic in a particulate form by suffocating fish or smothering the stream substrate, thereby eliminating habitat of aquatic macroinvertebrates and developing fish eggs.

Water hardness, pH, alkalinity, and many other factors affect chemical toxicity, and bioavailability. For example, the calcium and magnesium ions that contribute to water hardness generally lower metals toxicity. The State of Colorado has developed hardness-based metals standards due to the positive correlation between hardness and metals toxicity. The amount of metal allowed in streams and rivers increases as hardness levels increase.

Water quality standards for aquatic life are often based on laboratory conducted toxicity tests. In the laboratory, a targeted species are tested for acute (short term, lethal) and/or chronic (long term, sub-lethal, such as decreased growth) impacts at varying concentrations of metals. The usual test exposure duration for lethal studies is 96 hours. Data from these toxicity tests are then interpreted to determine the concentration that killed 50% of the test organisms over a four-day period. This concentration is known as the 96 hour lethal concentration (96h LC50) for the metal in question.

The reader is referred to Appendix 1 for more information about metals toxicity.

5.2 Water Quality Standards

The Colorado Water Quality Control Commission (WQCC) based water quality standards on the assigned “designated use” for a given water body. This ensures that the target water quality standard is reflective of how the water is currently being used. Five designated uses, or use classifications are recognized by the WQCC: recreation, agriculture, aquatic life, domestic supply and wetlands. Complete lists of use classifications for each section or water body ID (WBID) in the Uncompahgre Watershed are included as reference in Appendix 2 of this document.

Definition of Waterbody Use Classifications

Use Classification	Definition
Recreation	Class E - Existing Primary Contact Use Class P - Potential Primary Contact Use Class N - Not Primary Contact Use
Agriculture	These surface waters are suitable or intended to become suitable for irrigation of crops usually grown in Colorado and which are not hazardous as drinking water for livestock.
Aquatic Life	These surface waters presently support aquatic life uses as described below, or such uses may reasonably be expected in the future due to the suitability of present conditions, or the waters are intended to become suitable for such uses as a goal: (i) Class I - Cold Water Aquatic Life These are waters that (1) currently are capable of sustaining a wide variety of cold water biota, including sensitive species, or (2) could sustain such biota but for correctable water quality conditions. Waters shall be considered capable of sustaining such biota where physical habitat, water flows or levels, and water quality conditions result in no substantial impairment of the abundance and diversity of species. (ii) Class 1 - Warm Water Aquatic Life These are waters that (1) currently are capable of sustaining a wide variety of warm water biota, including sensitive species, or (2) could sustain such biota but for correctable water quality conditions. Waters shall be considered capable of sustaining such biota where physical habitat, water flows or levels, and water quality conditions result in no substantial impairment of the abundance and diversity of specifies. (iii) Class 2- Cold and Warm Water Aquatic Life These are waters that are not capable of sustaining a wide variety of cold or warm water biota, including sensitive species, due to physical habitat, water flows or levels, or uncorrectable water quality conditions
Domestic Supply	These surface waters are suitable or intended to become suitable for potable water supplies.

WQCC Regulation 31: Basic Standards and Methodologies for Surface Water (5 CCR 1002-31), Section 31.13. State Use Classifications

The WQCC divided the waters of the Uncompahgre River Basin into twenty manageable segments for regulatory purposes (Appendix 3). Each of these segments has a distinct identification code (WBID). Each, WQCC segment was delineated on similarities in geology, water quality and designated uses.

Stream standards for metals and other parameters are derived using criteria documents produced by the US EPA. Stream standards are not designed to be protective of all aquatic species. Rather, standards are designed to protect 95% of the species found in an aquatic community. Standards provide long-term (chronic) protection of aquatic life and protection during a short-term (acute) event. Chronic standards are based on a 30-day average while acute standards are higher concentrations allowed one day in a three-year period.

Metallic elements seldom act as single stressors in a stream or river. Metals in combination have been shown to have additive toxicity to trout. Neither EPA criteria nor stream standards adopted by the WQCC take additive impacts of metals when establishing stream standards. As such, less than 95% of all aquatic species are actually protected by the suite of stream standards in place for Colorado waters. The stress to aquatic organisms may well increase as the level of any stressor increases. Increased temperatures may not be harmful as a single stressor but the addition of pollutants such as zinc or pesticides may result in harm to an aquatic population

The WQCC may assign a numeric standard on a statewide basis or to specific state surface waters. A numeric standard is based on the concentration of a parameter that is the suitable limit for protecting the classified use. A numeric standard may be exceeded infrequently due to temporary natural conditions such as unusual precipitation patterns, spring runoff or drought.

The WQCC has adopted a set of numeric “Table Value Standards” that are applied to most stream segments in Colorado. Most Table Value Standards (TVS) are based on EPA criteria and are assumed to protect both the designated uses and at least 95% of the aquatic taxa present in the stream reach. Standards have been developed and adopted for a multitude of different chemical parameters and some physical and biological parameters including temperature, metals, various dissolved salts, pH, bacteria, organic compounds, etc. The TVS for metals such as cadmium, copper, lead and zinc are expressed as regression equations based on the hardness of each stream segment.

The existing Colorado chronic TVS for iron is 1,000 ug/L total recoverable[2] iron. This standard was chosen as the value that will not result in excessive precipitation to the stream substrate and subsequent smothering of aquatic macroinvertebrates and fish eggs. The WQCC has also adopted site-specific total iron standards in many stream reaches, including segments in the Uncompahgre River where natural or uncorrectable total iron levels exceed the chronic Table Value Standard. A stream reach attains the total iron standard if 50% of the data points are less than the designated total iron stream standard.

The WQCC has not adopted aluminum standards for stream reaches in the Uncompahgre River Basin. As such, aluminum limits are not incorporated into discharge permits. Permit holders are not responsible for controlling or limiting aluminum concentrations in effluent flows.

EPA criteria also allow for site-specific standards to be developed. The WQCC adopted site-specific standards in many cases. For example, the mottled sculpin (*Cottus bairdii*) is native to waters west of the Continental Divide in Colorado. The mottled sculpin is sensitive to zinc (Woodling et al., 2002) and is not protected by the WQCC TVS for zinc. The WQCC has adopted a more restrictive zinc standard for waters where this species is present.

The WQCC also allows for more relaxed standards to be developed in certain waters based on EPA criteria. These “recalculated metal standards” are developed by eliminating zinc toxicity data for species that are not present in certain river segments in Colorado. Recalculated standards have been developed and approved by the WQCC for zinc. These recalculations use data sets where rainbow (*Onchorhynchus mykiss*) and brown trout (*Salmo trutta*) toxicity data represent the most sensitive species. These recalculated copper and zinc standards do not provide complete protection for these two

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[2] For all intents and purposes there is no difference between total metals and total recoverable metals. The distinction is based on subtle differences in digestion procedures performed on samples prior to the measurement step.

species, but do allow the taxa to survive either with reduced numbers or lowered growth rates. The recalculated zinc standard adopted by the WQCC is:

$$\text{Chronic zinc ug/L} = 0.987 * e^{(0.8537 * \text{natural log hardness mg/L} + 1.8032)}$$

This equation results in allowable zinc concentrations greater than TVS.

A temporary modification of a numeric standard may be granted by the WQCC that is less rigorous than numeric standards. These temporary modifications are valid for a limited time period. Temporary modifications are set with a goal of protecting a wide variety of aquatic standards. In general, temporary modifications are preferred over a more permanent downgrading of a present classification where it appears that the conditions causing the lower water quality might be temporary within a twenty (20) year time frame. There are 3 WQCC approved temporary modifications in the Uncompahgre River. The modifications expire in December, 2012. See Appendix 3 for the complete list of stream standards and temporary modifications in the Uncompahgre River

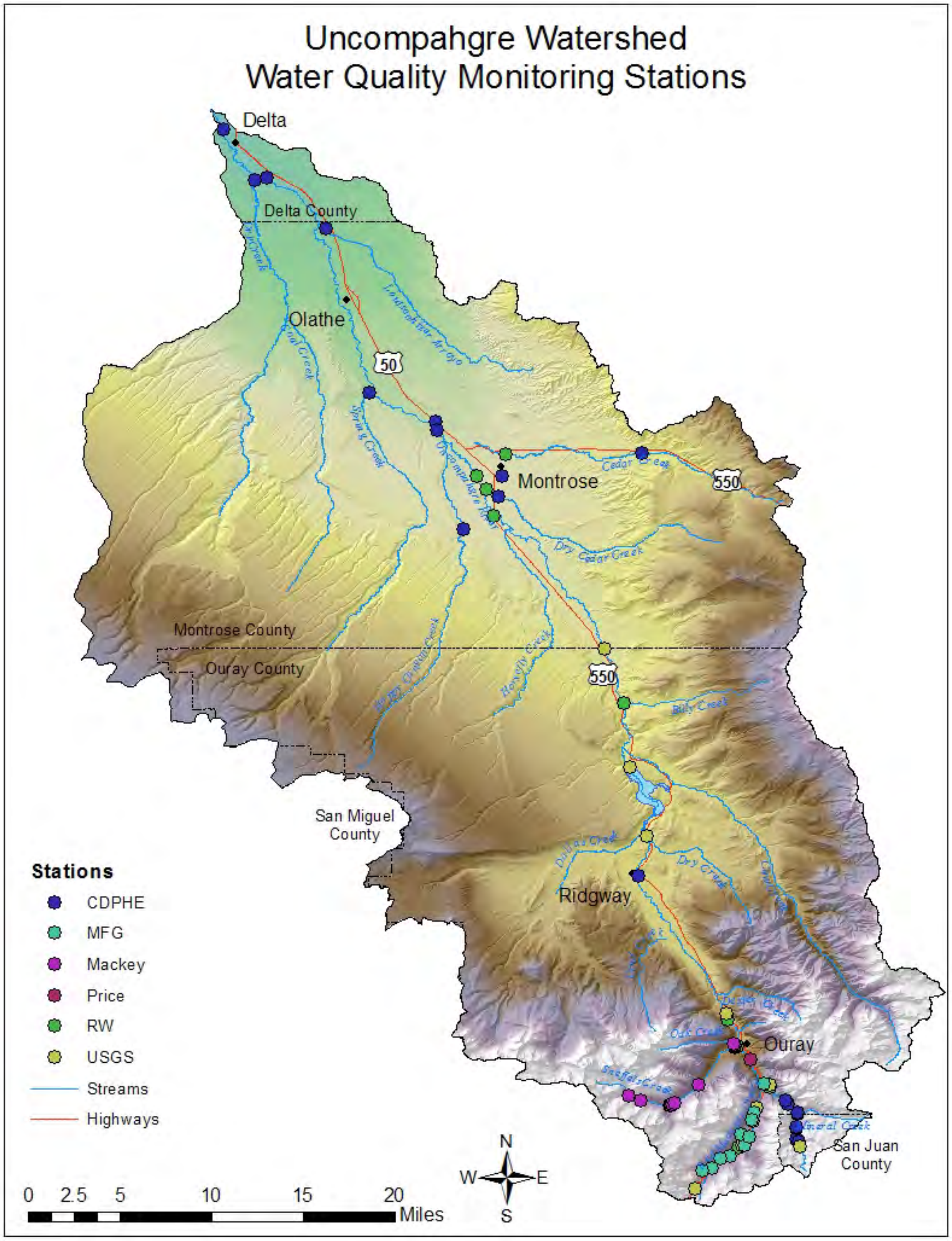
The preceding text is not intended to be a complete description of either Table Value Standards applied to Colorado waters or a complete description of the stream standards and uses applied to Colorado waters. For a complete representation the reader is referred to WQCC Regulation 35.

5.3 303(d) list

The Clean Water Act requires that the Colorado Water Quality Control Commission (WQCC) must submit a list of waters “for which technology-based effluent limitations and other required controls are not stringent enough to implement water quality standards” (WQCC, 2010). Multiple stream reaches within the Uncompahgre River Basin have been placed on this list (303(d) List) by the WQCC. A subset of these waters was identified as needing monitoring and evaluation to determine the extent of contamination. A Total Daily Maximum Loading must be determined for each stream reach actually on the 303(d) list to determine feasibility and methodology to bring the stream reach within compliance with stream standards. The list of Water-Quality-Limited Segments in the Uncompahgre River Basin is included in Appendix 4 of this report. Many of the 303(d) listings for selenium and sediments were not discussed in the report. Prior analyses by the Water Quality Control Division (WQCD, 2009) analyzed the selenium issues in the Uncompahgre River at a greater degree than could be included in this report. Readers interested in the issues involving selenium and 303(d) listings are referred to WQCD (2009).

6.0 Water Quality Review Uncompahgre River Basin

The water quality of the Uncompahgre River includes a variety of issues spread across the landscape of the basin. Issues differ in different portions of the basin. A list of stations evaluated in this report can be found in Appendix 5 and the map below. The data tables and figures referenced in this report can be found in Appendices 6 and 7.



6.1 Uncompahgre River upstream of Red Mountain Creek

The Uncompahgre River originates in Lake Como, along the Red Mountain Massive south of Ouray and flows north to a confluence with Red Mountain Creek. The Colorado Water Quality Control Commission (WQCC) designated this section of the mainstem Uncompahgre River as Segment UN02This approximately 5 mile long segment lies within the Uncompahgre National Forest and is impacted by multiple mine sites.

WBID	*UN02*	
Description	*Mainstem of the Uncompahgre River from the source at Como Lake (Poughkeepsie Gulch) to a point immediately above the confluence with Red Mountain Creek.*	
Use Classification	*Aq Life Cold 1, Recreation N, Water Supply, Agriculture*	
Meets Standards?	**Section not attaining chronic standards**	***Parameters not meeting standards***
No	*mainstem*	*Chronic TVS for Cd, Cu and Zn*

Water quality data are limited for this segment of the Uncompahgre River. Data sources include Colorado Department of Public Health and the Environment and Colorado River Watch.

In June, 2004 the Colorado Department of Public Health and the Environment, Hazardous Materials and Waste Management Division collected one-time samples at nine sites on the Uncompahgre River above the confluence with Red Mountain Creek (O'Grady, 2005). Metal concentrations generally decreased (Table 1) as the Uncompahgre River flowed downstream from the river source to the confluence with Red Mountain Creek with the exception of total iron (O'Grady, 2005). Due to the natural mineralization in the San Juan Mountains trace evidence of metals in the headwaters in the Uncompahgre is expected.

Metals concentrations exceeded Table Value Standards for cadmium, copper and zinc at all nine sites sampled on June 22, 2004 (Table 1). All but one zinc value exceeded the recalculated stream standard developed to provide protection for brown and rainbow trout (see section 4.1 for a review of recalculated stream standards). This recalculated zinc standard does not provide full protection for brown or rainbow trout, but would allow for individual fish to survive. Cadmium, copper and zinc concentrations did not exceed levels known to induce acute mortality to trout.

Aluminum exceeded the chronic Table Value Standard at the most upstream sampling site. Aluminum standards have not been adopted for the Uncompahgre River Basin, so this aluminum concentration did not constitute a violation of stream standards. The pH of the Uncompahgre River at the most upstream sampling site was 7.2 while the hardness was 68 mg/L as $CaCO_3$ and dissolved aluminum was 350 ug/L. Similar conditions limited juvenile trout growth in laboratory toxicity tests (Cleveland et al., 1986), suggesting that aluminum concentrations may be at least periodically toxic to trout populations in the headwater sample site on the Uncompahgre River (upstream of Canadian Creek) the one time sample event.

Data from three sources were used to assess seasonal variation in the Uncompahgre River at a sampling point close to the confluence with Red Mountain Creek (O'Grady 2005, WQCD 2009 and River Watch data 2002-2007). Concentrations of dissolved cadmium, copper and zinc exceeded table value standards in the Uncompahgre River above Red Mountain Creek in portions of all years for which data were available (Figures 1-3), the same finding reported by WQCD (2009). Dissolved lead concentrations were typically less than detection limits. The highest cadmium, copper and zinc measurements occurred in March and April, while the lowest concentrations were normally measured during May and June. In Colorado headwaters streams, maximum metal concentrations occur in March and April just before onset of spring snowmelt season. The lowest metal concentrations are typically present in late spring and early summer during the snowmelt period.

About 25% (10 of 42) of the dissolved zinc concentrations exceeded the recalculated stream standard that has been adopted as a site specific standard in some stream reaches by the Colorado Water Quality Control Commission to provide protection for brown and rainbow trout (Figure 4). However, zinc levels were not elevated to a point where brown trout populations would be eliminated from the mainstem Uncompahgre River above the confluence with Red Mountain Creek.

Maximum total iron and aluminum measurements occurred in April and May of each year. Only one total iron measurement, 1,315 ug/L on May 28, 2006, exceeded the chronic Table Value Standard (1,000 ug/L). The total iron concentrations in the Uncompahgre River were low in the fall, the time of year when brown and brook trout (*Salvelinus fontinalis*) spawn. Total iron concentrations probably did not impact fish populations in the Uncompahgre River just upstream of the confluence with Red Mountain Creek.

Aluminum exceeded the chronic Table Value Standard that could be applied to Uncompahgre River in nine of the 38 samples collected from 2002 to 2007 (Figure 5). Aluminum exceeded the chronic Table Value Standard[3] during the spring snowmelt months of May and June. Total aluminum concentrations typically exceeded 300 ug/L in the months of May and June (Figure 5) while hardness concentrations were less than 100 mg/L $CaCO_3$ and pH values were less than 7.9 but greater than 7.0. These conditions may well result in chronic toxic impacts to trout such as reduced growth (See Appendix 1, Cleveland et al. study {1986}).

The Colorado Division of Wildlife conducted a series of presence/absence studies in segment two over the past forty years. One hundred percent of the species found were brook trout (Dan Kowalski, DOW Aquatic Biologist, personal communication). Trout would not be expected to colonize the portion the Uncompahgre River close to the source due to both metals (including aluminum), and other factors such as low water temperatures that normally limit fish presence in the very headwaters of many Rocky Mountain streams.

Load reduction targets for copper, cadmium and zinc were developed by the Colorado Water Quality Control Division as part of the Red Mountain Creek TMDL to attain the stream standards currently applied to the Uncompahgre River upstream of Red Mountain Creek (WQCD, 2009). Table 2 Load reductions of 64% to 83% are required for cadmium, copper and zinc to meet applicable standards in the Months or March through May (Table 2). A load duration analysis demonstrated that exceedances of chronic copper, cadmium and zinc concentrations are the result of both natural geology and historic mining activities (WQCD, 2009).

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[3] Aluminum standards have not been adopted for the Uncompahgre River Basin, so these concentrations did not constitute violations of stream standards.

Summary: Uncompahgre River Upstream of Red Mountain Creek

1. The Uncompahgre River upstream of Red Mountain Creek is not a pristine mountain stream. Copper, cadmium, and zinc often exceed Table Value Stream Standards for aquatic life. Unlike most stream systems, the water quality in this segment improved moving downstream.
2. A naturally reproducing brook trout population inhabits the Uncompahgre River just upstream of Red Mountain Creek.
3. Sources of metals to the Uncompahgre River above Red Mountain Creek include both natural geology and historic mine activity. Historic mine activities are estimated to contribute between 23% and 73% of the metal load to the Uncompahgre River upstream of Red Mountain Creek, depending on the metal.
4. The aquatic biota found in this stream reach could be designated as the reclamation goal for the Uncompahgre River downstream of Red Mountain Creek following implementation of future recovery programs within the Red Mountain Creek Basin.

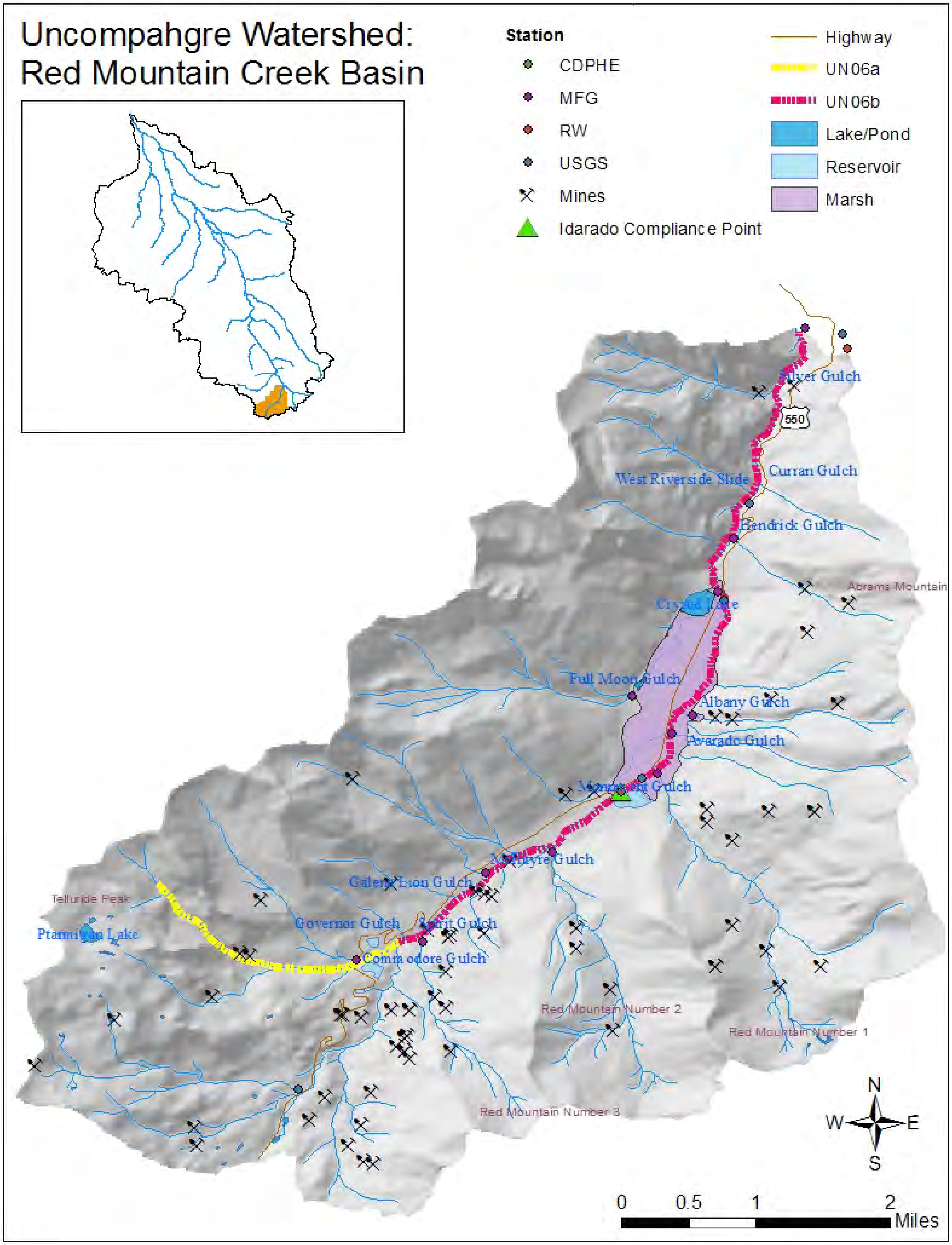
6.2 Red Mountain Creek, source to confluence with the Uncompahgre River

In 2001, the WQCC separated Red Mountain Creek into two distinct management units, 6a and 6b, to reflect the differences in aquatic life uses. Segment 6b is the lower eight-mile portion of Red Mountain Creek. Segment 6a includes everything upstream of segment 6b. The water quality in the Red Mountain Creek drainage is heavily influenced by the natural mineralized geologic formations as well as the inactive mine features that are contained within the Idarado Natural Resource Damages site.

6.2.1 Red Mountain Creek from source to confluence with East Fork of Red Mountain Creek

Segment 6a is a 0.8 mile long reach that extends from the source of Red Mountain Creek at Red Mountain Pass to the confluence with the East Fork of Red Mountain Creek. This high-gradient stream segment that is located above major mining activities.

WBID	*UN06a*	
Description	*Mainstem of Red Mountain Creek from the source to immediately above the confluence with East Fork of Red Mountain Creek*	
Use Classification	*Aq Life Cold 2, Recreation N, Agriculture*	
Meets Standards?	**Section not attaining chronic standards**	***Parameters not meeting standards***
No	*Lower portion of segment*	*Zinc TVS(sculpin)*



Water quality data are limited for this segment of the Uncompahgre River. Data sources include Colorado Department of Public Health and the Environment and Colorado River Watch. The status of the aquatic life in this segment has not been evaluated in recent time periods.

Metal concentrations were generally not an environmental issue in this segment 6a. This reach of Red Mountain Creek attained table value stream standards with the exception of zinc (WQCD, 2009). Data collected in 1985 as part of the CERCLA investigation demonstrated that Red Mountain Creek was not a pristine stream even close to the source. Six of seven dissolved zinc concentrations exceeded the chronic zinc Table Value Standard in 1985 (Remedial Action Plan). Dissolved cadmium and copper did not exceed the chronic Table Value Standards.

Newmont mining sampled Red Mountain Creek upstream of the confluence with the East Fork twice a year since 1992, (usually in June and September) as a condition of the consent decree. Data are limited to dissolved zinc, pH, temperature and specific conductance. Zinc concentrations Newmont were less than 60 ug/L for 24 of 28 sampling events since 1992. The two highest dissolved zinc concentrations were 2,490 and 2,010 ug/L. Lack of hardness data precluded an analysis of stream standard attainment; however zinc concentrations greater than 2,000 ug/L would be high enough to cause a toxic response in most aquatic life found throughout the mountains of Colorado (See Appendix 1). The two sample events where zinc exceeded 2,000 ug/L were in September (1992) and October (2004); months where young trout (a sensitive life stage) would be expected to be present.

Zinc data collected by WQCD were also evaluated as part of the Red Mountain TMDL (WQCD, 2009). “The entire zinc load was considered to be natural background or non-point source,” (WQCD, 2009) since segment 6a begins at the stream source and has not been impacted by mining. A 75% reduction in zinc loads would be required to attain chronic standard during high flow months, and 45% zinc load reduction in low flow months to attain current stream standards. Additional data are required to better understand seasonal variations in zinc loading.

Fifteen of 28 pH measurements in this section did not meet the minimum Colorado Table Value stream standard of 6.5 from 1992 through 2007. The median pH was 6.35 during that time period (N=26).

Summary: Red Mountain Creek Source to confluence with East Fork of Red Mountain Creek

1. Red Mountain Creek from the source to the confluence with East Fork Red Mountain Creek is a typical headwater stream system. Zinc and pH did not attain chronic Table Value Stream Standards for aquatic life and would be expected to induce some degree of toxic impact to a wide variety of aquatic biota.
2. However, small stream channel size and flow as well and low temperature regimes probably precluded natural colonization by fish.
3. The zinc in upper Red Mountain Creek was considered to be either natural background or the result of non-point source loading.

6.2.2 Red Mountain Creek downstream of the confluence of the East Fork of Red Mountain Creek to confluence with the Uncompahgre River

Red Mountain Creek from the confluence of the East Fork of Red Mountain Creek to the confluence with the Uncompahgre River was designated as UN06b. This section of Red Mountain Creek flows through the Idarado Mining District and along Highway 550. Tributaries to Red Mountain Creek include Champion Gulch, Corkscrew Gulch and Gray Copper Gulches.

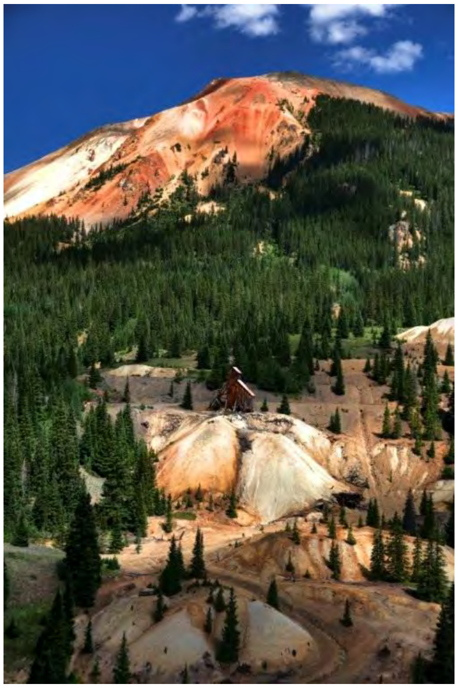
Segment 6b supports “a very limited, metal tolerant macroinvertebrate community that results from degraded water quality and physical characteristics (in Red Mountain Creek and) it is not feasible to improve the water quality to a degree that will improve the aquatic community” according to a Use Attainability Analysis (UAA) completed by the Colorado Water Quality Control Division (Johnson 2002). A UAA is “an assessment of the factors affecting the attainment of aquatic life uses or other beneficial uses, which may include physical, chemical, biological, and economic factors” (5 CCR, §1002-31, §31.5 (30)). The aquatic life Use Designation was removed from 6b by the WQCC based on the findings of the UAA. A UAA is required in order to justify the omission of an aquatic life class classification.

WBID	*UN06b*	
Description	*Mainstem of Red Mountain Creek from immediately above the confluence of East Fork of Red Mountain Creek to the confluence with the Uncompahgre River. All tributaries to Red Mountain Creek within Corkscrew and Champion Basins.*	
Use Classification	*Recreation N, Agriculture, Use Protected**	
Meets Standards?	**Section not attaining chronic standards**	***Parameters not meeting standards***
No	Compliance Point	Zinc
* A “Use Protected” designation means the stream segment doesn't warrant special protection through the anti-degradation process because it is already degraded		

The Colorado Water Quality Control Commission (WQCC) determined that the aquatic life use is not attainable in parts of Red Mountain Creek, Champion and Corkscrew Gulches based on the 2002 UAA and removed the aquatic life designation from the stream reach. The only water quality standards that exist in segment 6b include Dissolved Oxygen, pH and E. *coli*.

The water quality in Red Mountain Creek is heavily influenced by both the mineralized geologic formations as well as the inactive mine features within the Idarado Natural Resources Damages Site.

> “The mountains on the east side of the watershed are hydrothermally altered and consist of acid-sulfate and quartz-sericite-pyrite assemblages. In these assemblages, original feldspar and other silicate minerals have been replaced by fine grained minerals predominately by quartz, illite (sericite), alunite and other clay minerals and 10 to 15 percent finely disseminated and fracture-filling pyrite. In contrast, bedrock along the west side of the watershed is primarily over printed by propylitic alteration, which consists of calcite, chlorite, epidote and in places fine-grained disseminated pyrite. Nash (2002) notes that these different alteration assemblages have a striking effect on water quality. Waters draining the west side of the watershed tend to have circumneutral concentrations, whereas waters draining the east side tend to be acidic with high metals concentrations” (Nash 2002 USGS SIR 2005-5101).



During the 1880's, the Red Mountain District was the nation's second largest silver producer. The Red Mountain District landscape was littered wit hundreds of small shafts, mines and tailings piles. Many of the small mine claims were consolidated into large company holdings such as Idarado (now a subsidiary of Newmont Gold Company) after World War II. The Idarado mine complex operated until 1978.

In 1983, the State of Colorado filed suit against Idarado Mining Company under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) to ensure site cleanup, mitigation of impacts to the ecosystem, and to recover state costs for losses of natural resources. The case was settled in 1992 and the resulting cleanup included stabilizing and revegetating 11 tailings piles, clearing sediments from the underground mine, diverting surface runoff around mine wastes, diverting surface runoff around mine wastes, and re-directing internal mine waters away from highly mineralized regions. In addition to the prescribed remediation actions, the Natural Resources Damages (NRDs) Settlement included water quality goals (performance objectives) for Segment 6b of Red Mountain Creek (http://www.cdphe.state.co.us/hm/rpidarado.htm).

Pre-Remediation Water Quality

Data do not exist that describe the pre-mining water quality regime in Red Mountain Creek prior to the mining activities in the basin. A simulation of pre-mining conditions was completed by the USGS (Runkel et al. 2007). Pre-mining pH values were generally higher and dissolved metals concentrations were generally lower than existing conditions. Pre-mining concentrations of dissolved aluminum, copper and zinc exceeded Colorado chronic aquatic life Table Value Standards. Metal concentrations that exceed Colorado chronic Table Value Standards to a certain level does not result in loss of all aquatic species. Metal concentrations somewhat exceeding chronic standards would still allow for less sensitive aquatic life to survive and reproduce in the Red Mountain Creek and greatly improve aquatic life in the mainstem of the Uncompahgre River downstream of Red Mountain Creek.

Limited data are available that describe the aquatic life in Red Mountain Creek prior to 1983 when the State of Colorado filed the CERCLA lawsuit. No aquatic life was present in the mainstem Uncompahgre River downstream of Red Mountain Creek to the confluence with Canyon Creek (Rouse, J.V. 1970). Fish and aquatic macroinvertebrates were absent from Red Mountain Creek downstream of the mines "due to the very high metals concentrations, low pH, large amounts of suspended iron hydroxide and sediment, and possibly low dissolved oxygen" (Wentz 1974). Red Mountain Creek did not appear to support aquatic life downstream of the East Fork of Red Mountain Creek to the confluence with the Uncompahgre River for many years.

In a similar manner few data are available that describe water quality in Red Mountain Creek downstream of the East Fork of Red Mountain Creek prior to 1983 when the CERCLA lawsuit was filed by the State of Colorado. A stream flow of 148 gallons per minute (gpm) and a zinc concentration of less than 5 ug/L was measured in September 1989 in Red Mountain Creek upstream of the Red Mountain Adit by McCulley, Frick and Gillman (MFG 1990 and 1991). Downstream of that point stream flow nearly doubled (292 gpm) and the zinc concentration increased 300 fold to 1,500 ug/L. Zinc concentrations continued to increase downstream to a maximum of 6,200 ug/L (408 gpm) at a point upstream of Idarado Waste Rock Pile 2. Below this point, zinc concentrations decreased downstream to 5,300 ug/L (727 gpm) below Waste Rock Pile 3 and 2,900 ug/L with a flow of 2,042 gpm just above the mouth of Corkscrew Gulch. Downstream of Hendrick Gulch the zinc concentration was 1,200 ug/L at a flow of 3,877 gpm. Cadmium and copper concentrations followed the same pattern (MFG 1990 and 1991). The decrease in zinc concentrations (as well as cadmium and copper) through the length of Red Mountain Creek was attributable to dilution by metal free water sources, sorption and precipitation.

Current Water Quality

Remediation of Idarado Natural Resources Damage Site in the Red Mountain Creek drainage was completed in the late 1990s. Remediation projects focused on mine-waste removal and consolidation, surface drainage routing, and revegetation. The State of Colorado and Newmont Mining agreed that success of the remediation program would occur

> “when flows (In Red Mountain Creek) are between 3.15 and 3.85 cfs, the average dissolved zinc concentration from six samples collected between August 15 and October 15 at RMC -1 will be less than 1.5 mg/L.”

In-stream compliance with this reclamation objective is determined from samples collected in Red Mountain Creek at a compliance monitoring site located downstream of Tailing Pile #4.

Idarado also collects monthly samples at the compliance point since 1992 as part of the CERCLA agreement. Idarado’s sampling results are available in the Idarado Annual Water Quality Monitoring Reports. Idarado reports only pH, temperature, conductivity and zinc. River Watch volunteers (Arlene Crawford, Eric Funk and Ethan Funk) have sampled mainstem Red Mountain Creek at a point about 2000 feet upstream of the actual compliance point since 2002. The River Watch sampling effort included results for metals, hardness, pH and hardness among others. Idarado and River Watch data from the compliance point were combined for purposes of this report.

Red Mountain Creek was acidic at the compliance monitoring site. The median pH was 3.3 for 227 samples collected from 1990 through 2008 (maximum = 5.1, minimum 2.1). The pH of vinegar in comparison is 2.5. Brook trout cannot survive at pH levels less than 4.5 in nature (Cleveland et al., 1986 and See Appendix 1). No trout species could survive and reproduce in waters as acidic as Red Mountain Creek below from East Red Mountain Creek.

Hardness data are required to compare water quality data for metals such as cadmium, copper, lead and zinc to Colorado chronic Table Value Standards and toxicity data for fish species. Idarado does not report hardness concentrations. The hardness data reported by River Watch allowed for a comparison of ambient conditions to applicable Colorado stream standards for the time period of 2002 through 2007. The median hardness was 216 mg/L $CaCO_3$ (minimum 25 mg/L $CaCO_{3,}$ maximum 373 mg/L $CaCO_3$, n=39). Hardness concentrations fluctuated seasonally at the compliance monitoring point with lowest values reported in May and June and highest values reported in low flow winter months of November, December and January. The mean hardness in May and June was 47 mg/L $CaCO_3$ (minimum 25 mg/L $CaCO_3$ and maximum 77 mg/L $CaCO_3$). The May and June hardness concentrations reported typify high elevation Colorado mountain streams during the spring snowmelt season. Hardness concentrations for the remainder of the year exceeded those found in high elevation Colorado mountain stream basins including the San Miguel River and Gunnison River Basins (Woodling 1974 and 1975).

Dissolved cadmium, copper, lead and zinc exceeded Table Value Steam Standards (Figures 6-9) in Red Mountain Creek at the compliance monitoring location from 2002 through 2007 (Colorado River Watch data). Zinc concentrations also exceeded the recalculated zinc standard adopted on a site-by-site basis by the WQCC (see section 4.1) to protect brown trout (Figure 10) although this standard is not applied to the Uncompahgre River. Copper concentrations exceeded Table Value Standards to a much larger degree than the other three metals. These comparisons to water quality standards do not constitute violation of stream standards as numeric standards are not been applied to Red Mountain Creek. Rather, the comparisons demonstrate the magnitude of water quality issues in Red Mountain Creek from East Red Mountain Creek to the confluence with the Uncompahgre River.

The median hazard quotient (HQ) was 91.98 (maximum 122, minimum 53, 2002-2007). A HQ greater than 1.0 indicates that aquatic biota may be expected to exhibit indications of chronic toxicity due to the additive interaction of these four metals (Figure 11). The HQs found in Red Mountain Creek, 53 to 122, indicate that the metal toxicity of Red Mountain Creek is many times higher than that needed to induce sub lethal impacts on aquatic life. The combination of metals would prove lethal to trout species. Most of the toxic units that comprise the HQ were attributable to copper concentrations in Red Mountain Creek at the compliance site. Copper was more toxic to aquatic life than cadmium, lead or zinc in Red Mountain Creek at the compliance monitoring site.

The individual toxicity of cadmium, copper, lead and zinc acting singly was difficult to assess due to the influence of pH and hardness. The metal and acidic pH regime in Red Mountain Creek would be increasingly toxic during the months of May and June when hardness concentrations decreased in response to elevated stream flows associated with spring snowmelt.

Dissolved cadmium concentrations ranged from 2.8 ug/L to 87.9 ug/L (median = 49.7 ug/L) in Red Mountain Creek from 2002 through 2007. The median cadmium concentration during May and June was 2.3 ug/L and 1.6 ug/L, while the mean hardness for the two months was 61 mg/L as $CaCO_3$ and 63 mg/L as $CaCO_3$. The cadmium concentrations at the Red Mountain Creek compliance location were lethal to brown trout (See Appendix 1) in May and June when hardness concentrations were relatively low due to spring snowmelt flows. Cadmium may well have been toxic during other portions of the flow year when hardness concentrations were higher but may not have reached concentrations lethal to brown trout.

The median copper concentration during May and June was 345 ug/L and 295 ug/L, respectively in Red Mountain Creek at the compliance sampling location. The mean hardness for the two months was 47 mg/L as $CaCO_3$. Red Mountain Creek copper concentrations were at least a decimal higher than the level needed to kill brown trout and brook trout in 96 hours during laboratory tests (See Appendix 1). The copper concentrations in Red Mountain Creek would prove lethal to brown trout and brook trout within a few days during the months of May and June, even if pH levels were high enough to support fish populations.

Zinc concentrations ranged from 192 ug/L to 1,875 ug/L (median = 1875 ug/L) in Red Mountain Creek from 1992 through 2008. The median zinc concentration in Red Mountain Creek at the compliance monitoring site in May and June was 1,275 ug/L and 580 ug/L, respectively while the mean hardness for the two months was 47 mg/L as $CaCO_3$. Dissolved zinc would prove acutely toxic to brown trout (See Appendix 1) during the months of May and June.

During spring runoff, copper, zinc and possibly cadmium concentrations were each high enough to induce toxic impacts on trout populations in Red Mountain Creek. Using the Hazard Quotient approach, copper was determined to be more toxic to trout than cadmium and zinc at the compliance monitoring site.

Dissolved lead concentrations at the Red Mountain Creek compliance site ranged from 2.8 ug/L to 87.9 ug/L (median = 53.6 ug/L) in Red Mountain Creek from 2002 through 2007 while the median hardness was 213 mg/L as $CaCO_3$. Toxicity test data at hardness concentrations similar to Red Mountain Creek suggests that lead concentrations less than 1,320 ug/L in Red Mountain Creek were not acutely toxic to rainbow trout (See Appendix 1).

Chronic lead toxicity may have been an issue, however, at the Red Mountain Creek compliance site. From 2002 to 2007, the median dissolved lead concentration was 53.6 ug/L and 30 of the 40 dissolved lead measurements exceeded 31.6 ug/L. Test data (See Appendix 1) suggests that the lead and hardness levels in Red Mountain Creek at the compliance point would result in trout less fit than fish exposed to lower levels of lead.

Total aluminum concentrations in Red Mountain Creek at the compliance-monitoring site ranged from 2,655 ug/L to 49,890 ug/L (median 26,363 ug/L) from 2002 through 2007 (N=40). All total aluminum measurements exceeded the chronic Table Value Standard that could be applied to the mainstem of Red Mountain Creek if and when the WQCC adopts aluminum standards for this stream reach (Figure 12).

Aluminum toxicity is highly dependent on pH. The median pH in Red Mountain Creek was 3.3. Both pH and aluminum levels at the Red Mountain Creek compliance site were at levels known to be toxic to trout. Aluminum concentrations alone were ten times greater than the level which is known to induce a lethal response in brook trout and ninety percent (90%) of the total pH measurements were less than 4.0. Aluminum and pH in combination were lethal to trout in Red Mountain Creek at the compliance point.

Total iron concentrations ranged from less than detection limits to 71,850 ug/L (median 42,420 ug/L) from 2002 through 2007 (N=41) in Red Mountain Creek at the compliance site. Forty of 41 measurements exceeded the chronic iron Table Value Standard of 1,500 ug/L total iron (Figure 13). Red Mountain Creek would not attain the Colorado chronic iron Table Value Standards at the compliance monitoring location that could be adopted by the WQCC if and when stream standards are assigned to Red Mountain Creek from East Red Mountain Creek to the confluence with the Uncompahgre River.

Most of the iron present was in the dissolved form (10% to 83%) due to acidic pH conditions and iron toxicity increases in acid conditions. In general the pH of Red Mountain Creek was lower than 5.5 while the median iron value (42,420 ug/L) was two decimal points higher than the 1,750 ug/L concentration needed to kill brook trout (See Appendix 1). Iron concentrations in combination with acidic conditions would have eliminated trout from Red Mountain Creek even if all other metal concentrations met Colorado stream standards.

Dissolved cadmium, copper, lead and zinc were present in toxic concentrations in Red Mountain Creek at the compliance monitoring site. Total iron and aluminum were also present in toxic concentrations and aluminum and pH interacted to produce a potentially lethal response. Cadmium and lead contributed a lower fraction of the total metal toxicity regime as indicated by relatively lower toxicity units compared to zinc and copper (Figure 11). Lead was not present at acutely lethal concentrations. In general aluminum, iron and copper likely contributed the largest amount of toxicity to mainstem Red Mountain Creek stream system.

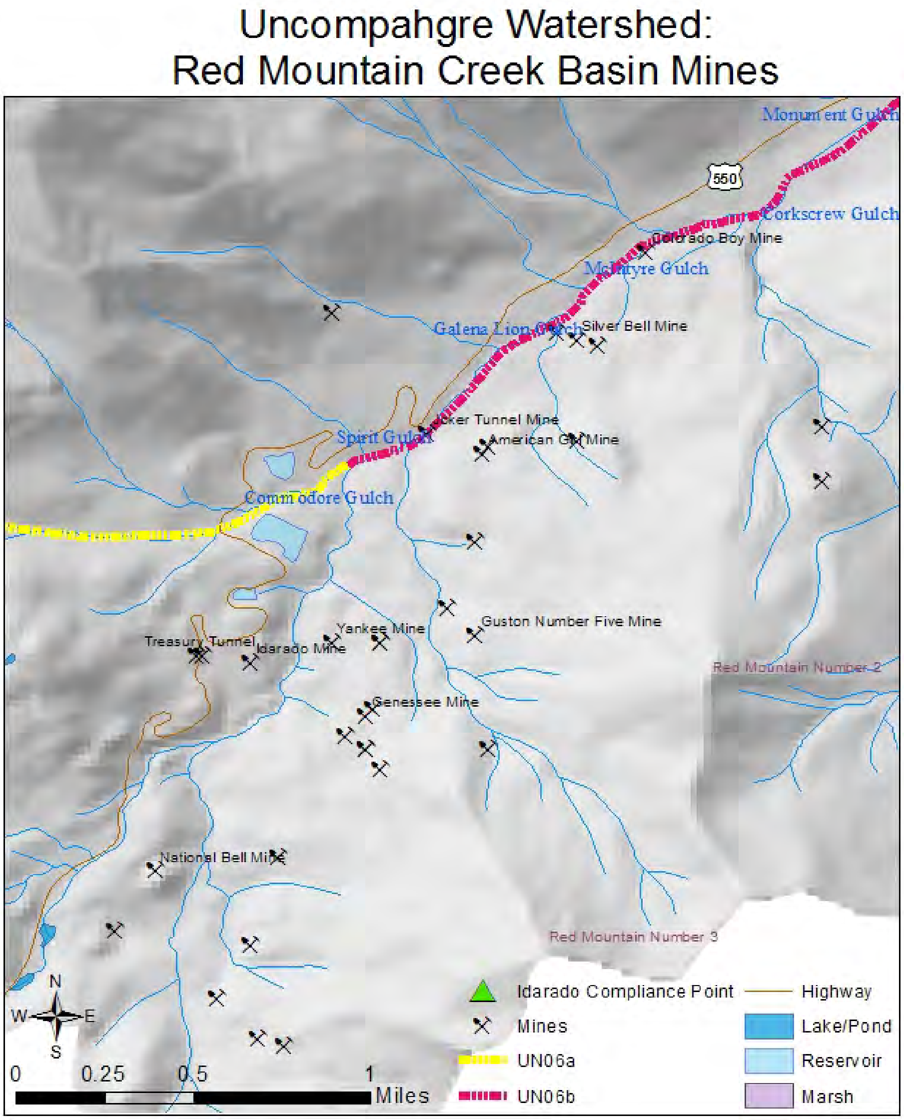
Sources of Metals

The metal loading and acidity of Red Mountain Creek has been attributed to both natural and human induced sources (Nash 2002). The human induced sources include water flowing from mine adits, seeps from waste rock piles and other mine related activities. Four discrete sources accounted for 83%, 72%, 70%, 69%, 64% and 61% of the aluminum, iron, arsenic, zinc, copper and cadmium loading in Red Mountain Creek based on an investigation of 29 sites from Red Mountain Pass to the confluence of Red Mountain Creek with Corkscrew Creek. The four major sources appear to be the result of surface inflows affected by mining activities near the Genesee, Red Mountain Adit, Guston/Rouville and Joker Mines (Runkel et al, 2005).

A loading analysis of the Red Mountain Creek basin loading analysis was performed by MFG (1991). Copper concentrations were generally very low or less than detection limits (Table 3) at the headwater sampling sites on the various gulches and drainages (MFG 1991). Copper concentrations often increased a thousand fold to acutely lethal concentrations when the gulches and drainages reached a confluence with Red Mountain Creek. The same pattern was observed for cadmium and zinc (MFG, 1991). The source of metal loading was determined to be from both natural and mine related activities:

> *"Portal and waste rock loadings are much greater than observable background loading for natural mineralization"* (MFG 1991).

The Genessee, Rouville and Red Mountain Adits contributed a substantial amount of the total copper load leaving the Red Mountain mining area (Figures 14 and 15j). The relative contribution of these three adits to Red Mountain Creek loading was demonstrated by comparing the total copper loading at a sampling point downstream of Hendrick Gulch to a selected set of mine adits using data from MFG (1991). These graphs may well overestimate the total contribution of these three adits to the metal loading in Red Mountain Creek downstream of Hendrick Gulch. Sedimentation, dilution and other factors decrease metal concentrations before Red Mountain Creek reached Hendrick Gulch. However, these three adits do contribute a substantial part of the metal load to the Red Mountain Basin, a conclusion supported by other investigators including Runkel et al. (2005 and 2007) who indicated, "the number of sources requiring treatment may be small." For example, Runkel et al. (2005) indicated that 64% of the dissolved copper in Red Mountain Creek originated from only four sources while data extracted from MFG (1991) demonstrated that up to 88% of the zinc originated from six sources in low flow conditions (Figures 14 and 15j).



Corkscrew and Gray Copper Gulch are two of the principle tributaries to Red Mountain Creek. Corkscrew Gulch contributes approximately two pounds per day total zinc to Red Mountain Creek and that the metals loads from Gray Copper Gulch are negligible (TLR, 2007). Corkscrew and Gray Copper Gulches dilute the metals loading in Red Mountain

Mine Reclamation and Water Quality

Extensive surface water quality sampling was not included as part of the settlement. Extensive sampling is necessary to assess long-term water quality improvement in Red Mountain Creek resulting from restoration projects. Monthly sampling was completed at only one site, Red Mountain Creek downstream of Waste Rock Pile 4 (the compliance monitoring site). Zinc was the only metal monitored. The compliance site zinc measurements are the only samples available in adequate numbers to determine if any decrease in metal concentrations occurred in the intervening time since the settlement agreement was signed.

Zinc concentrations measured at the CERCLA compliance-monitoring site from 1985 - 2007 did not appear to decrease on an annual basis (Figure 16). Maximum concentrations were observed in the low flow months of December through March. Lowest metal concentrations were mostly measured in July. Minimum concentrations were seldom less than 500 ug/L. Maximum concentrations usually exceeded 2,500 ug/L.

Zinc concentrations did not vary from 1985 to 2007 at the compliance site for the months of June through February as determined by linear regression analyses (Table 4). However, dissolved zinc concentrations appeared to decrease at the compliance site downstream in May. Forty two (42%) of the variability ($R^2 = 0.415$) is attributable to time. Dissolved zinc may also have decreased in March and April. These analyses suggest reclamation projects implemented by Newmont may have reduced zinc loading to the Red Mountain Creek system in the three months prior to the onset of spring snowmelt.

The sum of all existing remedies installed by Newmont Mining was not equal in scope and magnitude compared to other mining related restoration programs in Colorado. A mechanical plant was not constructed to treat metal contaminated water prior to release to Red Mountain Creek. Metal contaminated rock or waste piles were not moved, capped, or drained. Waste Rock Pile 2 was built of top of a natural spring that continues to leach metals to the system to this day. Buttresses were added to the toe of waste rock piles or rip-rap was added but the tops of the piles were not capped to exclude infiltration.

More intensive and extensive restoration programs have resulted in improved stream conditions in other streams throughout Colorado. Mechanical treatment plants were constructed to reduce metals reaching Coal Creek above Crested Butte, Clear Creek above Golden, to the Eagle River above Minturn, and the Arkansas River below Leadville, among others. Mandated by CERCLA actions in some cases, these plants all reduced metal concentrations by orders of magnitude. Trout populations either improved or became reestablished (Todd et al. 2002, Woodling and Rollings 2008a and 2008b) due to decreased metal loadings attributable to mechanical treatment plants and capping or removal of tailings, waste rock or other contaminated mining related materials.

A total restoration of Red Mountain Creek to pre-mining conditions would require treatment of hundreds sources throughout the drainage to reduce acid loading to the stream as well as aluminum, cadmium, copper, iron, lead and zinc loadings. Achieving pre-mining conditions is not possible due to the extensive fissuring of mountains throughout the Red Mountain Creek Basin attributable to mining operations. Selected restoration projects could address multiple human induced sources such as mine adits, waste rock piles, etc. Treatment of selected sources related to past mining efforts could reduce metal loading to the point a brown trout fishery could become established in the mainstem Uncompahgre River downstream of the Red Mountain Creek confluence.

Additional restoration in Red Mountain Creek is a viable option since most sources to Red Mountain Creek are from surface flows in contrast to subsurface inputs (Runkel, et al. 2007). One treatment option for Red Mountain Creek would be to explore the benefits of treating selected mine adits in the basin such as the Genessee, Rouville, Joker and Red Mountain Adit. The Genessee is one source that has routinely been identified as the largest contributor of metals to Red Mountain Creek (MFG 1991, Runkel et al. 2005) and WQCD no date). One possible field experiment would be a construct a series of temporary wetland reactors to treat flows from these four and perhaps more adits for a several month period in the late spring, summer and fall months. These temporary facilities could be nothing more than dirt filled vaults. Plant growth is not needed in earth filled reactors to substantially reduce metal concentrations as demonstrated in the Clear

Creek Basin at the Big Five Tunnel in Idaho Springs, Colorado (Doug Jamison, personal communication). Bacterial action on the adit flows could decrease metal loadings to Red Mountain Creek. A permanent treatment plant could be designed and constructed if these temporary reactors indicate this partial treatment of the Red Mountain Basin flows benefits the Uncompahgre River downstream of Red Mountain Creek.

Summary

Red Mountain Creek may never have been a pristine stream. Several studies including Nash (2002) and Runkel et al. (2007) indicated the natural loading of metals to Red Mountain Creek was of a magnitude sufficient to limit numbers and kinds of aquatic life in mountain streams. The natural mineralization in combination with the metals loads attributable to mining activities resulted in the State removing the designated use of Aquatic Life. Aluminum, cadmium, copper, iron, lead, zinc and pH would each be in violation if numeric water quality standards were applied to this segment. A hazard quotient analysis indicates that levels of pH, aluminum, cadmium, copper, iron, lead and zinc in Red Mountain Creek were high enough to be acutely toxic to all trout species found in Colorado.

Much of the current metal loading to Red Mountain Creek has been attributed to a limited number of sources regardless of current elevated ambient metal loads (MFG, 1991, Runkel et al. 2005). Treatment of a selected number of metal sources could reduce metal loading to the Uncompahgre River downstream of Red Mountain Creek to the point brown trout could survive, although in reduced numbers.

The existing CERCLA remedy was based on reducing the zinc concentrations in Red Mountain Creek. However, aluminum, iron and copper likely contribute the largest amount of toxicity to mainstem Red Mountain Creek. Thus, the existing CERCLA remedy based on zinc criteria does not accurately describe or address the contaminants most responsible for the degraded conditions in the basin. The existing CERCLA remedy appears to have resulted in measurable improvements to water quality at the Red Mountain Creek Compliance Point in March, April and May but not for the rest of the year.

Additional sampling is needed in the Red Mountain Creek drainage to describe variation of contaminants other than zinc and to describe the water quality of the stream upstream of the confluence with the Uncompahgre River. Current sampling at the compliance site describes water quality and loading in Red Mountain Creek about 3.77 miles upstream of the confluence with the Uncompahgre River. Several tributaries including Full Moon Creek and Hendrick Gulch enter Red Mountain Creek below the compliance site. Dilution and precipitation may well reduce both metal concentrations and loading in Red Mountain Creek before the stream empties into the mainstem Uncompahgre River. In addition, current sampling efforts by Idarado should be expanded to include more parameters such as hardness, aluminum, cadmium, copper, iron and lead and additional locations such as the Red Mountain Creek confluence with the Uncompahgre River.

Summary: Red Mountain Creek from the East Fork of Red Mountain Creek to the Uncompahgre River.

1. Red Mountain Creek may never have been a pristine mountain stream from the confluence of the East Fork of Red Mountain Creek to the Uncompahgre River. Natural conditions at the best limited aquatic life in this stream reach.
2. Mining activities during the last decades of the Nineteenth Century increased the metals and acid loading to Red Mountain Creek.
3. Remediation actions related to the CERCLA lawsuit have not resulted in measurable decreases in zinc loading to Red Mountain Creek on an annual basis although zinc concentrations appear to have decreased in the months of March, April and May.
4. Copper, aluminum and iron not zinc are the most important contaminants in Red Mountain Creek.
5. Treatment of a limited number (4) of sources in the Red Mountain Creek basin could result in a significant decrease in metals loading to both Red Mountain Creek and the mainstem Uncompahgre River.
6. An expanded water quality sampling program is needed to assess water quality trends in Red Mountain Creek.

6.3 Uncompahgre River downstream of Red Mountain Creek to Canyon Creek confluence

Colorado Water Quality Control Commission Segment 03a is defined as the Uncompahgre River mainstem from Red Mountain Creek to the Highway 90 Bridge at Montrose. This 42 mile long segment parallels Highway 550 and falls approximately 2700 feet in elevation. Due to the length of Segment 3a, the ambient water quality conditions vary greatly. For the purposes of this report, Uncompahgre River segment 3a has been divided into six sections. The first of these sections is the mainstem Uncompahgre River from just downstream of Red Mountain Creek to Canyon Creek.

WBID	UN03a	
Description	Mainstem of Uncompahgre River from a point immediately above the confluence with Red Mountain Creek to the Highway 90 Bridge at Montrose	
Use Classification	Aq Life Cold 1, Recreation E, Water Supply, Agriculture	
Meets Standards?	**Section not attaining chronic standards**	**Parameters not meeting standards**
No	Red Mountain Creek to Canyon Creek	Cadmium and Copper exceed acute and chronic table value standards, Total Recoverable Iron exceeded the numeric chronic standard (1,500 ug/L), pH

The Uncompahgre River Gorge confines the Uncompahgre River downstream of Red Mountain Creek. The Ouray Hydroelectric Dam near the mouth of the gorge impounds the Uncompahgre River. The Ouray Hydroelectric dam provides water to produce 750 kW of electric power at a facility located in Ouray downstream of Canyon Creek. Water diverted from the Uncompahgre River at the base of the dam is piped downstream, through the turbines and returned to the mainstem downstream of the confluences of Canyon Creek and Oak Creek in Ouray.

Few data are available for the Uncompahgre River from Red Mountain Creek to Canyon Creek. Data sources include Colorado Department of Public Health and the Environment and Colorado River Watch. River Watch volunteers (Arlene Crawford and da Funk brothers) sample the mainstem Uncompahgre above the hydroelectric dam (station 4135). A second River Watch Sample Site was located on the mainstem Uncompahgre River about 300 feet upstream of Canyon Creek (Station 3581). The site 300 feet upstream of Canyon has not been sampled since 2006. Uncompahgre River water quality from Red Mountain Creek to Canyon Creek was assessed from samples collected at the sampling site upstream of the reservoir (Site 4135) because data from the downstream (Site 3581) was not available for the years since 2006. No other data for this stream reach are available, other than seven isolated samples collected by the Colorado Department of Public Health and Environment (Price, 2001 and O'Grady, 2004).

6.3.1 Uncompahgre River upstream of the Ouray Hydroelectric Facility

pH, Hardness, Alkalinity and Metals

The pH of Uncompahgre River pH was generally acidic at the River Watch sampling site upstream of the Ouray hydroelectric dam (Site 4135). The pH of 20 of 26 samples was less than the Colorado pH Table Value Standard of 6.5 (15th percentile = 4.3). This section of the Uncompahgre River did not meet the pH stream standard of 6.5.

The pH was greater than 7.0 on just 6 of the sample dates (N = 26). The median pH was 4.92 from 2006 through 2008 (maximum = 7.5, minimum 3.56). Fish probably could not reproduce at this pH regime. Rainbow trout reproduction is "likely to be affected" at pH levels less than 5.5 and developing rainbow trout eggs did not survive exposure to pH at or below 4.5 (Weiner *et al.* 1986). Fish could not colonize the Uncompahgre River upstream of the Ouray Hydro facility due to pH, even if all metals contamination were eliminated.

Alkalinity is a measure of buffering capacity, or the ability of water to resist change in pH with an acid or base is added. Moderate levels of alkalinity are desirable in aquatic systems in the mining regions of Colorado. Alkalinity limits or buffers the effects of acid mine drainage. Waters with low alkalinity (below 10 mg/L $CaCO_3$) are poorly buffered and very susceptible to changes in pH. The median alkalinity of the Uncompahgre River upstream of the Ouray hydroelectric power dam was 4 mg/L as $CaCO_3$ (85th percentile was 10 mg/L as $CaCO_3$). The low alkalinity of the Uncompahgre River above the Hydro facility indicated that small increases in acidity would overwhelm the buffer system of the Uncompahgre River in this stream reach resulting in rapid pH decreases.

Like alkalinity, hardness levels are important to aquatic life. Metals toxicity decreases for a given concentration of most metals as the hardness levels increase. The hardness data reported by River Watch upstream of the Ouray Hydroelectric dam allowed for a comparison of ambient conditions to applicable Colorado stream standards for the time period of 2006 through 2007. The median hardness was 157 mg/L $CaCO_3$ (minimum 64 mg/L $CaCO_3$, maximum 287 mg/L $CaCO_3$, N=26). Hardness concentrations fluctuated seasonally with lowest values reported in May and June and highest values reported in low flow winter months of November, December and January. The mean hardness in May and June was 82 mg/L $CaCO_3$ (minimum 64 mg/L $CaCO_3$ and maximum 101 mg/L

$CaCO_3$). The lowest hardness concentrations were typical of high elevation Colorado mountain streams during the spring snowmelt season and indicated that relatively low metal concentrations would prove toxic to fish and other aquatic life.

Dissolved cadmium, copper, lead and zinc in this section each exceeded Colorado Table Value Stream standards (Figures 17- 20) from 2006 through 2007 (River Watch, Station 4135). Zinc concentrations also exceeded a recalculated zinc standard (see section 6.2) designed to protect brown trout (Figure 21) in 8 of the 14 samples for which data were available. Copper concentrations exceeded Table Value Stream Standards to a greater degree than the other three metals.

The median hazard quotient was 19.7 (maximum 32.2, minimum 1.2, 2002-2007 River Watch data) in the Uncompahgre River upstream of the Ouray the Hydroelectric dam, lower than levels found in Red Mountain Creek at the compliance-monitoring site (median HQ = 91.8) (Figure 22). Decreased median hazard quotients relative to the Red Mountain Creek compliance site demonstrated that various tributaries and the Uncompahgre River had diluted the Red Mountain Creek contaminant loading. The HQs indicate that the total metal toxicity of the Uncompahgre River upstream of the Ouray Hydro Electric Facility induces toxic impacts to aquatic life. However, during part of the year even ambient cadmium, copper, lead and zinc concentrations may allow the presence of a limited aquatic assemblage of tolerant species. Most toxic units that comprise the HQ were attributable to copper. Copper is the most important Uncompahgre River toxicant upstream of the Hydro facility.

Zinc in this reach probably was not toxic to brook trout based on the 2006 and 2007 data. Upstream of the Ouray Hydro Facility, dissolved zinc concentrations were less than 601 ug/L in all 14 samples for which metal data were available (median 415 ug/L). Dissolved zinc levels upstream of the Ouray Hydroelectric Facility were less 800 ug/L, a concentration that brook trout can tolerate (See Appendix 1).

Brown trout are more sensitive to zinc than brook trout. Brown trout inhabited an Eagle River segment where zinc concentrations ranged from 302 ug/L to 655 ug/L (Wooding and Rollings 2008b) similar to the zinc regime in the Uncompahgre River from Red Mountain Creek to Canyon Creek. The hardness concentrations were lower in the Eagle River, (68 mg/L as $CaCO_3$ to 158 mg/L as $CaCO_3$) compared to this portion of the Uncompahgre River. Higher hardness in the Uncompahgre River ameliorates zinc toxicity. The zinc concentrations in the Uncompahgre River from Red Mountain Creek to Canyon Creek would be less toxic than zinc of the same concentration at an Eagle River segment where brown trout are found. Some brown trout or brook trout would be expected to colonize the Uncompahgre River from Red Mountain Creek to Canyon Creek if levels of parameters other than zinc were not toxic to brown trout.

The median lead concentration in the Uncompahgre River above Canyon Creek was 1.93 ug/L (maximum = 11 ug/L, minimum = x, N=14), slightly lower than a concentration of 4.1 ug/L that can induce a nonlethal chronic toxicity to trout (Appendix 1). However, the relatively high hardness level of the Uncompahgre River upstream of the Ouray Hydro facility may mitigate the possibility chronic toxicity to trout. All lead concentrations were more than two decimal points less than a concentration of 1.17 mg/L (Davies et al., 1976), which is known to induce acute mortality in rainbow trout. Lead toxicity did not appear to be an environmental concern in the Uncompahgre River from Red Mountain Creek to Canyon Creek for trout.

Cadmium concentrations did not appear to be sufficient to eliminate all trout from the mainstem Uncompahgre River in the stream reach from Red Mountain Creek to Canyon

Creek. Cadmium concentrations of 2.58 ug/L induced 30% mortality to brown trout at a mean hardness of 75 mg/L $CaCO_3$ while a concentration of 1.3 ug/L resulted in no mortality (Brinkman *et al.*, 2006) in 30 day exposure laboratory tests. Dissolved cadmium concentrations would have to exceed 2.58 ug/L and hardness concentrations would have to be less than 75 mg/L as $CaCO_3$ to induce a lethal response in brown trout. The maximum cadmium was 2.02 ug/L in the Uncompahgre River from Red Mountain Creek to Canyon Creek, 23% less than the concentration of 2.58 ug/L in brown trout (Brinkman et al. 2006). Hardness concentrations were less than 75 mg/L as $CaCO_3$ on two occasions (N=14), June 23,2006 and June 17, 2007 when dissolved cadmium was 0.93 ug/L and 0.67 ug/L, respectively. The cadmium/hardness regime did not appear to be lethal to brook trout in the stream reach of the Uncompahgre River extending from the confluence with Red Mountain Creek downstream to Canyon Creek.

Copper concentrations were probably lethal to brook trout in the Uncompahgre River from the confluence with Red Mountain Creek to Canyon Creek. A copper concentration of 29 ug/L was the LC50 to brook trout at a hardness of 180 mg/L as $CaCO_3$ (Besser *et al*., 2001). Copper concentrations of 29 ug/L are lethal to brook trout at all hardness concentrations less than 180 mg/L as $CaCO_3$ (Appendix 1). The copper concentration upstream of the Hydro facility exceeded 29 ug/L while the hardness concentration was less than 180 mg/L as $CaCO_3$ (Figure 23) on eight of the 14 sample dates for which data were available. The copper/hardness regime was lethal to brook trout in the stream reach of the Uncompahgre River extending from the confluence with Red Mountain Creek downstream to Canyon Creek when these eight samples were collected.

Aluminum concentrations in the Uncompahgre River from Red Mountain Creek to the Ouray Hydro facility ranged from less than detection limits on December 31, 2006 to 30,100 ug/L on December 4, 2007 (median = 3,614, N= 14). No seasonal pattern was observed; both the highest and lowest concentrations were measured in the month of December. Total aluminum concentrations exceeded the hardness based chronic Colorado Table Value Standard that could be applied to this segment on 12 of the 14 sample dates for which data exist (Figure 24).

The pH and aluminum regime in this section would reduce the survival of brook, rainbow and presumably other trout species. The aluminum in the Uncompahgre River (Figure 25) was over ten times greater than that needed to reduce brook trout survival at the pH range of 4.2 to 5.6 (See Appendix 1), Baker and Schofield, 1982). Even in more neutral pH conditions, dissolved aluminum in the Uncompahgre River ranged from 1,595 ug/L to 3,598 ug/L, concentrations from three to six times greater than the aluminum concentration that induced mortality and various sub lethal impacts (See Appendix 1 {Freeman and Everhart, 1971}).

Total iron concentrations ranged from 15 ug/L to 22,260 ug/L (median 3,819 ug/L) from 2006 through 2007 (N=14) in the mainstem Uncompahgre River upstream of the Ouray Hydro facility. The total iron regime in this section did not meet any of the three standards that could be applied to this stream reach for the time period of 2006 through 2007: 1,000 ug/L (Table Value Standard), 1,500 ug/L (existing site specific standard) or 1,673 ug/L (temporary modification set to expire on 12/31/2012) based on the 50th percentile of data used by the Colorado Water Quality Control Division (WQCD) to assess compliance with the total iron standard.

Iron was present in the dissolved form (from 10% to 83% of total iron concentrations) due to acidic conditions. The toxicity of iron increases as pH decreased from pH 7 to pH 5.5 (See Appendix 1). The pH was less than 5.5 in 50% (N=14) of the samples for which data were available from 2006 through 2007 in the mainstem Uncompahgre River above the Ouray hydro facility while the associated total iron concentration exceeded 410 ug/L. Iron concentrations greater than 410 ug/L are lethal to brown trout at pH of 5.5 (Appendix 1). Therefore, iron was acutely lethal to brook trout in this stream reach in half of the samples. Iron concentrations, in combination with acidic conditions, would have eliminated trout from the Uncompahgre River in this section even if all other metal concentrations met Colorado stream standards.

Not all metals were present in concentrations lethal to trout in the Uncompahgre River from Red Mountain Creek to Canyon Creek. The cadmium, lead and zinc regimes may have allowed the presence of at least some brook or brown trout. Numbers of trout would have been reduced compared to Colorado stream uncontaminated by metals, but some tolerant individuals would be present. However copper, aluminum and iron concentrations were acutely lethal to trout at the pH and hardness levels found in the Uncompahgre River from Red Mountain Creek to Canyon Creek. Copper, aluminum and iron concentrations would have to be reduced for trout to survive in the Uncompahgre River from Red Mountain Creek to Canyon Creek. Cadmium reductions are required for the Uncompahgre River to attain chronic Colorado Table Value Standards in this stream reach (WQCD, 2009). However, cadmium reductions are not considered in the following section since the current concentrations of this metal would allow presence of some tolerant brook or brown trout.

The Colorado Water Quality Control Division (WQCD) performed a Total Maximum Daily Load Analysis (TMDL) to determine reductions of dissolved cadmium, dissolved copper and total iron concentrations needed to attain applicable stream standards (Table 5) (WQCD, 2009). The premise of the WQCD study was that the Uncompahgre River from Red Mountain Creek to Montrose would attain applicable metal standards if the stream reach from Red Mountain Creek to Canyon Creek were in compliance. The analyses performed for the current analysis support the TMDL finding. Most of the metals in the Uncompahgre River originate in Red Mountain Creek Basin. The entire Uncompahgre River in segment 3a would attain applicable chronic Table Value standards if metal reductions were adequate to meet these standards in the stream reach immediately downstream of Red Mountain Creek.

The reductions in metal concentrations needed to support a brown trout or brook trout population in the Uncompahgre River from Red Mountain Creek to Canyon Creek may differ from reductions presented in the TMDL needed to attain applicable stream standards. Brown trout and brook trout tolerate cadmium at concentrations exceeding chronic Colorado Table Value Standards. The same two trout species may require concentrations of total iron less than the current site-specific standard of 1,500 ug/L. As noted in a preceding paragraph half the samples collected had a pH of less than 5.5 and a total iron greater than 410 ug/L in the mainstem Uncompahgre River upstream of the Ouray Hydroelectric Dam, conditions acutely lethal to brook trout (Appendix 1).

The toxicity of iron decreases as pH increases. The brook trout iron LC50 was 1,750 ug/L at a pH of 7.0 (Appendix 1). One tenant of metal toxicity biology is that metal concentrations equal to or less than half of the 96-h LC50 allows survival of some organisms. Reduced numbers of brook trout would be expected to tolerate a total iron regime where concentrations are about one half the 96-h LC50, or 900 ug/L. Total iron reductions ranging from 0% to more than 90% would be needed to attain a concentration of 900 ug/L, based on River Watch data collected upstream of the Ouray Hydroelectric dam. In contrast, monthly total iron reductions ranging from 0% (June and July) to 82% (January) are needed to attain the current site-specific total iron standard of 1,500 ug/L based on the TMDL (WQCD, 2009) in the Uncompahgre River from Red Mountain Creek to Canyon Creek. At a circumneutral pH (around pH 7), a total iron regime of about 900 ug/L could likely support a population of brook trout reduced in numbers. Efforts to reduce iron concentrations require concurrent endeavors to decrease stream acidity if trout are to tolerate total iron concentrations of 900 ug/L in the Uncompahgre River from Red Mountain Creek to Canyon Creek.

Copper levels would have to be decreased from 0% in April and August to 87% in October through March to attain applicable Colorado Stream Standards in the Uncompahgre River from Red Mountain Creek to Canyon Creek (WQCD, 2009). Reduced numbers of brown trout would be expected to tolerate a dissolved copper concentrations about one half the 96-h LC50, a value that varies with hardness concentrations (Figure 23). Copper levels would have to be decreased from 0% to 86% in the Uncompahgre River from Red Mountain Creek to Canyon Creek to attain concentrations of one half of the LC50 (see Appendix 1) in the Uncompahgre River upstream of the Ouray Hydro facility (Site 4135). This data set indicated, however, that the existing copper regime would allow a reduced number of brown trout to survive in the Uncompahgre River upstream of the Hydro facility in April through June.

Projections for aluminum reductions were not included in the TMDL (WQCD, 2009). A TMDL is developed only when stream conditions exceed designated standards and aluminum standards have not been adopted for the Uncompahgre River Basin. Aluminum however is present in concentrations lethal to trout in the Uncompahgre River from Red Mountain Creek to Canyon Creek (see preceding paragraphs) based on the current pH and total aluminum regime. From 51% to 91% of the total aluminum must be removed for the Uncompahgre River to attain the hardness based chronic Table Value Standard that could be applied to the Uncompahgre River from Red Mountain Creek to Canyon Creek. Total aluminum concentrations meeting Table Value standards could still be harmful to trout due to the acidic nature of the Uncompahgre River from Red Mountain Creek to Canyon Creek. Efforts to reduce aluminum concentrations require concurrent endeavors to decrease stream acidity if trout are to tolerate total aluminum concentrations equal to the current hardness based, chronic Colorado Table Value Standard in the Uncompahgre River from Red Mountain Creek to Canyon Creek.

Reductions in copper, iron and aluminum would have to be coupled to an increase in pH (decreased acidity) for an aquatic assemblage to appear in the Uncompahgre River from Red Mountain Creek to Canyon Creek. The current pH regime of the Uncompahgre River from Red Mountain Creek to Canyon Creek would not support a trout population even if metal concentrations met existing Colorado Table Value Standards increased alkalinity could be included in restoration projects in Red Mountain Creek basin.

Reductions in metals needed to either attain applicable stream standards or support some brook trout or brown trout are similar to restoration projections determined through the course of the CERCLA lawsuit in the Red Mountain Creek Basin. Runkel et al. (2005) postulated that up to 64% of the copper could be removed from Red Mountain Creek by treating only four sources in the Red Mountain Basin. Interpretation of data collected by MFG (1990, 1991) suggested up to 88% of the copper could be removed by treating six sources. The amount of copper that could be removed by treating low numbers of sources in Red Mountain Creek (64-88%) was approximately equal to the load reduction postulated in the TMDL (a maximum of 87%) and in this document (a maximum of 86%) needed to assure survival of limited numbers of brown trout in the Uncompahgre River upstream of Ouray.

SUSPENDED SOLIDS

Suspended solids data upstream of the Ouray Hydro facility were limited to 3 samples collected by River Watch from 2007 and 2008 and two samples collected by the Colorado Hazardous Materials and Waste Management Division in 2001. Suspended solids ranged from 8 mg/L on May 1, 2001 to 86 mg/L on May 1, 2001 (average = 46 mg/l). All but one of the 5 samples was collected in May and June, months traditionally associated with spring snowmelt and roily turbid mountain streams. These suspended solids concentrations are relatively low compared to levels found in many Colorado streams in the months of May and June. Suspended solids did not appear to be a serious issue in this portion of the Uncompahgre River based on the limited data available. More data collected over a longer period of time is needed to determine the magnitude and amplitude of suspended solids in the Uncompahgre River from the confluence of Red Mountain Creek to the confluence with Canyon Creek.

NUTRIENTS

Nutrient data were more limited than suspended solids information in the Uncompahgre River from the confluence of Red Mountain Creek to the confluence with Canyon Creek. Total nitrate ranged from 95 ug/L as N to 137 ug/L as N (N=3). Two ammonia concentrations were less than detection limits and the third was 40 ug/L as N. A level of about 130 ug/L total nitrogen as N is considered to be the natural background levels in western forested mountains (Smith *et al*., 2003). Background total phosphorus in western-forested mountains is about 20 ug/L (Smith *et al*., 2003). Total phosphorus in the Uncompahgre River from the confluence of Red Mountain Creek to the confluence with Canyon Creek ranged from 28 ug/L as P to 55 ug/L as P. Nutrient concentrations in this segment were similar to conditions in waters with no influence attributable to human actions, based on limited data.

6.3.2 Uncompahgre River below the Ouray Hydropower Reservoir

The Ouray Hydropower Reservoir is located about 1.5 miles upstream of the confluence of the Uncompahgre River and Canyon Creek. The metals and sediments trapped behind the impoundment are released into the mainstem Uncompahgre River via flushing maintenance operations conducted on a periodic basis. These sediments and metals were not created by the operation of the hydropower plant. Instead the metals accumulate in the streambed upstream of the dam as water velocity slows in the impounded stream reach.

The Colorado Hazardous Material and Waste Management Division sampled the Uncompahgre River upstream and downstream of the Ouray Hydropower Reservoir during two planned flushing actions on May 5, 2001 (Price, 2001). Metal and TSS concentrations below the dam increased during the flushing operation (Table 6). The pH of the stream did not change.

All metal concentrations measured before and after the flushing operation, both upstream and downstream of the dam, exceeded Colorado chronic stream standards (Table 6). The copper, zinc and iron concentrations would have either restricted or eliminated most trout species upstream and downstream of the hydropower plant without any influence from the facility. Data recorded included total metal fractions and not the dissolved fraction (which is the metal form regulated by Colorado Water Quality Control Commission stream standard process). The total fraction is usually greater than the dissolved fraction. However, the pH of the Uncompahgre River was less than 7.0 in all samples collected during the flushing procedure. The largest portion of the metals present would have been in the dissolved form.

River Watch volunteers collected data on the Uncompahgre River at a site 300 feet upstream of the Canyon Creek (Site 3581) confluence from 1995 through 2002 (Table 7), during the time period when the HAZMAT flushing study was performed. Maximum cadmium, copper, lead and zinc measurements recorded by River Watch from 1995 to 2002 were less than the concentrations measured by HAZMAT during the May 5, 2001 hydropower flushing operation in the Uncompahgre River downstream of the Ouray Hydroelectric dam. The flushing process did not increase or decrease the amount of metals transported through the Uncompahgre River on an annual basis. However, the flushing operations resulted in the highest instantaneous metal concentrations measured in the mainstem Uncompahgre River downstream of the Hydro dam for the period of record. Such peak measurements may prove toxic even if the exposure period is rather short.

The increase in metals may have resulted in acutely toxic conditions for a distance downstream during the flushing operations. Both metals and sediments from the flushing procedure are an additional stressor to a river segment with existing water quality issues including pH, metals and sediments. Episodic increases in metals have been observed in other Colorado streams impacted by heavy metal discharges during summer storm events including the Arkansas River, Clear Creek and the Eagle River. More intensive sampling of water quality during these flushing events is warranted to determine if potential impacts on the Uncompahgre River system from the Ouray Hydropower Reservoir flushing operations could potentially represent an acute environmental threat.

6.3.3 Summary Uncompahgre River from Red Mountain Creek to Canyon Creek

Metal concentrations and acid levels in the Uncompahgre River mainstem from the confluence of Red Mountain Creek to the Canyon Creek confluence were lower than those in Red Mountain Creek but still exceeded applicable stream standards. Dissolved copper, total iron and total aluminum concentrations remained acutely lethal to brook trout and brown trout, while the annual pH regime would have eliminated trout reproduction. Cadmium, lead and zinc concentrations however, may have allowed the presence of some brook trout or brown trout at least in the lower portion of this stream reach, just upstream of the Ouray Hydropower plant. Copper reductions of up to 72% would have allowed the presence of a low number of brown trout in this stream reach. Copper appeared to be the metal that limited aquatic life in the Uncompahgre River from Red Mountain Creek to Canyon Creek more than cadmium, lead and zinc. Reclamation actions directed at reducing copper would reduce the concentrations of other metals. The potential for creating a water quality regime that would allow survival of brown trout is an indication that restoration objectives for the Red Mountain CERLCA case should be reanalyzed. Conclusions concerning this stream segment must be considered with some caution. As of the date of this report, water quality data for the mainstem Uncompahgre River downstream of Red Mountain Creek are limited due to a low number of samples available for analysis. This situation will improve as River Watch volunteers collect more samples. Additional detailed sampling of the Uncompahgre River during flushing operations of the Ouray Hydropower station is needed. However, this stream reach could be considered for inclusion on the WQCC 303d list for a wide variety of constituents including pH, aluminum, cadmium, copper, iron, lead and zinc.

Summary: Uncompahgre River from Red Mountain Creek to Canyon Creek

1. Water quality exceeds stream standards applied by the Colorado Water Quality Control Commission in the Uncompahgre River from the confluence of Red Mountain Creek to the Ouray Hydroelectric Facility. Several water quality parameters were present in concentrations lethal to a wide variety of aquatic species including pH, aluminum, iron, and copper.
2. Red Mountain Creek is the source of most of this contaminant loading.
3. Not all metal loading attributable to Red Mountain Creek needs to be removed for aquatic life to colonize the Uncompahgre River in the Town of Ouray.
4. Reductions to levels currently present in the mainstem Uncompahgre River upstream of Red Mountain Creek and to those levels currently present in the mouth of Canyon Creek) would result in presence of a fishable population of brook trout and/or brown trout in the Uncompahgre River through Ouray.
5. The limited data available at this time indicate reduced numbers of brook trout and brown trout may be able to tolerate the cadmium, lead and zinc regimes currently present in the Uncompahgre River from Red Mountain Creek to Canyon Creek if other parameters such as pH, aluminum, copper and iron were not present in lethal concentrations.
6. The flushing operations at the Ouray Hydroelectric result in the maximum metal concentrations found in the Uncompahgre River from Red Mountain Creek to Canyon Creek on an annual basis. Additional sampling of the flushing operation may be able to determine if the metal spikes would be lethal to trout.

6.4 Canyon Creek

Canyon Creek is a small headwater stream that enters the Uncompahgre River south of Ouray. The stream originates at the confluence of Imogene Creek and Sneffels Creek and flows northeast towards town. The Colorado Water Quality Control Commission (WQCC) designated this section of the mainstem Uncompahgre River as Segment UN09. Past mining activities have left both historic mine sites that attract tourists and water quality issues that date back over a century.

WBID	UN09	
Description	Mainstem of Canyon Creek from its inception at the confluence of Imogene and Sneffles Creek to the confluence with the Uncompahgre River. Mainstem of Imogene Creek from its source to its confluence with Canyon Creek. Mainstem and all tributaries of Sneffles Creek from a point 1.5 miles above to its confluence with Canyon Creek.	
Use Classification	Aq Life Cold 2, Recreation P, Water Supply, Agriculture	
Meets Standards?	**Section not attaining chronic standards**	**Parameters not meeting standards**
Generally	Mouth	Occasional cadmium, copper, lead and zinc exceedances

The WQCC classified Segment UN09 as an aquatic life class 2 stream. An aquatic life classification of class 2 is applied to stream reaches where aquatic life is limited due to uncorrectable natural or human induced factors. Canyon Creek was also placed on the 2010 Monitoring and Evaluation List (M& List) for zinc and lead. The M&E list identifies pollutants that *might* be impairing a stream reach.

Data sources include Colorado River Watch and Colorado Department of Public Health and the Environment's Canyon Creek Analytical Results Report conducted in partnership with Ouray County and the Trust for Land Restoration as part of a Brownfields Assessment (Mackey, 2000).

- River Watch volunteers (Eric Fagerlius and the Ouray School) collected monthly samples (N=72) from 1995 through 2002 on Canyon creek approximately 300 feet upstream of confluence with the mainstem Uncompahgre River
- The Colorado Department of Public Health and the Environment conducted an intensive, one-time sampling event of the Canyon Creek basin at multiple sites in the summer of 1999 (Mackey, 2000) along the length of Imogene Creek, Sneffles Creek and Canyon Creek.

6.4.1 Canyon Creek Watershed Characterization

Variation of water quality throughout the length of the Canyon Creek Watershed cannot be described for a long period of time. Only a single synoptic sampling event has been performed along the length of Canyon Creek on September 20-22, 1999 (Mackey, 2000).

The pH of Canyon Creek was weakly alkaline (pH 7-7.8) from origin to confluence with the Uncompahgre River in 1999 (Table 8). Canyon Creek pH levels would not negatively impact aquatic life.

Metal concentrations generally met Colorado stream standards with two exceptions. First, Canyon Creek downstream of the Camp Bird Tailings exceeded chronic Table Value Standards for cadmium, iron and zinc (Table 8). Second, Sneffles Creek upstream of Imogene Creek exceeded the chronic zinc Table Value Standard. The majority of metals entering Canyon Creek appear to be originating in the Imogene Basin near the Upper Camp Bird workings (Mackey 2000).

Nutrient information collected by Mackey (2000) included both nitrogen and phosphorus. Total nitrate as N ranged from less than detection limits to 270 ug/L as N (median = 100 ug/L as N, N=17) along the length of Imogene, Sneffels and Canyon Creeks. A total nitrogen concentration of 130 ug/L as N is considered to be the natural background level of for nitrogen compounds in western-forested mountain streams (Smith *et al*., 2003). The nitrate concentrations in two samples from Imogene Creek were 210 ug/L as N and 270 ug/L as N. The total nitrate concentrations in Sneffels and Canyon Creeks were less than 130 ug/L as N with one exception in the headwater section of Sneffels Creek where the total nitrate as N was 140 ug/L. The nitrate levels in Imogene Creek may indicate of nitrogen loadings in excess on natural background conditions. Nutrient concentrations in Sneffels Creek and Canyon Creek did not appear to be influenced by human actions.

Background total phosphorus in western-forested mountains is generally 20 ug/L as P (Smith *et al.*, 2003). Total phosphorus in the Canyon Creek drainage ranged from less than detection limits to 80 ug/L as P (median = 10 ug/L as P, N =15). The highest total phosphorus measurement was in Sneffels Creek, 80 ug/L as P. Total phosphorus as P exceeded the 20 ug/L background level in Imogene Creek, Sneffels Creek and Canyon Creek.

Nutrient concentrations in most of the Canyon Creek system exceeded conditions expected in waters with no human influences. More data and sampling would be needed to determine if nitrate and phosphorus concentrations in that small headwater stream system were elevated due to human actions.

6.4.2 Water Quality at Canyon Creek near the Mouth

Canyon Creek near the confluence with the Uncompahgre River was sampled by River Watch volunteers (Eric Fagerlius and the Ouray School) at a site on Canyon creek approximately 300 feet upstream of confluence with the mainstem Uncompahgre River (Station 4134). The data set includes monthly samples (N=72) collected from 1995 through 2002.

The pH of Canyon Creek was weakly alkaline or circumneutral at the River Watch sampling site about 300 feet upstream of the confluence of Canyon Creek and the Uncompahgre River (Figure 26). The pH exceeded 7.0 on 56 of the sample dates (N=71). The median pH value was 7.83 (maximum = 8.56, minimum 5.96). Ten pH measurements (n=71) were less than the applicable Colorado Table Value Standard of 6.5. In general, the pH regime of Canyon Creek met the stream standard of 6.5 upstream on the Uncompahgre River confluence and would support reproducing trout populations (see Appendix 1).

Total alkalinity was moderately low in the downstream section of Canyon Creek compared to other Colorado streams of the same size (Woodling 1974 and 1975). The median total alkalinity in Canyon Creek was 60 mg/L as $CaCO_3$, (minimum 18 mg/L, maximum 94 mg/L as $CaCO_{3,}$ N=74). The lowest alkalinity concentrations were generally measured in May when snowmelt flows provided dilution water.

Alkalinity measures buffering capacity of water. The alkalinity provides the buffer system that protects aquatic life from extreme fluctuations in pH. Although relatively low, Canyon Creek alkalinity provided protection against small increases in acidity except perhaps during spring snowmelt.

The alkalinity of Canyon Creek waters also increased the buffering capacity in the mainstem Uncompahgre River. The median alkalinity was 4 mg/L as $CaCO_3$ in the Uncompahgre River upstream of Canyon Creek. The median alkalinity of the mainstem Uncompahgre River was 32 mg/L downstream of the confluence of the Uncompahgre River with Canyon Creek and Oak Creek. Elevated buffer capacity increases the opportunity for aquatic life to survive episodic acid pulses.

The median hardness was 284 mg/L $CaCO_3$ (maximum 474 mg/L $CaCO_3$, minimum 72 mg/L $CaCO_{3,}$ N=71). Hardness concentrations are typically less than 100 mg/L $CaCO_3$ in the headwater reaches of many Colorado stream systems. The high ambient hardness concentrations in Canyon Creek likely mitigate toxic impacts of metals most of the year (see Appendix 1). Hardness concentrations fluctuated seasonally with lowest values reported in May and June (Figure 27) and highest values reported in low flow winter months of November, December and January. The low May hardness concentrations detected in Canyon Creek near the mouth with the Uncompahgre River were typical of high elevation Colorado mountain streams during the spring snowmelt (Woodling 1974 and Woodling 1975). The relatively high Canyon Creek hardness concentrations near the confluence with the Uncompahgre River mitigate metal toxicity to a degree not found in many similar sized Colorado mountain streams except during spring snowmelt in some years.

Dissolved cadmium, copper, lead and zinc seldom exceeded Colorado Stream standards in Canyon Creek. Dissolved lead exceeded the Colorado Table value standard in only one sample (4.5 ug/L on 5/24/199, N=46), while dissolved cadmium, copper and zinc concentrations exceeded the chronic stream standards in three samples collected during the period of record, N = 44, 44 and 38, respectively (Figures 28-30). Less than 10% of all cadmium, copper, lead and zinc concentrations exceeded chronic stream standards. Cadmium, copper, lead and zinc concentrations were less than those found in Clear Creek and the Eagle River (Woodling and Rollings, 2008a; Woodling and Rollings, 2008b) and hardness concentrations were greater than in Clear Creek and the Eagle River. Naturally reproducing trout populations inhabit both Clear Creek and the Eagle River in stream reaches with lower metal concentrations and higher hardness levels.

The median hazard quotient (HQ) of 1.06 (maximum 32, minimum 0.42, N=38, 1995-2002 River Watch data) in Canyon Creek was lower than levels found in Red Mountain Creek (median HQ = 91.8), demonstrating that the waters of Canyon Creek provided dilution water and buffering capacity to the Uncompahgre River thus mitigating the impacts of metals and acid loading from Red Mountain Creek. The highest HQ was 3.2 (a HQ of 32 was deleted as an outlier). A HQ greater than 1.0 indicates that the aquatic biota of a stream may be expected to exhibit indications of chronic toxicity due to the additive interaction of these four metals (Figure 31). Fifty percent of the calculated HQs were less than 1.0 for the period of 1995 through 2002. The cumulative Canyon Creek metal toxicity near the confluence with the Uncompahgre River supports an aquatic community comprised of metals tolerant species. Reports by local anglers indicate that a naturally reproducing brook trout population inhabits the lower section of Canyon Creek. Three age classes of brook trout were present in Canyon Creek near the confluence with the Uncompahgre River in the early summer of 2010.

Aluminum data were available from May 1999 through May 2002 (N=18). The median aluminum concentration was 235 ug/L (minimum 50 ug/L, maximum 4,742 ug/L). Six of the 18 total aluminum concentrations exceeded the chronic Colorado Table Value Stream that would be applied to this stream reach if the Colorado Water Quality Control Division applied aluminum standards to the Uncompahgre River Basin (Figure 32). No seasonal pattern of total aluminum variability was observed. The highest total aluminum concentrations were detected in spring snowmelt (May), late summer (July) and fall (October). Total aluminum concentrations were generally less than the chronic standard in months normally associated with low stream flows.

Aluminum toxicity to aquatic life is complex (Appendix 1). The pH, hardness and total aluminum concentrations in Canyon Creek appeared to be similar to the test conditions utilized by Freeman and Everhart (1971) and Cleveland et al. (1986). Thus the Canyon Creek aluminum regime in Canyon Creek may have resulted in reduced growth in rainbow trout and brook trout on seven of the 18 dates for which aluminum and hardness data were available (Table 9). Rainbow trout are not present in Canyon Creek perhaps in part due to aluminum. Aluminum concentrations along the length of Canyon Creek, from origin to the mouth, were high enough to limit the aquatic community that would be expected to inhabit a headwater mountain stream free from aluminum loadings.

Total iron concentrations ranged from below detection limits to 5,176 ug/L (median 164 ug/L) from 1999 through 2002 (N=44) in Canyon Creek at the River Watch sampling site just upstream of the confluence of Canyon Creek and the Uncompahgre River. The total iron measurements at this site met the chronic Colorado Stream Standard of 1,000 ug/L. The elevated iron concentrations were often associated with high stream flow. Iron precipitating from the water column may negatively influence aquatic by physically smothering habitat required for trout eggs to develop and hatch and/or habitat needed by a variety of aquatic insects.

Most of the iron was present in the total form due to basic pH conditions. In general the pH was high enough and iron concentration low enough that iron was not directly toxic to trout. The pH was 6.2 and total iron was 1,115 ug/L (dissolved iron was 1,068 ug/L) on May 28; conditions acutely toxic to brook trout as demonstrated by Decker and Menendez (1974) (Appendix 1). Total iron was not directly toxic to trout in Canyon Creek except during this single sampling event.

Stream sedimentation is an issue in the Canyon Creek drainage. The stream substrate of Canyon Creek was covered with fine black sediments in pools, backwaters and eddy areas in 2009 and 2010. These sediments filled the interstitial spaces between the cobble on the stream bottom, eliminating the physical habitat required by aquatic macroinvertebrates. These same deposits would have smothered the eggs of any trout that spawn in these areas. These sediments likely limit the aquatic life in this stream reach but were not of a magnitude sufficient to eliminate all trout. The source of these sediments is not known but would probably include any metals such as iron and aluminum that had settled from the water column.

Summary Canyon Creek

Water quality in Canyon Creek occasionally violated metal stream standards for pH, cadmium, copper, lead, zinc, and total iron. The chronic Table Value aluminum standard was not met but aluminum standards have not been adopted for the Uncompahgre River Basin. Many individual hazard quotients for cadmium, copper, zinc and lead exceeded a level of 1.0 indicating that the combined impact of these four metals would be expected to negatively impact the aquatic assemblage to some degree in Canyon Creek. Aluminum was present in concentrations that would induce toxic impacts to trout. The stream substrate was buried in places by deposits of fine black sediments that eliminated habitat needed by aquatic macroinvertebrates and trout. However, brook trout maintained a naturally reproducing population in the lower reaches of Canyon Creek (Personal communication, multiple Ouray anglers).

Canyon Creek supported an aquatic community despite elevated metal concentrations (as indicated by Hazard Quotients greater than 1.0) and sediments. Aquatic species in Canyon Creek would be expected to display some negative response to the metals that exceed stream standards such as reduced numbers, growth, weight or reproduction. The combined impact of metals probably has more effect on aquatic life than any single metal such as copper or zinc. Modest remediation activities at the Upper Camp Bird Mine could result in an overall reduction of metals flowing down through Canyon Creek and decrease the cumulative impact of metals throughout Canyon Creek.

Metal concentrations in the lower end of Canyon Creek were far less than in the mainstem Uncompahgre River where the two waters merge. As a result Canyon Creek waters dilute the metal concentrations in the Uncompahgre River. Canyon Creek could be used as a surrogate to describe what aquatic life conditions could be like if mainstem Uncompahgre River pH and metal regimes were similar to those in Canyon Creek.

Canyon Creek has been designated as a class 2 cold water stream segment by the Colorado Water Quality Control Commission and placed on the Monitoring & Evaluation List (M&E List) for zinc and lead. Canyon Creek supports a naturally reproducing trout population, at least the portion of the stream near the confluence with the Uncompahgre River. As such, Canyon Creek may actually represent a cold water class 1 system and warrant a change in aquatic life use as designated by the Colorado Water Quality Control Commission. Canyon Creek near the confluence with the Uncompahgre River did not warrant inclusion on the M&E list for zinc and lead. This segment of Canyon Creek was generally in compliance with appropriate stream standards. The upper portion of Canyon Creek (near Camp Bird Mine) with Imogene Creek and Sneffels Creek may well warrant inclusion on the M&E List but additional sampling is needed to accurately define a listing on the 303d Impaired Waters List.

Summary: Canyon Creek

1. Canyon Creek is not a pristine mountain stream.
2. The Canyon Creek metal regime probably limits both growth and types of aquatic life that inhabit the stream. Canyon Creek does support a reproducing trout population.
3. The ambient water quality in Canyon Creek could be used as a restoration goal for the mainstem Uncompahgre River downstream of Red Mountain Creek. The objective could be to establish water quality goals in the mainstem Uncompahgre River based on conditions in Canyon Creek and the Uncompahgre River upstream of Red Mountain Creek.

6.5 Oak Creek

Oak Creek is a small headwater stream that enters the Uncompahgre River in the City of Ouray about 50 yards downstream where Canyon Creek enters the river. The steep gradient of Oak Creek precludes colonization of this stream by trout.

WBID	UN05	
Description	All tributaries to the Uncompahgre River, including all wetlands, lakes and reservoirs, from the source to a point immediately below the confluence with Dexter Creek, except for specific listings to Segments 1 and 6 thru 9.	
Use Classification	Aq Life Cold 2, Recreation E, Water Supply, Agriculture	
Meets Standards?	**Section not attaining chronic standards**	**Parameters not meeting standards**
Yes	n/a	n/a

Dexter Creek is one of the tributaries to the mainstem Uncompahgre River included in Segment UN05 as currently defined by the Colorado Water Quality Control Commission. The Commission applied an aquatic life class 2 classification to segment UN05. Aquatic life class 2 designations are applied to stream segments where aquatic life is limited due to uncorrectable natural or human induced factors.

Oak Creek (River Watch Station 3585) was sampled from 2002-2006 by River Watch volunteers (Arlene Crawford, Ethan Funk and Eric Funk). A single site was sampled, just upstream of where Oak Creek enters the Uncompahgre River. A total of 33 samples were collected during this time period.

6.5.1 Water Quality

Oak Creek is an alkaline system (median pH = 8.2, maximum = 8.6, minimum = 7.4), with a moderate buffering capacity (median alkalinity = 74 mg/L as $CaCO_3$, minimum = 28 mg/L as $CaCO_{3,}$ maximum = 120 mg/L as $CaCO_3$,) and a relatively low hardness regime (median hardness = 88 mg/L as $CaCO_3$, maximum = 204 mg/L as $CaCO_3$, minimum = 40 mg/L as $CaCO_3$) in relation to other streams in the Uncompahgre River basin.

Metal concentrations were generally less than detection limits. Twenty-two (22) of 31 dissolved zinc measurements, 22 of 31 copper measurements, and 26 of the 31 cadmium measurements were less than detection limits. No violations of chronic stream standards were found for cadmium, copper, lead or zinc. No toxic units for a single metal exceeded the level of 1 and only one combined HQ (1.5 on 8/21/2005) exceeded 1, the level that indicates potentially chronic toxic impacts to the aquatic community. Metal concentrations in Oak Creek did not negatively influence the aquatic community.

Suspended solids ranged from below detection limits on four occasions to 120 mg/L on May 7, 2002 (mean = 25 mg/l, N=9). Oak Creek suspended solids concentrations were relatively low compared to levels found in many Colorado streams in the months of May and June. Suspended solids did not appear to be an issue in Oak Creek based on limited data.

Nutrient data for Oak Creek was limited to nine River Watch samples collected from 2001 through 2005. Total nitrate ranged from 40 ug/L NO_3 as N to 230 ug/L NO_3 as N (N=8), while all eight ammonia measurements were less than detection limits. The natural background level of nitrogen in western-forested mountain streams is considered to be 130 ug/L total nitrogen as N (Smith et al. 2003). Six of eight samples in Oak Creek exceeded a level of 130 ug/L as N. Total phosphorus ranged from less than detection limits to 38 ug/L as P (mean = 16 ug/L as P, N =8) at the mouth of Oak Creek. The natural background level of phosphorus in western-forested streams is 20 ug/L as P (Smith et al. 2003). Nutrient concentrations in Oak Creek at the mouth were similar to conditions in waters with no influence attributable to human actions.

5.6.3 Summary Oak Creek. Like Canyon Creek, the waters from Oak Creek diluted contamination of the Uncompahgre River. The alkalinity strengthened the buffer capacity of the Uncompahgre River while the relatively metal free water diluted the metal levels in the mainstem. Oak Creek met applicable stream standards for all parameters sampled and would be considered to be supporting of a wide variety of aquatic species. Aquatic species in Oak Creek would not be limited by water quality parameters. The application of a class 2 coldwater designation is not appropriate for Oak Creek. A coldwater class 1 designation appears to be warranted. Thousands of headwater streams throughout Colorado are designated as class 1 aquatic life systems where no data are available that describe either water quality or aquatic life. In addition thousands of headwater streams that do not support trout are designated as cold water class 1 aquatic life systems.

Summary: Oak Creek

1. Oak Creek is a typical high elevation stream in the Colorado Mountains. The steep gradient stream does not support a trout population but water Quality meets or exceeds applicable stream standards and nutrient concentrations are similar to natural background conditions in western-forested mountain streams.
2. The Colorado Water Quality Control Commission has classified this stream as a cold water class 2 stream reach. Most high elevation streams like Oak Creek are classified as cold water class 1 systems.
3. A proposal to upgrade Oak Creek to a cold water class 1 stream is warranted since existing water quality is better than the chronic Table Value Standards adopted by the Water Quality Control Commission.

6.6 Uncompahgre River in Ouray

Downstream of the Uncompahgre Gorge and confluence with Canyon Creek, the Uncompahgre River continues to flow north through the box canyon and City of Ouray. The riparian corridor in this stretch of the river has been encroached upon by homes and businesses. In 1998, the City of Ouray completed a river restoration project called the Uncompahgre River Walk with funds from the Idarado NRD Fund. A USGS flow gage (09146020) is located near the foot bridge of the park, 0.4 miles downstream from Bridalveil Creek and 1.6 miles north of Ouray. The mainstem Uncompahgre River is part of Colorado Water Quality Control Commission segment 3a through the Town of Ouray.

WBID	UN03a	
Description	Mainstem of Uncompahgre River from a point immediately above the confluence with Red Mountain Creek to the Highway 90 Bridge at Montrose	
Use Classification	Aq Life Cold 1, Recreation E, Water Supply, Agriculture	
Meets Standards?	**Section not attaining chronic standards**	**Parameters not meeting standards**
No	Near Ouray Gage	Chronic TVS for cadmium, copper and zinc

Water quality data in this section were available from USGS and two River Watch sites. The first Colorado River Watch Site is located on the Uncompahgre River downstream of Oak Creek (Station 3584) and the second site was further downstream at the USGS gage (Station 3586). Colorado River Watch data from the site downstream of Oak Creek were available for 2002-2007. Water quality data from USGS gage (Station 9146020) were available for 2001- 2009. Unless otherwise noted the USGS data and River watch data collected at the USGS gage were combined for analysis.

The creation of a trout fishery in the mainstem Uncompahgre River through the City of Ouray would be a reasonable outcome of mine restoration projects in the Red Mountain Creek drainage. The objective of the following discussion is to compare current water quality of Uncompahgre River water quality through the City of Ouray to a metal regime that would support brook trout or brown trout, species that are somewhat tolerant of metals that exceed chronic Colorado Table Value Standards.

6.6.1 Water Quality

The water quality regime in the Uncompahgre River is difficult to describe from Oak Creek to the Ouray USGS gage station due to operation of the Ouray hydroelectric facility. The Ouray hydroelectric dam is located on the mainstem Uncompahgre River upstream of the Canyon Creek confluence. Metal-laden, acidic water is diverted from the mainstem at the base of the Ouray Hydroelectric Dam and piped by gravity down gradient to the hydropower plant. The dewatered portion of the Uncompahgre River mainstem continues to flow north through Ouray where relatively uncontaminated native flows from both Canyon Creek and Oak Creek enter the mainstem. Just upstream of the Ouray USGS flow gage the diverted water is returned to the river, re-introducing metals to the system. The Ouray Hydropower Plant does not act as a source of metals to the Uncompahgre River.

Hot springs also enter the Uncompahgre River downstream of Canyon Creek and upstream of the Ouray USGS flow gage location. Water from these springs adds an unknown level of dissolved salts and metals such as aluminum and iron.

The Uncompahgre River was slightly alkaline from Oak Creek downstream to the USGS Ouray gage. The pH levels met Colorado Table Value Stream standards (pH 6.5) in over 99% of water samples. At the site downstream of Oak Creek, the median pH was 7.7. Only two measurements were lower than 6.5 (minimum = 5.0, N=42). The median pH at the USGS gage site was 7.62 and four measurements were less 6.5 (minimum = 4.7, N=133). The pH in the Uncompahgre River from Oak Creek to the USGS gage did not negatively influence aquatic life or increase the toxicity of metals.

Hardness in this section increased relative to the Uncompahgre River upstream of Canyon Creek. The median Uncompahgre River hardness downstream of Oak Creek was 228 mg/L $CaCO_3$ (N=43) with eight measurements less than 100 mg/L $CaCO_3$ (minimum 56 mg/L, maximum 435 mg/L). The median hardness in the Uncompahgre River at the USGS station was 266 mg/L $CaCO_3$ (N=133) with 17 measurements less than 100 mg/L (minimum 36 mg/L $CaCO_{3,}$ maximum was 526 mg/L $CaCO_3$). The lowest concentrations were measured in May and June of each year during elevated flows from spring snowmelt. Metals may be more toxic to fish in the months of May and June due to seasonal decreases in hardness concentrations.

Copper and aluminum concentrations were often lower in the Uncompahgre River downstream of Oak Creek compared to the downstream USGS flow gage site (Figure s 33 and 34). Dissolved cadmium, lead and zinc and total iron had the same distribution pattern. Canyon and Oak Creeks provide low metal loads to this dewatered stretch of Uncompahgre River, temporarily diluting metals concentrations. Metal concentrations then increased at the USGS station, where the water diverted to the hydroelectric facility is returned to the mainstem.

Dissolved cadmium, copper and zinc concentrations exceeded chronic Colorado Table Value Standards (Figures 33 and 34)) in the Uncompahgre River downstream of the confluence of Oak Creek and at the Ouray USGS gage station from 1999 to 2006 despite the temporary dilution effect from Oak and Canyon Creeks. Lead concentrations exceeded the chronic Colorado Table Value Standard in 3% of the 144 total measurements at these two sample sites. Lead toxicity probably did not harm aquatic life in the mainstem Uncompahgre River from Oak Creek to the Ouray USGS gage station.

The median hazard quotient (HQ) was 2.8 in the Uncompahgre River (Table 10) downstream of Oak Creek (minimum 0.07, maximum 9.0, N = 43) and 2.6 in the

Uncompahgre River at the Ouray USGS gage (minimum 1.04, maximum 22.9, N =58), much lower than the median HQ of 19.7 found in the Uncompahgre River upstream of Canyon Creek[4]. Waters from both Canyon and Oak Creeks dilute the metal concentrations in the mainstem Uncompahgre River, attenuating contaminant impacts attributable to Red Mountain Creek.

HQs exceeding 1.0 indicate that the aquatic biota of a stream could be expected to exhibit indications of chronic toxicity. Thus metal toxicity of the Uncompahgre River from Oak Creek to the Ouray USGS gauge could induce toxic impacts on aquatic life. Most of the toxic units that comprise the combined HQ were attributable to cadmium, copper and zinc in the mainstem (Table 10).

Zinc concentrations met the recalculated zinc standard (See Appendix 1) in all 43 samples at the sampling site downstream of Oak Creek and in 97 of 98 samples collected at the Ouray USGS gage station. Zinc resistant species such as the brook and brown trout could maintain a population reduced in numbers if other contaminant loads were eliminated. However, zinc sensitive species such as the cutthroat and rainbow trout would not be expected to colonize this river segment (See Appendix 1). The Uncompahgre River mainstem from Oak Creek to the Ouray USGS gage was the first stream reach downstream of the Red Mountain Creek confluence where metal contamination (zinc and lead) was reduced to the point that metal tolerant trout species would be able to colonize the stream if other parameters were not toxic to trout.

The direct toxicity of cadmium to trout may be assessed using toxicity test data for brown trout. Cadmium concentrations of 1.83 ug/L and 6.5 ug/L did not induce a lethal response in brown trout in a 30-day laboratory study at hardness concentrations of 75 mg/L $CaCO_3$ and 150 mg/L $CaCO_3$, respectively. The maximum dissolved cadmium concentrations were less or equal to 1.83 ug/L in the Uncompahgre River (1.75 ug/L downstream of Oak Creek, N=43 and 1.89 ug/L at the Ouray USGS gage, N=49, excluding a concentration of 2.19 ug/L on 5/24/1999) while hardness concentrations generally exceeded 75 mg/L $CaCO_{3.}$ Cadmium would not be lethal to brown trout when hardness exceeded 75 mg/L $CaCO_3$ in the Uncompahgre River from a point just downstream of Oak Creek to the USGS gage in Ouray. In a similar fashion, dissolved cadmium concentrations in the Uncompahgre River downstream of Oak Creek were less than 1.0 ug/L when hardness concentrations were less than 75 mg/L $CaCO_3$ (N=1) and dissolved cadmium concentrations were less than 0.76 ug/L when hardness concentrations were less than 75 mg/L $CaCO_3$ (N=6) at the Ouray USGS station. Cadmium was likely not acutely lethal to brown trout in the Uncompahgre River from downstream of Oak Creek to the Ouray USGS station either in the spring snowmelt period when hardness concentrations were less than 75 mg/L as $CaCO_{3,}$ or in the remaining portions of the year when stream flow was relatively low and hardness concentrations exceeded 150 mg/L as $CaCO_3$. Cadmium may have induced nonlethal chronic toxic impacts but cadmium would not have eliminated brown trout from the mainstem Uncompahgre through the City of Ouray.

The direct toxicity of copper to trout can be assessed using toxicity test data for brook trout. A dissolved copper concentration of 29 ug/L induced 50% mortality to brook trout during 96-hour toxicity tests conducted at a mean hardness of 180 mg/L $CaCO_3$ (Besser *et al.*, 2001). Two of 11 dissolved copper concentrations at the Oak Creek site exceeded 29 ug/L when total hardness was less than 180 mg/L $CaCO_3$ in the Uncompahgre River downstream of Oak Creek in the months of November and December. At the Ouray

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[4] Note that one hazard quotient at this site in 1999 was 60 but was deleted from consideration as an outlier

USGS gage station, 3 of 32 dissolved copper concentrations exceeded 29 ug/L when total hardness was less than 180 mg/L $CaCO_3$ in April and May. Copper remains potentially lethal to brook trout in the mainstem Uncompahgre River from the Oak Creek confluence to the Ouray USGS station. Chronic impacts would be expected to trout species such as reduced growth, impaired reproduction and reduced numbers.

Total aluminum concentrations ranged from 23 ug/L to 3,988 ug/L (median = 1,500, N= 43) in the Uncompahgre River at the sample site downstream of the Oak Creek confluence. Total aluminum concentrations at the Ouray USGS gage station ranged from 1,336 ug/L to 8,275 ug/L (median = 3,347 ug/L, N=59). In general, the highest concentrations were measured in during the summer snowmelt period and early fall months. The lowest concentrations were found during the winter months of low base stream flows. Lower total aluminum concentrations measured downstream of Oak Creek compared to the Ouray USGS gage were attributable to dewatering by the hydro facility and dilution flows from Canyon and Oak Creeks.

Total aluminum concentrations exceeded applicable Colorado chronic Table Value standards in the Uncompahgre River from downstream of Oak Creek to the Ouray USGS gage station. About 68% (N=43) of the aluminum measurements at the sampling site downstream of Oak Creek exceeded the hardness based Colorado chronic stream standard that would be applied to the Uncompahgre River if the WQCC adopts standards for the basin. All of the total aluminum measurements at the Ouray USGS gage exceeded the applicable chronic standard.

Rainbow trout experienced mortality and various sub-lethal impacts during exposure to 530 ug/L total aluminum at pH levels from 7.0 to 8.5 in laboratory toxicity tests (Freeman and Everhart, 1971). Aluminum concentrations and pH levels in the Uncompahgre River in Ouray were similar to the Freeman and Everhart (1971) exposure conditions. A total of 29 of 43 total aluminum measurements collected downstream of Oak Creek and all 59 total aluminum measurements collected at the Ouray USGS gage station exceeded 530 ug/L. pH exceeded 7.0 in 55 samples (90%, N=61) in the Uncompahgre River downstream of Oak Creek and in 68 samples (87%, N=68) in the Uncompahgre River at the Ouray USGS gage station. The total aluminum and pH regime likely induced a lethal response in rainbow trout in the Uncompahgre River between Oak Creek and the Ouray USGS gage station.

The 50th percentiles of total iron were 1,619 ug/L downstream of Oak Creek (N=43) and 3,510 ug/L at the Ouray USGS gage (N=59). Total iron concentrations exceeded the site specific chronic iron standard of 1,500 ug/L adopted by the WQCC at both sites and current temporary modification of 1,673 ug/L at the Ouray USGS flow gage. The Uncompahgre River most likely met the temporary modified 1,673 ug/L chronic iron standard at the sample site downstream of Oak Creek due to dewatering of the mainstem and dilution flows from Canyon Creek and Oak Creek. Total iron concentrations exceeded all numeric values that could be or are applied to this stream reach as stream standards with the exception of the temporary modification applied to the Uncompahgre River in Ouray.

Iron is not normally present in lethal concentrations in Colorado mountain streams where pH regimes typically exceed 7.0 (see Appendix 1). Iron induced a lethal response (50% mortality) to brook trout in laboratory studies at a pH of 7 at a concentration of 1,750 ug/L (Decker and Menendez, 1974). Periodic total iron values above 1,750 ug/L with pH near 7 were measured in this segment of the Uncompahgre River. At a slightly higher pH (7.6), the total iron brown trout LC50 was to 28,000 ug/L at a hardness of 287 mg/L

$CaCO_3$ (Dalzell and Macfarlane, 2005). Total iron concentrations of this magnitude were not measured downstream of Oak Creek, but were detected on two occasions at the Ouray USGS gage station (27,790 ug/L at a pH of 7.6 on October 4, 2006 and 31,540 ug/L at a pH of 8.3 on July 29,2006). Total iron may directly induce acute short-term mortality to trout in some time periods in the Uncompahgre River, but iron precipitation on the stream substrate and perhaps fish gills may induce chronic toxic responses when total iron exceeds 1,000 ug/L.

Metal concentrations decreased in the Uncompahgre River from Oak Creek downstream to the Ouray USGS gauge in comparison to the Uncompahgre River upstream of Canyon Creek. The 85th percentile copper in the Uncompahgre River just upstream of Canyon creek was 112.9 ug/L (WQCD, 2009). In contrast, the 85th percentile of copper was 28.9 ug/L in the Uncompahgre River downstream of Oak Creek and 9.3 ug/L at the Ouray USGS gauge station. The 85th percentile cadmium in the Uncompahgre River just upstream of Canyon creek was 1.9 ug/L (WQCD, 2009). In contrast the 85th percentile of cadmium was 1.09 downstream of Oak Creek and 1.26 ug/L at the Ouray USGS gauge station. The decrease in metals was attributable to dilution effects of tributaries such as Oak Creek and Canyon Creek.

Nutrient data were limited for the Uncompahgre from Canyon Creek to the Ouray USGS flow gage. Ammonia concentrations were generally less than detection limits and nitrate/nitrite concentrations ranged from below detection limits to 0.21 mg/L (N=15). Nitrate as N ranged from 0.16 to 0.16 in the Uncompahgre River downstream of Oak Creek and from 0.12 to .0.21 in the Uncompahgre River at the Ouray USGS gauge site. Total phosphorus as P ranged from 12 ug/L to 78 ug/L below Oak Creek (River Watch data N = 6) and from less than detection limits to 0.66 ug/L at the Ouray USGS gauge site. The natural loadings in western forested mountain systems are 130 ug/L total nitrogen and 20 ug/L total phosphorus (Smith *et al*., 2003). Total nitrogen and total phosphorus levels exceeded the natural background loadings expected in uncontaminated mountain waters on most sample events. Sources of nitrogen and phosphorus are not known but include urban runoff from the streets of Ouray and possibly failed septic systems.

6.6.2 Summary Uncompahgre River in Ouray

Metals loading from Red Mountain Creek continued to impair water quality in this segment. Metal concentrations were often higher at the Ouray USGS gage station at the downstream end of this segment compared to the site near Oak Creek due to the operation of the Ouray Hydropower Station. The hydropower station removes water from the Uncompahgre River above Canyon Creek and then returns the same water with the same metal loading upstream of the sampling site at the USGS gage in Ouray. Water quality data from the Ouray USGS gage station provides a more accurate description of the water quality regime in this stream reach than data collected at a site downstream of Oak Creek.

Flows from both Oak and Canyon Creeks provide dilution water and increased hardness while pH levels and total alkalinity levels reduce the relative toxicity of the metals in the mainstem Uncompahgre River. Aluminum, cadmium, copper, zinc and iron would be expected to reduce the diversity and numbers of aquatic organisms in the Uncompahgre River from the Oak Creek confluence to the USGS gage station in Ouray despite the dilution effects of Canyon Creek and Oak Creek. Lead concentrations rarely exceed Colorado Table Value levels. Cadmium and zinc concentrations may reduce brown and brook trout numbers and growth but would not eliminate all brook trout and brown trout from the Uncompahgre River through Ouray. Copper, iron and aluminum concentrations would either be acutely or chronically toxic, reducing both numbers and kinds of species present. Despite the dilution from Canyon and Oak Creeks, the Uncompahgre River mainstem is not likely to support aquatic life from the Oak Creek confluence to the Ouray USGS gage station.

Summary: Uncompahgre River in Ouray

1. Uncompahgre River in Ouray, from Canyon Creek to the Ouray USGS Station is a short stream reach where impacts of the Red Mountain Creek Basin first begin to ameliorate. Flows from Canyon Creek and Oak Creek dilute the Uncompahgre as the river flows through Ouray.
2. Zinc and lead concentrations decreased to levels where tolerant species could inhabit this stream reach. Other metals such as cadmium, copper, iron and aluminum remained at lethal concentrations.
3. The Uncompahgre River mainstem is not likely to support aquatic life from the Oak Creek confluence to the Ouray USGS gage station.
4. Operation of the Ouray Hydropower Plant influences the water quality of the Uncompahgre River from Canyon Creek to the Ouray USGS gage station. Metal laden water diverted to power the turbines often resulted in temporarily lower metal concentrations at the sample site downstream of Oak Creek compared to the sample site at the Ouray USGS flow gage, an indication of a nonexistent point source of metals.

6.7 Uncompahgre River from Ouray to Ridgway

Below the City of Ouray, the Uncompahgre River continues to flow north through a narrow canyon to the Town of Ridgway. This river reach is included in Uncompahgre River Segment UN03a.

WBID	UN03a	
Description	Mainstem of Uncompahgre River from a point immediately above the confluence with Red Mountain Creek to the Highway 90 Bridge at Montrose	
Use Classification	Aq Life Cold 1, Recreation E, Water Supply, Agriculture	
Meets Standards?	**Section not attaining chronic standards**	**Parameters not meeting standards**
no	Ouray to Ridgway Reservoir	Cd, Total Fe

The Water Quality Control Commission (WQCC) has adopted temporary modifications for chronic cadmium (1.1 ug/L) and total iron (1,673 ug/L) for segment UN03a. These temporary modifications are used as stream standards until December 31, 2012. This segment of the river is also included in the Red Mountain TMDL targets for cadmium, copper and iron (WQCD, 2009).

River Watch volunteers sampled three locations utilized in this analysis on the mainstem Uncompahgre River from Ouray to Ridgway (Ouray School, Arlene Crawford, Eric and Ethan Funk) between 2002 and 2009. The three River Watch sites are:

1. The Uncompahgre River downstream of Ouray at County Road 23 (Site 3583)
2. The Uncompahgre River at Potter Ranch (Site 392)
3. The Uncompahgre River upstream of Ridgway Reservoir at County Road 24 (Site 395).

The USGS operates a flow gage (9146200) upstream of Ridgway Reservoir at a site corresponding to the Site 395 sampled by River Watch. USGS generated flow information utilized to calculate loads. The Colorado Water Quality Control Division (WQCD) maintains a long-term monitoring site on the mainstem Uncompahgre River in Ridgway (Site 79). Data were available for Site 79 from 1973 through 2008. The WQCD data were assessed to determine temporal change in suspended solids, nutrients, metals and bacterial levels (*E. coli*) at this location from the 1970s through 2008.

The presence of a naturally reproducing trout fishery would be desirable in the Uncompahgre River from Ouray to Ridgway Reservoir. Trout are absent from most of this stream reach. Brown trout are seasonally present in the Uncompahgre River from inlet of Ridgway Reservoir upstream to the Town of Ridgway. The public has often attributed to the absence of trout in the Uncompahgre River to metals contamination from Red Mountain Creek. However, another possible source of contamination may be sedimentation in the Uncompahgre River from Ouray to Ridgway Reservoir. The following discussion of Uncompahgre River water quality is focused on water quality conditions that would allow presence of naturally reproducing populations of brook trout or brown trout. Brook trout and brown trout are two salmonids species relatively tolerant of metal concentrations.

6.7.1 Water Quality

The pH of the mainstem Uncompahgre River was slightly basic from Ouray to Ridgway Reservoir, based on River Watch data from 2002 to 2008. No individual pH measurement was less than 7.08 at any of the three sampling locations. The pH became increasingly basic downstream. Median pH increased from 7.98 at Ouray to 8.33 at the USGS gage upstream of Ridgway Reservoir. The increase of pH in the Uncompahgre River near Ridgway Reservoir may actually increase the potential for aluminum toxicity. Aluminum toxicity increases between pH 8.5 and 9 (Appendix 1).

Hardness concentrations did not vary significantly in the mainstem Uncompahgre River between Ouray and Ridgway Reservoir. The median hardness was 256 mg/L as $CaCO_3$ (N=42) below Ouray at County Road 23 (Site 3583), 224 mg/L as $CaCO_3$ at Potter Ranch between Ouray and Ridgway (N=45), and 290 mg/L as $CaCO_3$ (N=121) upstream of Ridgway Reservoir. Seasonal variations were observed however, with total hardness concentrations less than 100 mg/L as $CaCO_3$ during spring runoff in May and June. In the rest of the year, hardness in the Uncompahgre River from Ouray to Ridgway was relatively high with maximum measurements near 400 mg/L $CaCO_3$.

Dissolved cadmium, copper, lead and zinc concentrations continued to decrease in the mainstem Uncompahgre as the river flowed from Ouray to Ridgway Reservoir. The median cadmium decreased from 0.74 ug/L to 0.31 ug/L and median zinc levels decreased from 60 ug/L to 21 ug/L. Lead was less than detection limits in over 90% of the samples collected at all three sites. The trend of decreased metal concentrations was due to two possibilities. First, the concentrations decreased due to dilution as uncontaminated tributaries entered the Uncompahgre River, including Cascade, Cutler and Dexter Creeks. Second, metals were removed form the water column, either by sorbing onto substrate or precipitating from solution and settling onto the stream substrate level.

Monthly metal concentrations (ug/L) were compared to flow (cfs) using River Watch metals data to determine if dilution alone reduced metal concentration or if precipitation and sorption to the sediment were responsible for decreasing metal concentrations in the Uncompahgre River at the USGS gage station in Ouray compared to the USGS Station above Ridgway Reservoir. Neither total iron nor the dissolved fractions of cadmium, lead and zinc varied with flow. Dissolved copper increased slightly with flow at the sample site upstream of Ridgway Reservoir. Total aluminum was negatively correlated to flow in Ouray at the Ouray USGS sampling site, but positively correlated to flow near Ridgway Reservoir (Figures 35 and 36), although the relationship at the Ouray USGS gage was somewhat tenuous. The seasonal trends of total aluminum suggested that aluminum settles out of solution during winter base flow periods and is re-suspended and transported downstream during spring high flow events (Figure 38). The Uncompahgre River acted as a sink for aluminum in periods of low flow and a source during periods of high flow a different pattern than observed for other metals.

The number of cadmium, copper, lead and zinc measurements exceeding chronic Colorado Table Value Stream Standards decreased downstream from Ouray to Ridgway Reservoir (Table 11). Cadmium exceeded chronic Colorado Table Value Stream Standards in 46% of the samples collected from 2002 through 2007 (N=41) in Ouray and only 3% of the samples collected upstream of Ridgway Reservoir (N=35). Similar reductions in copper, lead and zinc concentrations were also observed. Decreasing metal concentrations, increasing hardness measurements and dilution water from uncontaminated tributaries were all causes of the reduced number of violations of chronic Colorado Table Value Standards.

The WQCC adopted a temporary modification to the chronic cadmium standard for the segment UN03a. The temporary chronic cadmium standard is 1.1 ug/L for this segment. The 85th percentile of cadmium at all three sampling sites was less than 1.1 ug/L. The current temporary modification for cadmium is not appropriate for the Uncompahgre River from Ouray to Ridgway Reservoir and should be eliminate perhaps by re-segmentation of existing segment 3a.

The number of samples with hazard quotient (HQ) calculations exceeding a level of 1.0 also decreased as the Uncompahgre River flowed from Ouray to Ridgway Reservoir (Table 11). The median HQ decreased from 1.4 at the sampling site north of Ouray to 0.61 at the site upstream of Ridgway Reservoir. The number of HQs exceeding 1.0 decreased from 33 (80% of the samples) at the site north of Ouray to 7 (17.5% of the samples) at the site upstream of Ridgway Reservoir. A HQ less than 1.0 indicates that the aquatic biota of a stream would not exhibit indications of chronic toxicity due to the additive interaction of these four metals. The concentrations of cadmium, copper, lead and zinc, in combination or singly, upstream of Ridgway Reservoir would not have induced a lethal response in all aquatic life although sensitive aquatic species would be expected to exhibit effects of toxicity due to these four metals. The cadmium, copper, lead and zinc regime of the Uncompahgre River would support a trout fishery in the Town of Ridgway.

Cadmium, copper, lead and zinc concentrations between Ouray and Ridgway Reservoir were not at levels associated with toxicity to aquatic macroinvertebrates or fish. The 85th percentile of dissolved zinc concentrations measured in the Uncompahgre River upstream of Ridgway Reservoir was 18 ug/L from 2002 through 2006. This zinc concentration is a decimal point lower than dissolved zinc levels in Clear Creek and the Eagle River (Woodling and Rollings, 2008a). Both the Eagle River and Clear Creek support brown trout populations in stream reaches where zinc levels are a decimal point higher the Uncompahgre River in Ridgway.

The 50th percentiles of total iron were 2,675 ug/L, 2,097 ug/L and 1,554 ug/L respectively at the three sampling sites from Ouray to Ridgway Reservoir. Total iron concentrations exceeded the site specific chronic iron standard of 1,500 ug/L at all three sampling sites from County Road 23 north of Ouray to County Road 24 upstream of Ridgway Reservoir. The total iron concentrations also exceeded the temporary modification of 1,673 ug/L at two sites, County Road 23 north of Ouray and at Potter Ranch upstream of the Town of Ridgway. The Uncompahgre River met the total iron temporary modification of 1,673 ug/L at the sample site upstream of Ridgway Reservoir. Total iron concentrations exceeded all numeric values applicable to this stream reach except the temporary modification at the Uncompahgre River sampling site upstream of Ridgway Reservoir.

The iron in the stream reach from north of Ouray downstream to Ridgway Reservoir was present in the suspended not the dissolved form due to basic pH conditions. Iron present in the suspended form precipitates to the substrate, covering rocks on the stream substrate and filling the interstitial spaces that provide habitat for aquatic macroinvertebrates. Iron may be a limiting factor in this stream reach due to physical effects, not a physiologic impact.

Total aluminum concentrations decreased as the Uncompahgre River flowed from Ouray towards Ridgway Reservoir. The median total aluminum decreased from 2,741 ug/L north of Ouray to 1,657 ug/L at the sampling site upstream of Ridgway. Total aluminum concentrations exceeded the applicable chronic Table Value Standard that would be applied to the stream reach if the Colorado Water Quality Control Commission adopts aluminum standards for the Uncompahgre River Basin (Figures 38-40).

Aluminum toxicity to trout in alkaline waters is a complex issue (Appendix 1). Exposure to 530 ug/L of total aluminum at pH 7.0 to 8.0 induced mortality and various sub lethal impacts to rainbow trout in laboratory studies (Freeman and Everhart, 1971). The total aluminum concentrations in the Uncompahgre River exceeded by a decimal point the levels found to be lethal to rainbow trout at the pH regime present in the Uncompahgre River. Associated pH values ranged from 7.08 to 8.8 at the three locations. The pH and total aluminum concentrations were present in a combination where lethal impacts to trout could be an expected outcome. However, increasing hardness may have mitigated aluminum toxicity (Appendix 1). Aluminum chemistry in water is complicated and chemical reactions involving aluminum may take a rather long time to reach equilibrium, so predictions of toxicity or lack thereof are difficult to reach. Aluminum may be a water quality factor limiting trout colonization of the section of the Uncompahgre River from Ouray downstream to Ridgway Reservoir.

Suspended solids data were available from samples collected from 1969 to 2007 (N=156) at Site 79. The median of the suspended solids data was 24 mg/L with a range of below detection limits to 1,490 mg/L. Five measurements were greater than 400 mg/L, two of which were collected in April and June of 1984, a high runoff year and the other three, collected in July and August, may have been an artifact associated with a summer spate. Aquatic life in the mainstem Uncompahgre River do not appear to be exposed to suspended solids levels that could be considered detrimental to trout (Appendix 1). The median suspended solids concentration was a decimal point lower than 270 mg/L that resulted in 80% mortality to sub-adult rainbow trout after a 19-day exposure (Herbert and Merkens 1961).

The low water column suspended solids measurements are not an indicator of the sediment regime in the Uncompahgre River from Ouray to Ridgway Reservoir. The substrate of the Uncompahgre River from Ouray downstream to Ridgway Reservoir is covered with fine sediments, gray and black in color. Composition of these sediments is not known but will include both aluminum and iron depositions. These sediments fill the interstitial spaces between the rock cobbles on the stream bottom. Backwaters and eddies are often filled with these fines to a depth of several inches. The habitat needed by aquatic macroinvertebrates has been eliminated. The space needed by trout eggs and fry is filled with these sediments. Sediment levels in the mainstem Uncompahgre River are adequate to limit or even eliminate aquatic life even if the river met chronic Colorado metal Table Value Standards.

The source of these sediments is not apparent from the existing water quality database and routine sampling does not appear to have captured the potential short-term increases in sediments due to sudden summer spates and storms. Elevated stream flows and movement of the fine sediment bed load associated with intense summer rain events is one source of these fine sediments. A flashflood resulted from an extensive summer spate on July 27, 2010 (Melinda May, WQCD, personal communication). Rainfall in Sky Rocket Gulch basin resulted in a flashflood in that basin. The water level in the Uncompahgre River increased visibly and stream flow turned black with suspended sediments (photo). This small flood event moved fine black sediments into the mainstem Uncompahgre River. Similar sediment deposits were observed in the lower portions of Canyon Creek (See Section 6.4). Additional information concerning the bed load of the Uncompahgre River Basin is needed to assess influence of suspended solids on the designated uses of the river as assigned by the WQCC.

Fine sediment from Sky Rocket Gulch blanket the Uncompahgre River below Ouray after a summer flood event on July 27, 2010.

Nitrate nitrogen as N concentrations ranged from below detection limits to 310 mg/L (median = 200 ug/L, N=136, 85th percentile = 200 ug/L) at the WQCD Site 79 site from 1969 to 2007. Fourteen of the 136 nitrate-nitrogen concentrations exceeded 130 ug/L, the level considered background in western forested mountain streams (Smith *et al*., 2003). Overall nitrogen loading to the Uncompahgre River was still similar to the natural loading in western forested mountain systems despite return flows from irrigated lands bordering the river and the effluent from the domestic wastewater treatment plants.

The median total phosphorus concentration was 76 ug/L at Site 79 in Ridgway (maximum 1,200 ug/L as P, N=151). Four measurements exceeded 1,000 ug/L as P. A stream phosphorus standard has not yet been adopted in Colorado, but total phosphorus greater than 4 ug/L can result in eutrophication[5] in lakes. The total phosphorus concentrations would support extensive algal and plant growth in an impoundment or a stream reach where water velocities are reduced in period of low stream flow. Total phosphorus concentrations entering Ridgway reservoir would be expected to result in some eutrophication of the impoundment.

The median *E. coli* at Ridgway was 34.5 colonies/100 ml (N=24 from 2001-2007) (WQCD, Site 79). The maximum was 179 colonies /100 ml, with a geometric mean of 27 colonies/100 ml. The Uncompahgre River met the chronic Colorado Table Value Standard for *E. coli* (geometric mean of 126 colonies/100 ml). Human related actions such as domestic wastewater treatment plant effluents, urban storm water runoff and irrigation return flows can increase bacteria levels in rivers. Two domestic wastewater treatment plants discharge to the Uncompahgre River between Ouray and Ridgway Reservoir. These treatment plans did not appear to increase bacteria levels in the Uncompahgre River to a point that would be considered a human health concern.

6.7.2 Aquatic Life

Water quality improved as the Uncompahgre River flowed from Ouray towards Ridgway Reservoir. Metals concentrations were low enough that cadmium, copper, lead and zinc would probably not have induced a lethal response in many forms of aquatic life. However, the trout population in the Uncompahgre River remains depleted with a “seasonal fishery” present (Dan Kowlaski, Division of Wildlife, verbal communication) in the river upstream of Ridgway Reservoir. Adult brown trout are known to move upstream from Ridgway Reservoir to spawn, but a self-maintaining population has become established. The status of the aquatic life community in the Uncompahgre River is not well documented.

A total of 41 fish were collected 2.5 miles downstream of Ridgway in 1966 including sculpin, dace and two species of sucker (Federal Water Pollution Control Administration, 1968). Trout were not taken in 1966. The presence of sculpin and absence of trout may be an indicator the level of metal contamination in 1966. Sculpin are more sensitive to zinc than brown trout and brook trout (Appendix 1). Conversely brook trout and brown trout may well be more sensitive to copper than sculpin. The presence of sculpin and absence of trout in 1966 may be an indication that copper was a more significant pollutant in the Uncompahgre River than zinc in 1966, a condition that continues to 2011.

Sculpin, dace and suckers have not been reported from the Uncompahgre River 2.5 miles north of Ridgway since 1966. Environmental conditions may have degraded even

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[5] Eutrophication is the process whereby receiving waters become hyper-enriched by nutrient inputs, resulting in excessive plant growth and oxygen depletion

further in the Uncompahgre River downstream of Ridgway since 1966 as indicated by the absence of fish 2011.

Aquatic macroinvertebrate studies were sampled in the Uncompahgre River just upstream of Ridgway Reservoir in 1966, 1975 and 2009. In 1966, In 1966, only eight species of macroinvertebrates were collected at Ridgway (Federal Water Pollution Control Administration, 1968). The taxa collected included three species of mayfly (including the genus Baetis) and the caddisfly, Arctopsyche grandis. In 1975, eight taxa were collected, two mayfly genera, one caddisfly genus (*Brachycentrus*) and five midge genera at the same Ridgway site (Four Corners Environmental Research Institute, 1976). In 2009, nine taxa were collected, including two mayflies and five Dipteran taxa (Colorado Division of Wildlife sampling, Appendix 1). The two most numerous taxa were the mayfly genus *Baetis* and the caddis fly *Arctopsyche grandis*. *A. grandis* and *Baetis* are metals tolerant and have been collected in Eagle River and Clear Creek in stream reached with elevated metals (Woodling and Rollings 2008a, 2008b). Stoneflies, which are sensitive to many forms of pollution, were not found in the 1966, 1975 or 2009.

The macroinvertebrate samples taken in 1966 and 1975 were collected in July and August while the 2009 sample was taken in April. Direct comparison of 1966 and 1975 data with the 2009 results requires some caution. More aquatic macroinvertebrate species are present in April than in July compared to August in many Colorado streams. Species richness, however, was low in all three samples. An unimpaired mountain stream in Colorado would be expected to support between 25 and 50 aquatic macroinvertebrate taxa far more than the numbers collected in the Uncompahgre River upstream of Ridgway reservoir. The low species richness and low numbers of organisms collected in both studies indicated a seriously limited aquatic community. Absence of fish, absence of pollution sensitive stoneflies and low numbers of aquatic macroinvertebrates all indicate a degraded river even though metal concentrations would be expected to support a diverse aquatic life assemblage.

One possible reason for the limited aquatic community is the physical impairment caused by extreme sedimentation. The substrate of the Uncompahgre River from Ouray downstream to Ridgway Reservoir is covered with fine sediments, black in color. Sediments have “cemented” in the cobble on the stream bottom. The depth of the fines ranges from many inches to a foot or more. Fine sediments and the precipitating iron and aluminum, filled the interstitial spaces between river cobble eliminating habitat required by aquatic macroinvertebrates and developing trout eggs. Both total iron and total aluminum concentrations exceeded applicable Colorado Table Value Standards. Loss of habitat is one cause of the reduced aquatic macroinvertebrate assemblage present in the Uncompahgre River upstream of Ridgway Reservoir other than direct toxicity.

Episodic summer storm events may introduce more than suspended solids to the mainstem Uncompahgre River. Metal concentrations increased in the Arkansas River and Clear Creek in mining areas during summer rainstorms (Woodling 1993). The increased metals concentrations can be of more than two orders of magnitude. The same type of event probably exists in the Uncompahgre River basin. Such episodic events may well increase metal concentrations to lethal levels. A storm event sampling program is needed to determine the extent of metals increases associated with severe summer spates and storms in the mainstem Uncompahgre River from Ouray to Ridgway Reservoir.

6.7.3 Summary Uncompahgre River from Ouray to Ridgway

The water quality regime in the Uncompahgre River from Ouray to Ridgway Reservoir is dynamic. Metals such as copper, lead and zinc, normally associated with Colorado’s metal contaminated streams, decreased to concentrations lower than chronic Colorado Table Value Standards in most samples at the downstream end of the reach. Cadmium concentrations exceeded Colorado chronic stream standards near Ouray, but not at Ridgway Reservoir. Total aluminum and iron concentrations exceeded various stream standards throughout this stream reach and may have been toxic to trout. Aluminum deposited on the stream substrate during periods of low flow in the stream reach downstream of Ouray appeared to re-suspend and flow towards Ridgway Reservoir during periods of elevated stream flows in the months of May and June each year.

The aquatic community in this Uncompahgre River from Ouray to Ridgway is impaired. The number of aquatic macroinvertebrate taxa present upstream of Ridgway Reservoir was lower than most Colorado mountain streams. The fishery in the Uncompahgre River at Ridgway is “seasonal” (Dan Kowalski, Colorado Division of Wildlife, personal communication) with no fish present upstream of the Town of Ridgway. The cause of the limited aquatic assemblage was not readily apparent, but may attributable to the physical effects of excessive sedimentation as opposed to direct metals toxicity. Cadmium, copper, lead, and zinc concentrations seldom exceeded levels toxic to aquatic life, although aluminum and iron exceeded levels known to result in toxic impacts to aquatic life. The substrate of the Uncompahgre River in this section of the River was smothered with fine sediment as well as iron and aluminum precipitation. Source of the fine sediments in the mainstem Uncompahgre River from Ouray to Ridgway Reservoir was not known but may be associated with an episodic storm events more than annual water level cycles in the mainstem Uncompahgre River Basin upstream of Ridgway Reservoir. Sampling is needed to determine how these fines move within the basin.

Summary: Uncompahgre River, Ouray to Ridgway

1. The water quality of the Uncompahgre River improved as the River flows north from Ouray to Ridgway Reservoir.
2. Metals such as cadmium, copper, lead and zinc were often lower than chronic Table Value Standards.
3. Total aluminum and iron exceeded applicable stream standards at a sampling point upstream of Ridgway Reservoir.
4. Perhaps the most interesting observation concerning metals was that the mainstem Uncompahgre River in Ouray was a sink for aluminum during periods of low stream flow but acted as a source of the metal during spring high flow periods a phenomenon was not observed for any other metal.
5. Aquatic life including trout of the Uncompahgre River remained extremely limited in numbers and variety despite the decreases in cadmium, copper, lead and zinc.
6. The impacts to aquatic life may attributable other water quality issues such as stream sediments as well as metals in the water column.
7. Episodic contamination attributable to summer storm events may also be an issue in this section of the Uncompahgre River but that assertion would have to be supported by a sampling program.

6.8 Tributaries to Uncompahgre River from Ouray to Ridgway Reservoir

Many tributaries enter the Uncompahgre River between Ouray and Ridgway Reservoir. Some of the tributaries contain trout populations such as Dexter Creek and Cutler Creek (Dan Kowalski, personal communication). Dallas Creek, a relatively large tributary enters the Uncompahgre River at Ridgway Reservoir. Dallas Creek also supports a reproducing trout population.

WBID	UN10	
Description	All tributaries to the Uncompahgre River, including all wetlands, lakes and reservoirs, from a point immediately below the confluence with Dexter Creek to the South Canal near Uncompahgre, except for specific listings in Segments 1 and 11.	
Use Classification	Aq Life Cold 2, Water Supply, Agriculture: Nov 1 - April 30 Recreation N: May 1 - Oct 31, Recreation P	
Meets Standards?	**Section not attaining chronic standards**	**Parameters not meeting standards**
No *	Cow and Dallas Creeks	Phosphorus
* The State has not adopted a phosphorus standard. However, the phosphorus detected in Cow and Dallas Creeks exceeded levels known to cause eutrophication in lakes.		

Water quality data for these tributaries were rather sparse. The Colorado Water Quality Control Division sampled many of these tributaries on at least one occasion in the past decades. Raw data collected by the Water Quality Control Division may be accessed at www.epa.gov/storet.

In general, water quality in these streams was of high quality and better than applicable stream standards. The streams were typical of most Colorado high elevation waters. Dilution flow from these tributaries provided dilution flows that attenuated metal concentrations in the mainstem Uncompahgre River.

Two water quality parameters were of interest in the tributaries to the Uncompahgre River from Ouray to Ridgway Reservoir: aluminum and phosphorus. Total aluminum concentrations in Cow Creek and Dallas Creek exceeded the chronic Colorado Table Value Standard after a high flow event on April 28, 1998. Phosphorus concentrations in Cow Creek and Dallas Creek were greater than 20 ug/L, the level considered background in forested mountain streams by Smith *et al*. (2003). The 85th percentile of the phosphate as P data was 82 ug/L as P in Cow Creek and 130 ug/L as P in Dallas Creek, N= 5 and N= 12, respectively. The water quality of both Cow Creek and Dallas Creek appeared to be influenced to an observable degree by anthropogenic activities possibly related to agricultural endeavors. However, these stream reaches met applicable water quality standards and designated uses.

All tributaries in segment UN10 are have a class 2 cold water aquatic life use designation. The application of a class 2 coldwater designation is not appropriate for many streams in segment UN10 including Dexter Creek and Cutler Creek. A coldwater class 1 designation appears to be warranted. Thousands of headwater streams throughout Colorado are designated as class 1 aquatic life systems where no data are available that describe either water quality or aquatic life. In addition thousands of headwater streams that do not support trout are designated as cold water class 1 aquatic life systems.

Summary: Tributaries between Ouray and Ridgway Reservoir

1. Some of the tributaries, such as Dexter Creek and Cutler Creek contain trout populations.
2. Tributaries did not exceed applicable water quality standards.
3. Cow and Dallas Creek exceeded Aluminum and Phosphorus standards that could be applied to segment.
4. A proposal to upgrade many streams in segment UN10 to a cold water class 1 stream is warranted since existing water quality is better than the chronic Table Value Standards adopted by the Water Quality Control Commission

6.9 Uncompahgre River: Upstream and Downstream of Ridgway Reservoir

Ridgway Reservoir is a mainstem impoundment of the Uncompahgre River downstream of Dallas Creek. Constructed in the 1987 by the Bureau of Reclamation, the project purpose is to increase irrigation, municipal, and industrial water supplies, and to provide flood control. Initial water storage began in about 1987. The reservoir was first filled in 1990.

WBID	UN03a	
Description	Mainstem of Uncompahgre River from a point immediately above the confluence with Red Mountain Creek to the Highway 90 Bridge at Montrose	
Use Classification	Aq Life Cold 1, Recreation E, Water Supply, Agriculture	
Meets Standards?	**Section not attaining chronic standards**	**Parameters not meeting standards**
yes	n/a	n/a

On-channel reservoirs like Ridgway Reservoir influence water quality of a system by acting as a contaminant source or sink. A reservoir can act as a sink if more of a contaminant remains in the impoundment than is released. Contaminants remain in the system if material precipitates out of solution and settle to the bottom of the reservoir. A reservoir acts as a source if the contaminant is later re-suspended and released from the impoundment. Metals may re-suspend in waters at the bottom of Reservoirs during periods of stratification and diminished oxygen content. A bottom release could result in an increase in metals downstream of the Reservoir during periods of stratification. Ridgway Reservoir does stratify, but the soils and river sediments on the bottom of the reservoir will release only small amounts of metals to the hypolimnetic waters on the reservoir bottom during periods of oxygen depletion (Craft and Miller 2001). The bottom release from the Ridgway Reservoir is at least 45 feet above the streambed at the dam (Mike Berry personal communication). No evidence exists demonstrating that the reservoir stratification is strong enough or lasts long enough for these re-suspended metals to reach the release structure. Metals settling or precipitating to the bottom of Ridgway Reservoir appear to be retained within the impoundment for many years.

A mass balance of metals loading was performed to determine if Ridgway Reservoir is a source or sink for metals to the Uncompahgre River. Metal loading is determined by using both flow rate and contaminant concentration and is expressed as pounds per day of contaminant. Metal loads were determined by multiplying the flow (cfs) by the metal concentration (mg/L) and a correction factor (5.39) to determine pounds per day (see section 4.2). Daily metal loads entering and leaving Ridgway Reservoir were determined using River Watch metals data and USGS flow data for sampling events where water samples were collected upstream (Gage 09146200) and downstream (Gage 09147025) of Ridgway Reservoir on the same day for the period of record 2002-2006. River Watch sampling sites are generally located adjacent to the USGS gage sample sites so flow data can be paired with water quality data.

6.9.1 Water Quality

Ridgway Reservoir acted as a significant metals sink in the Uncompahgre River using data only from the actual dates samples were collected. A notable decrease in metals load and improvement in water quality was determined in the mainstem Uncompahgre River downstream of Ridgway Reservoir. A total of 114,942 pounds of aluminum entered Ridgway Reservoir on just the 41 days when samples were collected both upstream and downstream of the Reservoir from 2002 to 2006 (Table 12). In contrast only 10,896 pounds of aluminum exited the Reservoir on the same 41 days, a 90.5% reduction. Ninety-six percent of the total iron that entered Ridgway Reservoir was retained within the impoundment in the same 41 days. The amounts of cadmium, copper, lead and zinc stored in the Reservoir ranged from 89% (zinc) to 94% (cadmium).

Annual metal loads were estimated above and below Ridgway Reservoir using River Watch metals data and USGS flow data collected at the same two locations described in the preceding paragraph. Metals loads were determined using data when samples were collected both above and below the Reservoir on the same day (see Section 4.2). The estimated annual total aluminum and total iron loading into Ridgway Reservoir exceeded 2.9 million pounds per year (Table 13). Smaller amounts of cadmium, copper, lead and zinc were retained within Ridgway Reservoir on an annual basis. Annual loading of cadmium was 12.6 pounds, a rather insignificant amount that illustrates the relative toxicity of this element where parts per billion are toxic to trout (See Appendix 1). More than 99% of the metals introduced to the Reservoir were retained in the Reservoir (Table 13). Actions within Ridgway Reservoir remove nearly 3 million of pounds of metals annually from the Uncompahgre River, resulting in a notable improvement of water quality downstream of the reservoir. The role of Ridgway Reservoir as a metal sink has also been documented by Carter and Burgess (2007).

Metal concentrations vary seasonally in rivers that drain from Colorado Mountains. Concentrations are typically low in the spring due dilution water provided by melting snow and high in the winter due to low base river flows. Metal concentrations leaving Ridgway Reservoir did not exhibit seasonal variation as illustrated by annual total aluminum regime. Examination of information for other metals demonstrated the same absence of seasonal variation. The metal regime in the Uncompahgre River downstream of the reservoir was based on chemical and physical actions within the Reservoir, not seasonal changes in the amount of water leaving the reservoir as demonstrated by the lack of seasonal change in metal concentrations in the river downstream of the dam.

Metal concentrations downstream of Ridgway Reservoir were less than chronic Colorado Table Value standards with one exception, a total iron measurement of 2,159 ug/L on March 9, 2004. The total iron measurement exceeded the chronic Colorado Table Value Standard, the current site-specific total iron standard and the temporary modification currently adopted by the WQCC. The median total aluminum concentration was 99.5 ug/L for the period of record (February 2002 through November 2007), while median cadmium, copper, lead and zinc concentrations were below the detection limits. Ridgway Reservoir did not act as a metal source to the Uncompahgre River Basin downstream of the impoundment except potentially for iron on an infrequent basis such as on March 9, 2004. Instead the water leaving Ridgway Reservoir was of relatively high quality and met all applicable Colorado Table Value Standards for metals.

Freeman and Everhart (1971) suggested that total aluminum concentrations less than 100 ug/L would support trout populations in a wide variety of streams and rivers. Half of the Uncompahgre River total aluminum measurements exceeded 100 ug/L. Aluminum toxicity is typically not a concern in Colorado mountain streams with metal regimes similar to the Uncompahgre River downstream of Ridgway Reservoir where both pH and hardness are relatively high (see Appendix 1). Total aluminum concentrations may exert some form of toxicity on aquatic life downstream of the reservoir but presence of other limiting factors may be more likely.

Ridgway Reservoir also acts a nutrient sink. Craft and Miller (2001) measured a 38% decrease in nitrogen loading and a 77% decrease in total phosphorus downstream compared to upstream conditions. The Uncompahgre River is a dynamically different river downstream of Ridgway Reservoir with relatively uncontaminated waters low in metals and nutrients.

6.9.2 Aquatic Life

The highest biomass of riverine trout in the Uncompahgre River is located downstream of Ridgway Reservoir. Trout biomass ranged from 40 pounds/acre to 60 pounds/acre at Pa-Co-Chu-Puk (Dan Kowalski, Division of Wildlife, personal communication), levels that are lower than many other Colorado rivers where hundreds of pounds of trout per acre are present. This brown trout fishery would not be present if the dam were not in place. Cadmium, copper, lead, and zinc concentrations were less downstream of Ridgway Reservoir than concentrations found in sections of Clear Creek and the Eagle River contaminated by metals. However, brown trout population estimates were higher in mine-impacted portions of Clear Creek and the Eagle River Reservoir (Woodling and Rollings, 2008a and Woodling and Rollings, 2008b) than in the Uncompahgre River downstream of Ridgway Reservoir. Thus, the metal regime of the Uncompahgre River downstream of Ridgway Reservoir did not seem to be a cause of relatively low numbers of brown trout. Two other factors that could limit the trout fishery downstream of the reservoir include gas bubble trauma and low winter flows.

Fifty percent to 60% of the fish present exhibit “severe gas bubble trauma” (Dan Kowalski, personal communication). Gas bubble trauma is similar to the “bends” experienced by divers. Water released from the bottom of Ridgway Reservoir is often super-saturated with nitrogen gas. Gas levels can quickly equalize to non-toxic levels within a short distance downstream of dams. However, fish in the reach downstream of the dam are exposed to nitrogen super-saturated water and can exhibit signs of gas bubble trauma. Gas bubble trauma seems to decrease when the amount of water released from the dam are increased (Dan Kowalski, personal communication).

The aquatic macroinvertebrate community in the Uncompahgre River downstream of Ridgway Reservoir was been sampled in 1966, 1976 and 2009. The 1966 and 1976 studies represent conditions prior to the construction of Ridgway Reservoir. In 1966, ten taxa including two mayfly species were collected (Federal Water Pollution Control Administration, 1968), including three mayfly taxa and three caddisfly taxa. Three mayfly genera and two caddis fly genera were collected along with 7 other taxa at the same sampling site in 1975 (Four Corners Environmental Research Institute 1976). The low numbers of species reported in both 1966 and 1975 were indicative of a restricted aquatic macroinvertebrate community although mayflies are considered to be relatively pollution sensitive.

A qualitative aquatic macroinvertebrate sample was collected in the Uncompahgre River downstream of Ridgway Reservoir in April 2009 at Pa-Co-Chu-Puk (near the site sampled in 1966 and 1975). A total of ten taxa were identified Pa-Co-Chu-Puk, including three mayflies[1]. The two most numerous taxa were the mayfly genera *Baetis* sp. and *Ephemerella* sp. The taxa reported from downstream of Ridgway Reservoir are often found in Colorado streams with varying levels of metal contamination. The number of taxa collected downstream of Ridgway Reservoir in 2009 was similar to the number of taxa collected upstream and much lower than the numbers of aquatic macroinvertebrates that would be encountered in a pristine Colorado mountain streams.

Some environmental factor other than metals reduced the number of aquatic macroinvertebrate taxa downstream of Ridgway Reservoir.

An additional macroinvertebrate sample was collected downstream of Billy Creek in April 2009. Billy Creek is a tributary that joins the Uncompahgre River below Ridgway Reservoir and Cow Creek. The Billy Creek drainage has limited human related activities and drains the Billy Creek State Wildlife Area. A total of 17 taxa were collected at this site[6], including three species of stonefly and five mayfly taxa. More pollution-sensitive aquatic macroinvertebrate species were identified at the Billy Creek site than at the site near the dam. The higher number of taxa collected downstream of Billy Creek suggests that the aquatic community near Billy Creek is healthier than the community in the Uncompahgre River upstream at Pa-Co-Chu-Pak. The amount of sediment fines present was greater in the macroinvertebrate sample collected at Pa-Co-Chu-Pak compared to the sample collected downstream of Billy Creek. Many aquatic macroinvertebrate taxa are sensitive to increased stream sediment loads.

6.9.3 Summary upstream and downstream of Ridgway Reservoir

Ridgway Reservoir is the pivotal control point for water quality in the Uncompahgre River watershed. Millions of pounds of potentially toxic metals have been retained in the bottom sediments of the Reservoir. Metals contamination is not a water quality concern immediately downstream of the Reservoir. The amount of iron and aluminum stored in Ridgway Reservoir is about 3 million lbs/year. Without the reservoir, metals would continue to flow downstream in the Uncompahgre River and limit aquatic life. Brown trout would not be present in the Uncompahgre River downstream of Ridgway Reservoir in the absence of the dam and the sequestering of metals in the bottom of the reservoir.

The aquatic community downstream of the reservoir was better than the community upstream of the reservoir. The trout fishery improved downstream compared to upstream, but “could be better” (Dan Kowalski, Colorado Division of Wildlife, personal communication). Macroinvertebrate species richness in samples collected downstream of the Reservoir in April 2009 exceeded that found upstream of the reservoir, but still low compared to most Colorado mountain streams. The exact cause of macroinvertebrate and trout impairment is not readily apparent, but may be due to low winter flows and gas super-saturation downstream of the reservoir and also sediment loadings at a point just downstream of the Ridgway Reservoir dam.

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[6] Number of taxa would have been higher if the midges had been identified to genus.

Summary: Upstream and downstream of Ridgway Reservoir

1. Ridgway Reservoir acts as a sink for metals and nutrients in the Uncompahgre River Basin. Over 3 million pounds of metals (mostly aluminum and iron) are retained on the substrate of Ridgway Reservoir annually.
2. The Uncompahgre River meets chronic Colorado Table Value Standards downstream of Ridgway reservoir.
3. The trout population downstream of the reservoir would not exist without the presence of the dam and impoundment and subsequent metal removal.
4. Trout numbers in the Uncompahgre River remain lower than other rivers of similar size in Colorado. Possible causes of reduced trout numbers are gas bubble trauma, low winter flows and perhaps sedimentation.

6.10 The Uncompahgre River from Colona to Montrose

The Uncompahgre River continues to flow north through a confining canyon downstream of Ridgway Reservoir. At Colona the canyon opens and the Uncompahgre River enters the wide, expansive Uncompahgre River Valley. Approximately 12 miles below Colona the Uncompahgre River enters the Montrose urban corridor.

WBID	CUUN03a	
Description	Mainstem of Uncompahgre River from a point immediately above the confluence with Red Mountain Creek to the Highway 90 Bridge at Montrose	
Use Classification	Aq Life Cold 2, Recreation E, Water Supply, Agriculture	
Meets Standards?	**Section not attaining chronic standards**	**Parameters not meeting standards**
No	Colona to Montrose	Total Phosphorus *
* Nutrient standards have not yet been adopted in Colorado		

Flows in the Uncompahgre River in this section are highly regulated. Winter releases from Ridgway Reservoir are reduced due to irrigation storage. Spring and summer flows are augmented by water from the Gunnison River via the Gunnison Tunnel and South Canal. Flows from the Gunnison River provide dilution water and can significantly improve water quality conditions in the Uncompahgre River.

Limited water quality data were available for this stream reach. Water quality has been collected sporadically at the USGS gage in Colona (9147500). This station is located upstream of the South Canal, which discharges Gunnison River water into the Uncompahgre River. River Watch volunteers have sampled two locations on the mainstem Uncompahgre River near Montrose (Columbine Middle School and currently J.W. Wertz) from 1996 through 2009. These two sites are:

1. The Uncompahgre River at Chipeta on the south side of Montrose (Site #508)
2. The Uncompahgre River at Town Park in Montrose (Site #537)

6.10.1 Water Quality

Water temperature controls the rate of chemical reactions in rivers and determines the composition of the aquatic community. The Colorado Water Quality Control Commission (WQCC) designated the Uncompahgre River from Red Mountain Creek to Highway 90 in Montrose as a coldwater aquatic life class 1 stream segment. However, the WQCC adopted new temperature standards in 2007. These new standards will be applied to the Uncompahgre River Basin at the next WQCC rulemaking hearing in 2012.

The WQCC could apply a tier 1 cold-water temperature standard to this segment of the Uncompahgre River if the mean weekly temperatures are less than 17°C and brook trout and cutthroat trout are expected to be present. The temperature of the Uncompahgre River in this segment rarely exceeded 17° C. The available temperature data were collected as discrete measurements when water samples were collected, not at eight hour intervals over an extended time period so mean weekly temperature regimes cannot be determined. Temperatures above 17° C were detected on only four occasions from 1977-2009 (N=111) at the USGS Colona gage and two occasions in River Watch sample sites in Montrose from 1995-2009 (N=151), so this stream segment would probably meet a Tier 1 standard.

This segment of the Uncompahgre River may well meet the temperature criteria necessary for the application of a tier 1 cold-water standard, but not the fish criteria. Brown trout are the expected trout species in the Uncompahgre River downstream of Ridgway Reservoir with few or any brook trout and cutthroat trout present. Trout streams are classified as tier 2 if cutthroat trout and brook trout are the expected trout species. Therefore, this segment of the Uncompahgre River will likely be classified as a tier 2 cold water stream. This designation would allow an increase in temperatures to a mean weekly level of 18.3°C in the mainstem Uncompahgre River from Ridgway Reservoir to Montrose.

The Uncompahgre River from Ridgway Reservoir to Montrose was slightly basic. The median pH values at Colona, Chipeta and in Montrose at Town Park were 8.3 (N=31), 8.41 (N=121) and 8.66 (N=146), respectively.

Median hardness concentrations varied from 290 mg/L $CaCO_3$, to 194 mg/L $CaCO_3$, to 203 mg/L $CaCO_3$ in the Uncompahgre River at Colona, Chipeta and at Town Park in Montrose, respectively. Hardness concentrations generally increase in a downstream manner through a river basin as geology and land use changes contribute additional dissolved solids (salts) to the river. The lower hardness level in the Uncompahgre River in Montrose compared to Colona is attributable to a diluting influence of the waters from the Gunnison River. Typical hardness values in Gunnison River (USGS Site 09128000) range from 90 mg/L $CaCO_3$ to 110 mg/L $CaCO_3$ (2005-2007).

Hardness concentrations decreased in the Uncompahgre River in Montrose in March. Spring snowmelt typically dilutes hardness and other water quality constituents in Colorado mountain systems. In the Uncompahgre River, hardness decreased prior to the onset of spring runoff, corresponding to the timing of diversions from the Gunnison River. The reverse occurred at the end of irrigation season (late October). Hardness concentrations increased in November when inflow of Gunnison River water ceased. Water originating from the Gunnison River acted as a dilutant in the Uncompahgre River, reducing the concentration of many water quality parameters during the months of April through October.

Sulfate measurements can be a sign of the amount of solids dissolved in water. The average sulfate concentration in the Uncompahgre River in Montrose was 152 mg/L SO_4 (N=20) at Chipeta and 156 mg/L SO_4 (N=25) at Town Park. The 85th percentile concentrations were 214 mg/L SO_4 and 232 mg/L SO_4. Sulfate concentrations met the state drinking water supply standard of 250 mg/L SO_4 applied by the WQCC.

The Uncompahgre River exceeded the chronic Table Value Standard (TVS) for dissolved selenium in Montrose. A stream reach does not attain a standard when the 85th percentile of the data exceeds the chronic standard. The chronic TVS for selenium is currently 4.6 ug/L. The 85th percentile value was 6 ug/L at Chiptea and 5.9 at Town Park. These concentrations were the first indications of the selenium regulatory issue that exists in the Uncompahgre River. A variety of natural and human induced actions mobilize selenium from Mancos Shale, the prevalent geologic feature exposed in the lower Uncompahgre Watershed.

Cadmium, copper, lead and zinc concentrations between Colona and Montrose did not exceed chronic Colorado Table Value Standards (Table 14). The WQCC adopted a temporary modification of 1.1 ug/L dissolved cadmium for the Uncompahgre River segment 3a. The 85th percentile of dissolved cadmium was 0.17 ug/L upstream of Montrose at Chipeta. The 85th percentile concentration was less than detection limits in Montrose at Town Park. The dissolved cadmium concentrations below Ridgway Reservoir attain the chronic Colorado Table Value Standard, thus eliminating any need for the current temporary modification currently adopted by the WQCC.

The median total aluminum concentrations in Montrose were 226 ug/L at Chipeta and 253 ug/L at the Town Park (Table 15). Seven of the total aluminum measurements (19%) at Chipeta and 14 of the measurements (22%) at Town Park violated the chronic total aluminum standard that would be applied if the WQCC adopted aluminum standards in the Uncompahgre River.

Maximum total aluminum concentrations increased as the Uncompahgre River flowed north through Montrose. Some samples exceeded 4,000 ug/L total aluminum. The majority of total aluminum concentrations greater than 1,000 ug/L were measured in April, May and June. Elevated aluminum concentrations were commonly associated with increased suspended sediment loadings associated with spring snowmelt.

Conclusions regarding aluminum toxicity to fish in the Uncompahgre River near Montrose were difficult to ascertain. Exposure to 530 ug/L total aluminum at pH levels 7.0 to 8.5 induced mortality and various sub lethal impacts to rainbow trout in laboratory studies (Freeman and Everhart, 1971). At the present pH regime, total aluminum concentrations in the Uncompahgre River at Montrose are routinely ten times greater than levels known to be toxic to rainbow trout. However, the hardness of the Uncompahgre River in the Montrose area exceeded the hardness regime in the Freeman and Everhart (1971) study, which may ameliorate aluminum toxicity. The actual relationship between hardness and aluminum toxicity has not been determined at conditions typical of the Uncompahgre River in Montrose.

Total iron concentrations in segment 3a met the chronic Table Value Standard (1,000 ug/L), site specific standard (1,500 ug/L) and temporary modification (1,673 ug/L). The 50th percentile of total iron was 370 ug/L (N=12) at Colona, 378 ug/L at Chipeta and 368 ug/L at Town Park. Existing data for this stream reach does not demonstrate a need for either the site-specific standard or the temporary modification for total iron.

The pH regime of the Uncompahgre River at Colona and Montrose, coupled with relatively low total iron concentrations, demonstrate that total iron in the Uncompahgre River from Colona to Montrose was not directly toxic to fish or aquatic life. Iron can be indirectly toxic through precipitation that smothers the stream substrate and eliminates the required habitat for aquatic macroinvertebrates. Total iron concentrations present in the Uncompahgre River from Colona to Montrose did not appear to be elevated to the point that indirect toxicity was likely.

Total aluminum and iron concentrations were greater at the sample sites in Montrose than the sample site below Ridgway Reservoir. This suggests that upper basin sources such as Red Mountain Creek were not the source of aluminum and iron in the Uncompahgre River below Ridgway Reservoir. One possible source is the Mancos Shale, which is rich in iron and aluminum and prevalent in the lower basin.

Nutrient data are limited for the mainstem Uncompahgre River between Colona and Montrose. Over half of all total ammonia measurements were below detection limits (Table 16) and no ammonia concentrations exceeded the chronic ammonia standard. The median nitrate-nitrogen concentration was 160 ug/L as N at Colona, 98 ug/L as N at Chipeta, and 114 ug/L as N at Town Park. Both levels were less than natural background levels for forested mountain lands (130 ug/L as N) (Smith et al. 2003). Nitrate was lower in Montrose than Colona. This may be due to imported dilution water from the Gunnison River.

Median total phosphorus concentrations in Montrose were 19 ug/L and 30 ug/L at Chipeta and Town Park, respectively (Table 16). Total phosphorous at Town Park was greater than expected natural background phosphorus concentrations (20 ug/L) western-forested streams (Smith et al., 2003). The maximum total phosphorus concentration was 600 ug/L. Phosphorous standards have not been applied to Colorado streams, but total phosphorus greater than 4 ug/L can result in eutrophication in lakes and standing bodies of water. The total phosphorus concentrations in the Uncompahgre River at Montrose are high enough support extensive algal and plant growth in impoundments or stream reaches where water velocities are reduced in period of low stream flow.

The USGS collected 12 samples for *E. coli* analysis at Colona between 1990 and 1993. *E. coli* was not detected in 10 of the samples and the other two contained 22 and 25 colonies/100 ml. Based on the limited amount of bacteria data available for this stream reach, *E. coli* did not violate Table Value Standards.

6.10.2 Summary: Uncompahgre River from Colona to Montrose

The Uncompahgre River from Ridgway Reservoir to Montrose transitions from a confined forested stream to an urban system where agriculture and increasing urban development fill an ever-widening river valley. Stream temperatures indicated the river was still cold enough to support trout populations. Concentrations of metals commonly associated with mining impacts decreased to levels not toxic to fish. The concentrations of dissolved cadmium, copper, lead and zinc were far less than the existing chronic Table Value Standards applied to this stream reach. Total aluminum concentrations frequently exceeded the chronic Colorado Table Value Standard that would be applied if the WQCC adopts aluminum standards to the Uncompahgre River basin. Total phosphorus was higher than expected natural conditions in Montrose. This segment has the best water quality in the entire Uncompahgre River mainstem.

The WQCC currently includes the Uncompahgre River from downstream of Ridgway Reservoir to Montrose in the same stream reach (segment 3a) as *the Uncompahgre*

River from downstream of Red Mountain Creek to Ridgway Reservoir. This WQCC Uncompahgre River stream reach warrants division into at least two stream reaches due to the wide dichotomy of water quality regimes in the mainstem Uncompahgre River above and blow Ridgway Reservoir. Upstream of the reservoir the Uncompahgre River bears elevated and frequently toxic loads of metals. Downstream of the reservoir the Uncompahgre River meets chronic Table Value Standards for metals. In addition the total iron concentrations in the Uncompahgre River downstream of Ridgway Reservoir attain the chronic Colorado Table Value Standard and obviate any need for the current site-specific standard or temporary modification currently adopted by the WQCC.

Summary: Uncompahgre River from Colona to Montrose

1. The water quality in the Uncompahgre River below Ridgway Reservoir to Montrose was of higher quality than in any other mainstem reach through the entire river basin. Metals associated with mining activities such as cadmium, copper, lead and zinc were often less than detection limits and met existing table value standards.
2. Total phosphorus exceeded expected background levels in Montrose and could cause eutrophication in standing bodies of water.
3. Total iron concentrations met the current chronic Table Value Standard as applied to Colorado waters by the WQCC. The existing site-specific total iron standard and temporary modification for total iron for the Uncompahgre River are no longer applicable to the mainstem Uncompahgre River below Ridgway Reservoir.
4. Existing WQCC stream reach 3a merits re-segmentation to acknowledge the different water quality regimes in the Uncompahgre River above and below Ridgway Reservoir.

6.11 Uncompahgre River near Montrose, from Highway 90 to LaSalle Road

Uncompahgre River Segment COGUUN04a is a short 3 mile stretch of the Uncompahgre River through the City of Montrose from the Highway 90 Bridge to LaSalle Road. The City of Montrose is the most populous in the Uncompahgre Watershed.

WBID	COGUUN04a	
Description	Mainstem of the Uncompahgre River from the Highway 90 bridge at Montrose to La Salle Road	
Use Classification	Aq Life Warm 2, Recreation E, Agriculture	
Meets Standards?	**Section not attaining chronic standards**	**Parameters not meeting standards**
no	entire reach	selenium

A limited data set was available for this stream reach. River Watch volunteers sample one site in this stream reach, the Uncompahgre River just downstream of the LaSalle Road Bridge (Site #159). Data were available for this sample site from the fall of 2007 to the spring of 2009.

6.11.1 Water Quality

The Uncompahgre River from Highway 90 to the LaSalle Road is classified as a warm water class 2 stream. Warm water class 2 streams are not supporting of trout population and generally have temperatures above 18.3°C. Contrary to this classification; local anglers commonly fish for brown trout in the Uncompahgre River downstream of the La Salle Bridge (JW Wertz, personal communication). Additionally, the Division of Wildlife reported that a reproducing population of brown trout inhabits the Uncompahgre River through Montrose with multiple age classes present and from 30 pounds to 40 pounds/acre of brown trout biomass (Dan Kowalski, DOW, personal communication). Regular temperature monitoring indicated that the temperature at LaSalle Road did not exceed 16°C (Figure 41). Due the presence of a healthy brown trout population and temperatures below 18.3°C, the Uncompahgre River in this segment appeared to meet the definition of a coldwater class 1 aquatic life stream. The WQCC will examine temperature standards at the next standard review hearing for the Uncompahgre River Basin in 2012.

The Uncompahgre River at the La Salle Road was basic. The pH of the river ranged from 8.15 to 8.5 (N=25). The stream met the WQCC pH standard of 6.5 to 9.0.

Dissolved solids, as indicated by hardness and sulfate concentrations, increased as the Uncompahgre River flowed north through Montrose (Figure 42 and 43). The median hardness was 242 mg/L as $CaCO_3$ at LaSalle Road compared to 203 mg/L as $CaCO_3$ upstream at Town Park. The average sulfate concentration was 156 mg/L SO_4 in at the Highway 90 Bridge and 211 mg/L at La Salle Road Bridge on the north side of the Montrose. The water in the Uncompahgre River from the Highway 90 Bridge to the LaSalle Road Bridge appeared to meet the domestic drinking water criteria for sulfate, although a drinking water supply use has not been applied to this stream reach.

Nitrate/nitrite concentrations ranged from less than detection limits to a maximum of 1,840 ug/L NO_3 as N at La Salle Road. The median nitrate/nitrite concentration was 196 ug/L NO_3 (Figure 44) In contrast, the median nitrate/nitrite value was 98 ug/L NO_3 as N above Montrose at Chipeta. Median total nitrogen levels at LaSalle Road exceeded estimated background levels (90 ug/L) for xeric western streams (Smith et al. 2003). Nitrate/nitrite appeared to increase in the same manner as dissolved salts as the Uncompahgre River flowed through the Town of Montrose.

The minimum total aluminum concentration was 72 ug/L in the Uncompahgre River at the LaSalle Road Bridge (N=6). The maximum total aluminum value, 1,514 ug/L, was the only sample result to exceed the Colorado chronic stream standard that would be applied to this river segment if and when the WQCC adopts total aluminum standards for the Uncompahgre River Basin.

6.11.2 Summary: Uncompahgre River from Highway 90 Bridge to LaSalle Road Bridge

This Uncompahgre River segment, flowing through the City of Montrose, is one where agriculture and increasing urban development began to exert a negative influence on the river's water quality. Stream temperatures suggest that the river reach was cold enough to support trout populations and local accounts have documented a naturally reproducing brown trout population. Except for one sample, total aluminum concentrations met the chronic Colorado Table Value Standard that would be applied if the WQCC adopts aluminum standards for the Uncompahgre River basin. The number of data points for total aluminum was relatively low (N=6) so additional aluminum data are warranted for this sample site. The dissolved solids in the Uncompahgre River increased as the stream flowed through Montrose to LaSalle Road. High dissolved solids concentrations can diminish the economic and ecological value of a stream. In general the water quality was still better than standards applied to the Uncompahgre River at the LaSalle Road Bridge north of Montrose.

Summary: Uncompahgre River in Montrose from Highway 90 Bridge to LaSalle Road Bridge

1. The dissolved solids in the Uncompahgre River increased as the stream flowed through Montrose. High dissolved solids concentrations can diminish the economic and ecological value of the Uncompahgre River.
2. The use classification of the Uncompahgre River (warm water class 2) needs to be evaluated in comparison to a coldwater class 1 system due to the presence of multiple age classes of trout and a temperature regime that seems to be less than 18.3°C.

6.12 Tributaries to the Uncompahgre River from Montrose to Delta

Multiple tributaries enter the mainstem Uncompahgre River from Montrose to Delta including Loutsenhizer Arroyo, Dry Creek, Dry Cedar Creek and Cedar Creek. A multitude of other small drainages and ditches return irrigation and storm water to the Uncompahgre River. These tributaries drain lands used for farming, ranching, confined feedlot operations and the urbanized areas of Montrose and Delta.

WBID	UN12	
Description	All tributaries to the Uncompahgre River, including all wetlands, lakes and reservoirs, from the South Canal near Uncompahgre to the confluence with the Gunnison River, except for specific listings in Segments 13, 14, 15a and 15b	
Use Classification	Aq Life Warm 2, Recreation N, Agriculture	
Meets Standards?	**Section not attaining chronic standards**	**Parameters not meeting standards**
no	Dry Cedar Creek Dry Cedar Creek Cedar Creek	selenium manganese Iron

Water quality data for the tributaries in this segment were sparse. Data collected by the Water Quality Control Division (WQCD) were obtained from EPA STORET. The number of times a tributary was sampled varied, as did the parameters analyzed. Results were not adequate to describe seasonal or temporal trends. Dissolved cadmium, copper, lead and zinc concentrations were generally below or near detection limits. The Division of Wildlife sampled an irrigation return to the mainstem Uncompahgre River in Delta at Confluence Park on a monthly for a period of 12 months in 2003 and 2004.

6.12.1 Dry Cedar Creek

Dry Cedar Creek enters the mainstem Uncompahgre River from the east, south of Montrose. The Water Quality Control Division data for Dry Cedar Creek (WQCD Site #10664) was collected near the confluence with the Uncompahgre River.

Dry Cedar Creek is a known source of the selenium to the Uncompahgre River (Butler and Leib, 2002 and Anthony, 2010). The 85th percentile of selenium was 56.5 ug/L in 1995 and 67.4 ug/L in 1996, concentrations ten times greater than the applicable chronic stream standard of 4.6 ug/L. The amount of selenium that must be removed to attain the chronic standard (4.6 ug/L) ranges from 52% of the load in June to a maximum of 95% in the month of December for Dry Cedar Creek (WQCD, 2009).

Concentrations of dissolved salts were elevated in Dry Cedar Creek compared to the mainstem Uncompahgre River near Chipeta (a sample site located upstream of Dry Cedar Creek) as demonstrated by hardness and sulfate concentrations. Hardness is a measurement of both calcium and magnesium ions dissolved in water. The median hardness value in Dry Cedar Creek was 1,200 mg/L $CaCO_3$ (Table 17) compared to a median of hardness of 194 mg/L $CaCO_3$ in the Uncompahgre River at Chipeta. The hardness levels in Dry Cedar creek were ten times higher than in the Uncompahgre River.

The median Dry Cedar Creek sulfate concentration was 2,200 mg/L SO_4 (maximum 2,600 mg/L SO_4, N=5). The median sulfate concentration in the Uncompahgre River near Chipeta was 133 mg/L SO_4, a level 20 times less than in Dry Cedar Creek and well below the Colorado drinking water standard (250 mg/L SO_4). These levels of calcium, magnesium, and sulfate did not represent violations of any stream standards, but do provide and indication of the magnitude of dissolved solids increases in the mainstem Uncompahgre River attributable to Dry Cedar Creek.

Manganese concentrations in Dry Cedar Creek ranged from 67 ug/L to 170 ug/L (N=5). The hardness-based chronic aquatic life manganese standard Colorado Table Value Standard was 2,617 ug/L, based on a maximum hardness of 400 mg/L $CaCO_3$ used by the WQCC in stream standard calculations. Dry Cedar Creek met the aquatic life manganese standard. If drinking water was a designated use in this segment, Dry Cedar Creek would be in violation of the standard.

Dry Cedar Creek met the chronic site-specific iron standard of 1,200 ug/L. The median total iron concentration was 360 ug/L (N=5), slightly lower than the median total iron in the Uncompahgre River above Dry Cedar Creek (378 ug/L, N = 106).

The nitrate-nitrogen concentrations in Dry Cedar Creek were often two orders of magnitude greater than those found in the Uncompahgre River at Chipeta. The median nitrate-nitrogen concentration was 2,000 ug/L at Dry Cedar Creek compared to 98 ug/L in the mainstem Uncompahgre River at Chipeta. Dry Cedar Creek is a major source of nitrate to the Uncompahgre River. In contrast ammonia concentrations were relatively low in Dry Cedar Creek. The median ammonia concentration was 50 ug/L, well below the chronic Colorado Table Value standard.

The median total phosphorus concentration in Dry Cedar Creek was 41 ug/L, more than twice that of the background level (20 ug/L) in Xeric Western Lands (Smith *et al.*, 2003). The median total phosphorus in Dry Cedar Creek, however, was less than in the Uncompahgre River downstream of Ouray, an indication of how little phosphorus increased over a rather long stream reach from Ouray to Montrose.

The Colorado Water Quality Control Commission has not adopted nutrient (nitrate and phosphorus) standards for streams in Colorado. Excess nitrogen and phosphorus levels, like those detected in Dry Cedar Creek, can result in algal growth, loss of suitable habitat for aquatic insects, and low dissolved oxygen levels.

Low bacteria levels in concert with low ammonia concentrations suggest that livestock are not an important contaminant source in Dry Cedar Creek. The geometric mean was 14 colonies/100 ml (N=3) and the median ammonia concentration was 50 ug/L, a relatively low level of ammonia.

Except for selenium, water quality in Dry Cedar Creek met most applicable stream standards. Current WQCC standards and use designations allow for a significant degradation of existing Dry Cedar Creek water quality. A review of WQCC standards and use designation regime for Dry Cedar Creek is appropriate during the next triennial review for the Uncompahgre River Basin. Better protection of the ambient water quality in Dry Cedar Creek may be of value in the Uncompahgre River Basin.

6.12.2 Cedar Creek

Cedar Creek enters the mainstem Uncompahgre River downstream of Dry Cedar Creek confluence and LaSalle Road. Cedar Creek captures drainage from Cerro Summit on the eastern edge of the Uncompahgre Valley. Montrose Arroyo joins Cedar Creek on the northern side of Montrose. The Cedar Creek drainage includes lands used for ranching and farming operations as well as urbanized areas. Data used in this description of the Dry Cedar Creek water quality were collected by the Colorado Water Quality Control Division at Site 10622, upstream of Montrose Arroyo.

Cedar Creek is a known source of the selenium to the Uncompahgre River. The 85th percentile of selenium ranged from 40.8 ug/L in 1992 to 29.5 ug/L in 2000 (WQCD, 2009) concentrations a decimal point greater than the chronic standard of 4.6 ug/L. The amount of selenium that must be removed from Cedar Creek to attain the chronic standard ranged from 31% of the load in June to a maximum of 90% in the months of December and January (Butler and Leib, 2002 and WQCD, 2009).

Dissolved solids were elevated in Cedar Creek compared to the mainstem Uncompahgre River at the LaSalle Road Bridge, as indicated by hardness and sulfate measurements. Hardness measurements quantify the calcium and magnesium concentrations in water. The median hardness was 760 mg/L $CaCO_3$ (Table 17) near the mouth of Cedar Creek compared to a median 242 mg/L $CaCO_3$ for the Uncompahgre River at the LaSalle Road Bridge. The median sulfate concentration at Cedar Creek was 980 mg/L SO_4 with a maximum of 1,100 mg/L SO_4 (N=5) (Table 17) compared to a median concentration of 211 mg/L SO_4 in the Uncompahgre River at the LaSalle Road Bridge. Cedar Creek was a measurable source of dissolved salts such as calcium, magnesium and sulfate to the mainstem Uncompahgre River.

Water supply is not a designated use for Cedar Creek or the lower Uncompahgre River, so the state drinking water standard of 250 mg/L SO_4 does not apply. The median sulfate concentration in Cedar Creek (980 mg/L SO_4) was about 4 times greater than the drinking water standard and 4.5 times greater than the Uncompahgre River at the LaSalle Road Bridge. Cedar Creek is a source of sulfate to the Uncompahgre River.

The median total iron concentration in Cedar Creek was 3,660 ug/L (N=6), ten times higher than the median total iron value in the Uncompahgre at Town Park[7] (368 ug/L, N=106). Cedar Creek did not meet either the state chronic total iron Table Value Standard of 1,000 ug/L or the site specific standard of 1,200 ug/L. Cedar Creek was a measurable source of iron to the mainstem Uncompahgre River.

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[7] Note that total iron data from LaSalle Road not used as a comparison due to low number of total iron data points at the LaSalle Road sampling site.

The median nitrate nitrogen concentration in Cedar Creek (1,400 ug/L) was an order of magnitude greater than that found in the mainstem Uncompahgre River at LaSalle Road site (median = 180 ug/L). In contrast, ammonia concentrations were relatively low in Cedar Creek. The median ammonia concentration was 95 ug/L; less than the chronic Colorado Table Value standard.

Bacteria concentrations met the Colorado Table Value Standard (630 colonies/100 ml) in Cedar Creek. The geometric mean was 141 colonies/100 ml (N=3). Relatively low bacterial and ammonia concentrations in Cedar Creek suggest that livestock are not an important contaminant source in Cedar Creek.

6.12.3 Loutsenhizer Arroyo

The Loutsenhizer Arroyo enters the mainstem Uncompahgre River downstream of Olathe near the Delta/Montrose County Line. The Loutsenhizer Arroyo drains farmlands along the eastern side of the Uncompahgre River basin and is a known source of the selenium to the Uncompahgre River. The 85th percentile of selenium was 180 ug/L in 1996, 154 ug/L in 1997 and 215 ug/L in 2002 (WQCD, 2009), concentrations more than 30 times greater than the applicable Colorado chronic stream standard of 4.6 ug/L The amount of selenium that must be removed from the Loutsenhizer Arroyo to attain the chronic standard (4.6 ug/L) ranges from 89% of the load in May through August to a 98% in from November to March (Butler and Leib, 2002 and WQCD, 2009).

Dissolved solids concentrations in the Loutsenhizer Arroyo were elevated compared to the mainstem Uncompahgre River in Montrose as indicated by hardness and sulfate concentrations. The median hardness in the Loutsenhizer Arroyo near the mouth (WQCD Site 10661) was 665 mg/L $CaCO_3$ (Table 17) compared to 230 mg/L $CaCO_3$ in the Uncompahgre River at the La Salle Road Bridge. The median sulfate concentration in the Loutsenhizer Arroyo was 750 mg/L SO_4 (maximum 3,300 mg/L SO_4, N=16) compared to a median concentration of 211 mg/L SO_4 at the LaSalle Road Bridge. The Loutsenhizer Arroyo was a measurable source of dissolved solids to the mainstem Uncompahgre River. All sulfate measurements exceeded the state drinking water standard of 250 mg/L SO_4. The Loutsenhizer Arroyo is not classified as a drinking water supply. However, the comparison to the state standard provides an additional indication of the relatively low quality of water entering the mainstem Uncompahgre River from the Loutsenhizer Arroyo.

The median total iron concentration in the Loutsenhizer Arroyo was 6,500 ug/L (N=16). The Loutsenhizer Arroyo did not meet the state chronic total iron Table Value Standard of 1,000 ug/L or the site-specific standard of 1,200 ug/L. The Loutsenhizer Arroyo was a measurable source of total iron to the Uncompahgre River.

Nutrient concentrations were higher in the Loutsenhizer Arroyo than the mainstem Uncompahgre River. The median nitrate concentration was 2,250 ug/L Nitrate as N. Four of the measurements (N=17) exceeded 10,000 ug/L Nitrate as N. Nitrate-nitrogen concentrations in excess of 10,000 ug/L are seldom encountered in Colorado surface waters. A nitrate-nitrogen as N concentration of 10,000 ug/L exceeds the Colorado drinking water standard (which is not applicable to the Loutsenhizer Arroyo). Ammonia concentrations were relatively low with a median value of 70 ug/L. The median total phosphate as P was 550 ug/L. The maximum total phosphorus value was 1,300 ug/L (N=15). The levels of phosphate and nitrate found in the Loutsenhizer Arroyo were higher than in most surface waters throughout Colorado. The phosphorus and nitrate concentrations would have to be reduced by factors of 28 and 17, respectively, to resemble background levels in xeric western lands (Smith 2003). Sources of most nitrogen and phosphorus are typically related to human actions such as fertilizers, confined feedlots and failed septic systems.

The geometric mean of *E. coli* was 283 colonies/100 ml at the mouth of the Loutsenhizer Arroyo. This level of bacteria met the stream standard of 630 colony forming units/100 ml. The number of *E. coli* present in the Loutsenhizer Arroyo did, however, exceeded levels found in most Colorado streams of similar size.

6.12.4 Dry Creek

Dry Creek enters the Uncompahgre River just upstream of Delta. Dry Creek stream classifications are different from Cedar Creek, Dry Cedar Creek and Loutsenhizer Arroyo. The headwater streams in the Dry Creek basin are designated as coldwater class 1 while the mainstem of Dry Creek is designated as a class 2 warm water stream segment. Data used to characterize Dry Creek water quality were collected by the Colorado Water Quality Control Division Site 10611 near the confluence.

Dry Creek is a known source of the selenium to the Uncompahgre River. The 85th percentile of selenium was 9.8 ug/L in 1996 (WQCD, 2009), a concentration double the applicable Colorado chronic stream standard of 4.6 ug/L. The amount of selenium that must be removed from Dry Creek to attain the chronic standard ranges from 18% of the load in December to 54% in February. Selenium typically met the chronic standard in May (Butler and Leib, 2002 and WQCD, 2009). Dissolved solids were lower in Dry Creek than the mainstem Uncompahgre River upstream at Delta (WQCD Site 55) as indicated by hardness and sulfate concentrations. The median hardness of Dry Creek was 450 mg/L $CaCO_3$ (Table 17), lower than the median hardness of 673 mg/L $CaCO_3$ in the Uncompahgre River in Delta. The median sulfate concentration in the Uncompahgre River at Delta was 644 mg/L SO_4. Dry Creek was not a source of dissolved solids the Uncompahgre River on an annual basis.

The median total iron concentration in Dry Creek was 3,135 ug/L (N=5). Dry Creek did not meet either the state chronic total iron Table Value Standard of 1,000 ug/L or the site 17) was three times higher than the median iron concentration (1,100 ug/L) in the mainstem Uncompahgre River in Delta. Dry Creek was a measurable source of total iron to the Uncompahgre River at Delta.

The median nitrate-nitrogen value in Dry Creek was 2,300 ug/L while the median nitrate-nitrogen in the Uncompahgre River near Delta was 2,700 ug/L as N (N=217 ug/L). The median total phosphate as P was 170 ug/L in Dry Creek and 120 ug/L in the mainstem Uncompahgre River in Delta. Nutrient loads in both Dry Creek and the Uncompahgre River in Delta were much higher than background levels reported by Smith (2003) for xeric western waters. Dry Creek did not increase Uncompahgre River nutrient loads.

6.12.5 Fifth Street Ditch in Delta

A myriad of other small tributaries and ditches contribute water to the Uncompahgre River between Montrose and Delta. The Fifth Street Ditch conveys water flows to the mainstem Uncompahgre River along the southern edge of Delta’s Confluence Park. This ditch is not considered a “Water of the State” so stream standards or designated uses do not apply. The Fifth Street Ditch at one time acted as a conduit for irrigation return water from the east side of the Uncompahgre River in Delta. The Town of Delta took water from the ditch to Confluence Park Lake until the mid 2000’s.The Division of Wildlife sampled the Fifth Street Ditch from August 2003 through August 2004.

The Fifth Street Ditch did not freeze during the winter of 2003-2004 (Lori Martin, personal communication). The minimum temperature was 12.5°C on 1/12/2004, while all other streams in the area had winter temperatures of about 0°C to 1°C. The elevated winter temperatures indicated that all or some of the stream flow was attributable to surfacing groundwater or a discharge from a point source. No permit exists for a point source discharge on the Fifth Street Ditch, so water entering the ditch from a human related activity is not a likely explanation of elevated water temperatures in winter months. Wintertime flows in the Fifth Street Ditch are considered to be surfacing groundwater and storm water runoff.

The median total iron value in the Fifth Street Ditch was 33 ug/L. The median concentration of total iron in the Uncompahgre River about 50 yards downstream of where flows from the Fifth Street Ditch enter the mainstem was 1,100 ug/L. The median total aluminum was 132 ug/L, an order of magnitude less than the total aluminum in the mainstem Uncompahgre River in Delta. The Fifth Street Ditch was not a source of iron or aluminum to the Uncompahgre River.

In contrast, the median total hardness in the Fifth Street Ditch was 1,295 mg/L $CaCO_3$, a concentration two times higher than the median total hardness concentration in Cedar Creek, Dry Creek and the Loutsenhizer Arroyo. The median hardness of the Uncompahgre River in Delta was 674 mg/L $CaCO_3$ (N=391, 1968-2007). The Fifth Street Ditch increased the dissolved solid loads to the Uncompahgre River.

The 85th percentile of dissolved selenium was 52 ug/L (median = 44 ug/L, N=12) in the Fifth Street Ditch compared to 19 ug/L in the mainstem Uncompahgre River at WQCD Site 55 in Delta. The Fifth Street Ditch selenium concentration exceeded the 4.6 ug/L aquatic life standard. The annual selenium load to the Uncompahgre River from the Fifth Street Ditch was 106 pounds (4% of the total Uncompahgre River load at the confluence with the Gunnison River) based on flow and the average dissolved selenium concentration. The Fifth Street Ditch was a measurable source of selenium to the Uncompahgre River in Delta.

The periodicity of elevated selenium levels was different in the Fifth Street Ditch compared to selenium concentrations in the larger ditches like the Loutsenhizer Arroyo. The maximum dissolved selenium concentrations in the Fifth Street Ditch were measured in September while maximum selenium loadings in Dry Cedar Creek, Cedar Creek and Loutsenhizer arroyo were observed in the winter months. Selenium loading to the mainstem Uncompahgre River is not the result of a single phenomenon. Multiple sources of differing periodicity and magnitude of flows are involved. Decreasing selenium loading in the Uncompahgre River would involve addressing more than one source or time period during the year.

The Fifth Street Ditch median nitrate was 4,400 ug/L as N, which exceeded the median concentrations at the mouth of Cry Cedar Creek, Cedar Creek and Dry Creek, but was less than the median value in Loutsenhizer Arroyo. Total phosphorus concentrations were mostly below detection limits. The Fifth Street Ditch is a source of nitrogen to the mainstem Uncompahgre River in Delta.

Like many other tributaries and ditches, the Fifth Street Ditch was a source of pollutants to the mainstem Uncompahgre River. The timing of the contamination and parameters of interest were not the same in the Fifth Street Ditch compared to larger tributaries. Many of these smaller tributaries probably influence the mainstem Uncompahgre River in a manner that would have to be determined on an individual basis.

6.12.6 Summary Tributaries

The water quality in Dry Cedar Creek, Cedar Creek, Loutsenhizer Arroyo, Dry Creek and other small tributaries exemplified by the Fifth Street Ditch exerted a negative influence on the water chemistry of the Uncompahgre mainstem between Montrose and Delta. The tributaries contributed dissolved solids, nutrients, selenium, iron and aluminum to the mainstem Uncompahgre River.

Two possible sources for these contaminants include natural conditions and agricultural practices. The relatively high dissolved solids in these tributaries were in part attributable to naturally arid, salt-laden, lands drained prevalent in the lower Uncompahgre Watershed. The Mancos Shale is the main formation exposed in Dry Cedar Creek, Cedar Creek, Loutsenhizer Arroyo and Dry Creek. The Mancos Shale is relatively nutrient poor (USGS 2004), but rich in salts and selenium. The intense agricultural use of the lands within the drainage basins of these four tributaries resulted in increased nutrient, bacterial loads as well as aluminum and iron.

Dry Cedar Creek, Cedar Creek, Loutsenhizer Arroyo and Dry Creek each contributed pollutant loads to the mainstem Uncompahgre River. Flows from Cedar Creek, Dry Creek and Loutsenhizer Arroyo increased levels of total iron, phosphorus, nitrogen and bacteria to the mainstem Uncompahgre River. Loutsenhizer Arroyo in particular, contributed elevated levels of phosphorus. Water from Dry Cedar Creek and Cedar Creek increased the dissolved solids loads. Sulfate concentrations were the highest in Dry Creek. Dry Creek was a greater source of dissolved solids such as calcium, magnesium and sulfate to the mainstem Uncompahgre River than the other tributaries.

The WQCC does not regulate all water quality parameters in the mainstem Uncompahgre River. For example, the WQCC has not yet adopted nutrient standards (nitrogen and phosphorus). The elevated nitrogen and phosphorus loads entering the mainstem Uncompahgre River can induce excessive algal growth in the river and any small off channel reservoirs and ponds that are filled with water from the river. Nitrate - nitrogen concentrations exceeded 10,000 ug/L in Cedar Creek, Loutsenhizer Arroyo and Dry Creek, levels rarely encountered in Colorado surface waters. Phosphorus concentrations exceeded 500 ug/L as P measured in the four tributaries. The excessive nutrient loading documented in Dry Cedar Creek, Cedar Creek, Loutsenhizer arroyo and Dry Creek are likely attributable to the intense agricultural land-use practices.

Improving water quality in these four drainages necessitates treatment of nonpoint sources. Agriculture is vital to the Uncompahgre River from an economic and cultural perspective. Lands have been ranched and farmed for generations in the Uncompahgre Basin. The solution is not to eliminate agricultural activities or the creation of onerous regulations and controls that increase costs and decrease options. Lining and piping of irrigation water reduces salt and selenium loading. Such a program reduced the amount of selenium leaving the Montrose Arroyo (Butler and Leib 2002). Additional lining and piping could further reduce selenium and other contaminants to these four tributaries and the mainstem Uncompahgre River. Other options involve decreasing the amount of water used for irrigation by increasing irrigation efficiency. Spray and drip irrigation utilize less water than flood irrigation. Surge irrigation practices decrease the amount of water applied to lands and would decrease selenium loading.

Another possibility that may warrant at least discussion and consideration would be a voluntary program of retiring land from agricultural production. Perhaps lands could be purchased and retired from productions as farmers, ranchers or feedlot operators retire or decide to change professions. Water rights associated with those lands would be eliminated decreasing the total amount of water used for irrigation in the basin. Over time, this would decrease both the total amount of irrigation return flows and indirect flows such as perhaps the groundwater feeding smaller tributaries such as the Fifth Street Ditch. Conversion of irrigated lands to small “ranchettes” or individual homes and subsequent installation of ‘Bluegrass” lawns would reverse any benefits associated with removing lands from agricultural production.

The exact source of water in the Fifth Street Ditch in Delta was not known, but may consist of surfacing groundwater associated with irrigation, confined animal feed lots, or urban storm water flows from Delta. Decreasing the amount of water applied to lawns may decrease the amount of selenium, salts and nutrient loads.

Financial incentives could be created for xeriscaping both existing homes, parks and businesses to reduce the amount of water applied to lawns and parks. Regulations and covenants requiring xeriscaping are needed when lands are developed. Reducing the amount of water applied to lands throughout the Uncompahgre River Basin downstream of Montrose would result in improved water quality and perhaps decrease the expenditure of monies required to attain applicable stream standards.

Summary: Tributaries to the Uncompahgre River below Montrose

1. Waters from Dry Cedar Creek, Cedar Creek, Loutsenhizer Arroyo and Dry Creek degraded the quality of the mainstem Uncompahgre River.
2. The selenium from these four tributaries in part resulted in designation of the mainstem Uncompahgre River as a use impaired stream reach on the Colorado 303d list of impaired waters.
3. Other parameters also negatively impact mainstem river water quality including dissolved salts, total iron, nitrogen and phosphorus.
4. Nonpoint contaminant sources including irrigation return flows and confined feedlot operations must be corrected to improve water quality in these four tributaries and the mainstem Uncompahgre River.
5. Discharges from other smaller tributaries such as the Fifth Street Ditch in Delta introduce elevated loads of multiple parameters including selenium to the mainstem Uncompahgre River.

6.13 The Uncompahgre River from Montrose to the confluence with the Gunnison River in Delta

Downstream of LaSalle Road, the Uncompahgre River flows approximately 26 miles north to the confluence with the Gunnison River in Delta. Between Montrose and the confluence with the Gunnison the Uncompahgre River flows through two municipalities, the Town of Olathe and the City of Delta. The dominant land use in this portion of the watershed is irrigated agriculture. Downstream of Montrose, the Uncompahgre River is an active component of the irrigation network. The mainstem Uncompahgre River is used to convey irrigation water to downstream water users, not a series of off-stream ditches as found in other areas of Colorado.

The Water Quality Control Commission (WQCC) divided this stretch of the Uncompahgre River into two segments: COGUUN04b and COGUUN04c. Segment 04b extends from LaSalle Road in Montrose to Confluence Park in Delta. Segment 04c is a short segment (less than half a mile long) that reaches from Confluence Park to the confluence with the Gunnison River. The sections were separated to reflect a difference in recreational use. Segment UN04c has a Recreation E use classification, which means that people are expected to swim in the river. Segment UN04b has a Recreation N use classification, which means no swimming is expected.

In general, the WQCC applied Table Value Standards for these two stream reaches. However, the WQCC applied a chronic iron site-specific standard (2,250 ug/L) for both segments and a temporary modification for chronic selenium (20 ug/L) for segment UN04b.

WBID	COGUUN04b and COGUUN04c	
Description	COGUUN04b: Mainstem of the Uncompahgre River from La Salle Road to Confluence Park. COGUUN04c: Mainstem of the Uncompahgre River from Confluence Park to the confluence with the Gunnison River	
Use Classification	Aq Life Warm 2, Agriculture, Recreation N (COGUUN04b), Recreation E (COGUUN04c)	
Meets Standards?	**Section not attaining chronic standards**	**Parameters not meeting standards**
No	Entire reach	Selenium, Total Phosphorus *
* Nutrient standards have not yet been adopted in Colorado		

Routine water quality data are sparse for this river reach except a site (Site 55) monitored by the Colorado Water Quality Control Division (WQCD) in Delta. Site 55 is located in Uncompahgre River Segment COGUUN04b, but is a very short distance upstream from segment COGUUN04c. Therefore, water quality data from Site 55 was used to describe conditions in both segments. The Division of Wildlife (DOW) monitored a site in Segment UN04c on the south side of Confluence Park in Delta for one year, 2003 to 2004 (Data provided by Lori Martin, Division of Wildlife). Data from these two sources were assessed to determine temporal and longitudinal water quality changes in the lower Uncompahgre River.

Multiple studies have been conducted to evaluate selenium loading in the lower Uncompahgre River Basin (Butler and Leib, 2002 and WQCD, 2009). This report could not to improve upon their findings. Selenium concentrations in the mainstem Uncompahgre River at Delta will be discussed to a limited degree in this paper and compared to stream standards.

6.13.1 Water Quality

The median pH of the Uncompahgre River in Delta (Site 55) was 8.2 (minimum = 6.53, maximum = 9.5, N=419). Two measurements exceeded the Colorado Table Value pH maximum of 9.0 over the 39 years of record (1968-2007). The pH of a river influences other water quality parameters such as ammonia and iron. For example, the toxicity of ammonia increases as pH increases. The reverse relationship is true for pH and iron. The pH regime of the Uncompahgre River in Delta supports a wide variety and diversity of aquatic life.

The median total dissolved solid (TDS) concentration in Delta was 1,300 mg/L (N=435). A total of 313 measurements exceeded 1,000 mg/L. The total dissolved solids concentrations in the Uncompahgre River in Delta are excessive compared to dissolved solids loadings in many Colorado streams and rivers.

Prior to 1991, the median TDS concentration was 1,430 mg/L. The median TDS concentration decreased to 1,180 mg/L from 1991 to 2004 (Figure 45). The mean monthly TDS concentration decreased for the years 1991 to 2004 compared to the 1968 to 1990 time period (Table 18). The decrease in monthly mean TDS was statistically significant from September through March. The same trend was observed in other water quality parameters including sulfate and hardness. Prior to 1990, flow was maintained in the irrigation ditches on a year round basis. This practice was curtailed in the fall of 1990 (Dan Crabtree, personal communication). Ditches no longer carry water in late fall and winter months. The change in water management demonstrated that irrigation practices can be performed in a manner that can improve water quality in the mainstem Uncompahgre River.

Hardness concentrations were nearly three times higher in Delta than in Montrose. The median hardness in was 203 mg/L $CaCO_3$ in Montrose at LaSalle Road and 673 mg/L $CaCO_3$ (N=392) in Delta. A wide variety of anthropogenic activities may have contributed to the increased hardness concentrations, including irrigation return flows via tributaries.

Sulfate concentrations, like hardness, indicate the amount of solids dissolved in river water. Sulfate concentrations were nearly four times higher in Delta than in Montrose. The median sulfate concentration was 181 mg/L SO_4 in Montrose at the LaSalle Road Bridge and 647 mg/L SO_4 (N=261) in the Uncompahgre River at Delta. The average sulfate concentration was 655 mg/L SO_4 in Delta. The average sulfate concentration exceeded the Colorado water supply standard of 250 mg/L SO_4 by more than 250%. Segments COGUUN04b and COGUUN04c are not designated as a water supply, so the high sulfate values do not constitute a violation of water quality standards. The comparison to standards does, however, demonstrate the degree of relative water quality degradation in the Uncompahgre River in Delta compared to 26 miles upstream in Montrose.

Like total dissolved solids and total iron, the median suspended solids concentration in the Uncompahgre River decreased significantly (Mann Whitney U test, p=0.01) after 1991. Prior to 1991, the median suspended solids concentration was 170 mg/L. After 1991, the median suspended solids concentration dropped to 150 mg/L (Figure 45). The decrease in suspended solids represented an improvement in water quality in the Uncompahgre River that occurred in 1991.

Connecting suspended solids concentrations to adverse environmental impacts is difficult. Suspended solids concentrations can be directly toxic to fish through suffocation and clogged gills. Most studies concerning impacts of suspended solids were performed using coldwater species including trout and salmon. On August 10, 1982, the suspended solids concentration in the Uncompahgre River was 54,300 mg/L. This level exceeded the value (39,400 mg/L) known to be acutely toxic to salmon (Newcomb and Flagg, 1983). In laboratory studies, exposure to suspended solids concentrations of 270 mg/L resulted in mortality to rainbow trout after 19 days (Herbert and Merkens, 1961). Suspended solids concentrations are frequently greater than 270 mg/L in the Uncompahgre River (Figure 46 and 47).

Results of suspended solids toxicity studies on fish populations should be applied with some caution to the lower Uncompahgre River. The Uncompahgre River below

Montrose does not support a trout fishery and to date, no studies have been performed to determine toxic amounts of sediment on the various federally listed endangered fish species found in the Gunnison Basin. Native fish, in general, have adapted to erosional river systems and can maintain populations in sediment filled water such as the Colorado River in desert states such as Utah and Arizona. Many of the federally listed fish species are minnows. Some minnows have adapted to waters with elevated suspended solids loadings. However, minnows have been shown to exhibit reduced growth in when exposed to suspended solids concentrations as low as 25 mg/L (Sutherland and Meyer, 2007) and are thus more sensitive than some trout species to sediment. Other species such as the flathead chub (*Platygobio gracilis*) depend on high sediment loads and their populations have declined with diminishing suspended sediment concentrations.

Cadmium, copper, lead and zinc were not water quality issues in the Uncompahgre River in Delta. Total aluminum data at Site 55 were limited (Table 19). Aluminum standards have not been adopted by the Colorado Water Quality Control Commission for the Uncompahgre River Basin. In winter months total aluminum exceeded the current chronic Table Value Standard that *could* be applied the Uncompahgre River. Data collected by the DOW demonstrated that total aluminum met the state Chronic Table Value Standard in the Uncompahgre River at a sample site less than ¼ mile downstream of Site 55 in the winter of 2003 through 2004 (Figure 48), the opposite observation indicated by Colorado Water Quality Control Division data. The impacts of aluminum on aquatic life cannot be assessed due to relative lack of data, the differences in two data sets, and lack of knowledge of aluminum toxicity at high hardness concentrations (See Appendix 1). Regardless, total aluminum probably was not lethal to aquatic life in the Uncompahgre River at Delta and probably did not result in long-term direct impacts to aquatic life. Aluminum precipitation can, however, cause loss of habitat for aquatic macroinvertebrates and incubating fish eggs.

The median total iron concentration was 1,100 ug/L (N=279) in the Uncompahgre River at Delta. A total of 87 samples (31%) exceeded the site specific standard of 2,250 ug/L. Monthly total iron concentrations were evaluated from 1991 through 2007. The median monthly iron measurements exceeded the existing chronic iron standard of 2,250 ug/L from April through July (Table 20). The total iron did not meet the site-specific chronic iron stream standard in the Uncompahgre River in Delta from April through July for the period of record.

Total iron concentrations decreased in 1991 compared to prior years, but not in the exact same manner as dissolved solids. The median winter (November through February) total iron concentration was 410 ug/L prior to 1991 (Table 21). After 1991, the winter median monthly total iron concentration decreased to 290 ug/L, a significantly lower value than prior to 1990 as determined by a Mann Whitney U test (p=0.01). In direct contrast, the opposite was true in the spring, summer and fall. Median monthly (March through October) total iron concentrations prior to 1991 were 1,700 ug/L. After 1991, the median monthly total iron concentration increased to 4,200 ug/L in March through October, a significantly higher value than years prior to 1990 as determined by a Mann Whitney U test (p=0.0000). Changes to water management in 1991 were followed by a decrease in winter total iron concentrations and increase in warm weather total iron concentrations (Figure 49). The cause or causes of the increase in summer-time total iron measurements is not known. One possibility may be photo reduction of iron during daylight hours, a phenomenon observed in the Animas River in Durango in the 1990s during a DOW monitoring program (John Woodling, unpublished data). An intensive sampling program would be needed to determine the cause(s) of the anomalous increase in total iron in March through October, the irrigation season.

Total iron concentrations in excess of stream standards may result in negative impacts to aquatic organisms. Excessive iron deposition can be directly toxic or cause habitat loss by smothering algae and aquatic macroinvertebrates. However, elevated hardness concentrations and pH levels eliminated the possibility of direct total iron toxicity of iron to fish in the mainstem Uncompahgre River in Delta. Negative impacts of total iron to aquatic biota in the Uncompahgre River at Delta would be limited to indirect actions related to loss of stream bottom habitat.

The 85th percentile of the 114 dissolved selenium measurement was 19 ug/L in the Uncompahgre River at Delta, which exceeded the chronic aquatic life standard of 4/6 ug/L. The Uncompahgre River at Delta did not meet the chronic life standard of 4.6 ug/L. Selenium concentrations varied throughout the year with lowest levels generally in June and July. The highest selenium values were generally measured in January and February (Figure 50). Selenium reductions are needed in every month except September to attain the existing chronic water quality standard in segment 4c. The required load reductions vary from 56% in March to 82% in February of each year (WQCD, 2009).

Dissolved selenium concentrations increased as the Uncompahgre River flowed north from Montrose to Delta. Half of the dissolved selenium concentrations were less than detection limits in the Uncompahgre River in Montrose at LaSalle Road compared to a median level of 13 ug/L at Delta. The increase in selenium is attributable in part to irrigation return flows from systems such as Loutsenhizer Arroyo, Dry Creek and Dry Cedar Creek (WQCD, 2009).

The Uncompahgre River did meet the *E. coli* standard in Montrose at Town Park where the geometric mean was less than 1 colony/100 ml. *E. coli* data at LaSalle Road were not available for this report. The Water Quality Control Division monitors *E. coli* at Site 55 in Delta. The *E. coli* standard in the Uncompahgre River segment COGUUN04b is 630 colony forming units. The *E. coli* standard in segment COGUUN04c (Confluence Park to the confluence with the Gunnison River) is 126 colony forming units. Site 55 is located a few hundred feet above Confluence Park. The geometric mean[8] of the *E. coli* data at Site 55 was 147 colonies/100 ml (N= 37) from 2001 through 2007. The Uncompahgre River may not meet the applicable *E. coli* standard in Delta downstream of Confluence Park. Several sources of *E. coli* exist in the Uncompahgre River Basin upstream of Delta including urban storm water runoff, irrigated pasture lands, and confined animal feedlot operations and effluent from domestic wastewater treatment plants in Montrose and Olathe. The increase in *E. coli* from Montrose to Delta is another example of decreasing in water quality in this short stream reach.

The median nitrate-nitrogen was 2,700 ug/L as N in the Uncompahgre River at Delta (N=217 ug/L). This level represented over a ten-fold increase in nitrogen in the Uncompahgre River compared to concentrations in Montrose where the median nitrate was 110 ug/L as N. The median total nitrogen levels exceeded the calculated background level (80 ug/L) for streams in the Xeric West (Smith et al. 2003) by two decimal points.

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[8] The geometric mean is a type of analysis that indicates the central tendency or typical value of a set of numbers. For instance, the geometric mean of the two numbers 5 and 25, is the square root of their product; that is 5 * 25 = 125. The square root of 125 = 11.18.

Total phosphorus concentrations increased by an order of magnitude in the Uncompahgre River from Montrose (median total phosphorus as P = 20 ug/L) to Delta (median total phosphorus as P = 120 ug/L, N=216). The maximum measurement in Delta was 4,200 ug/L while minimum total phosphorus concentrations were less than detection limits. Total phosphorus stream standards have not been developed or adopted in Colorado. The total phosphorus and nitrate concentrations would support an excessive algal growth in the Uncompahgre River.

The pH in the Uncompahgre River was often greater than 8.5 during low flow, winter months of November and December. The elevated winter pH measurements could be an indication of extensive in-stream algal growth attributable to decreased stream velocity, decreased suspended solids in the water column and elevated nitrogen and phosphorus levels. Extensive algal growth is often observed in Colorado rivers in the months of November and December, prior to formation of ice cover on the river.

The sources of nitrogen to the system include non-point urban runoff, irrigation return flows and domestic wastewater treatment plant effluents in Montrose and Olathe. Natural erosion does not contribute a substantial amount of nitrogen and phosphorus found in the Uncompahgre River since the Mancos shale lands drained by the river in Delta are nutrient poor (USGS, 2004).

6.13.2 Nitrogen Loading

Nitrogen loading in the lower Uncompahgre River is of particular interest because nitrogen concentrations are high relative to other rivers on the western slope of Colorado. Upstream of Montrose, the median nitrate/nitrite concentration was 85 ug/L as N. This concentration is similar to the accepted background nitrogen levels in xeric western streams like the lower Uncompahgre River (Smith *et al.*, 2003). By the time the Uncompahgre River reached Delta, however, the median nitrate/nitrite concentration increased over 30-fold to 2,700 ug/L as N.

The dominant geology in the lower basin, the Mancos Shale, is virtually void of nutrients (USGS, 2004). Therefore, nitrogen loading to the Uncompahgre River between Montrose and Delta is primarily attributable to human activities such as stormwater runoff, wastewater treatment, animal feeding operations and agriculture.

Nitrogen loading in pounds per day as N was determined for the Uncompahgre River in Delta at Site 55 using flow data from USGS flow gages at Colona and Delta, nitrogen data from water quality monitoring stations at Colona and Delta, and wastewater treatment plant Discharge Monthly Reports (DMRs) (See Section 4 for Ridgway Reservoir loading analysis methods). The total nitrogen load in the Uncompahgre River at Colona was determined to be 85,775 pounds per year. In Montrose, the Uncompahgre River gains nitrogen inputs from two wastewater treatment plants and urban stormwater runoff. The effluent from the Olathe domestic treatment lagoon system enters the Uncompahgre River in Olathe. The point-source annual nitrogen loads were estimated at 25,480 lbs/yr from the City of Montrose domestic wastewater treatment plant, 3,254 lbs/yr pounds from the West Montrose domestic waste water treatment plant[9] and 12,782 lbs/year from the Olathe domestic wastewater treatment lagoons. Nitrogen loading estimates from stormwater runoff are not available. The annual nitrogen load in the Uncompahgre River at Delta was 1,192,964 lb/year. Estimated daily nitrogen

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[9] The load from the West Montrose facility was based on an assumed nitrogen concentration of 4 mg/L, a value that is probably higher than the actual concentration of nitrogen discharged from this facility

loads in Delta ranged from 1,579 lb/day in April to 4,915 lb/day in July from 1995 through 2007 (Table 22). Between Montrose and Delta, the Uncompahgre River gains an additional 1,065,673 lbs/yr of nitrogen as N. The sources of the 1,065,673 lbs/yr of nitrogen as N to the Uncompahgre River at Delta include urban runoff from municipalities, agricultural runoff from farms and feeding operations, and irrigation return flows.

Nitrogen is often applied to lawns and farmland as a fertilizer to promote plant growth. The type of nitrogen applied varies based on the crop being grown. Generally anhydrous ammonia is used to fertilize corn, while urea is used to fertilize grass and 11-52 used to fertilize alfalfa fields. Anhydrous ammonia is 82% nitrogen, urea is 46% nitrogen and 11-52 is 11% nitrogen. Application rates for the different forms of nitrogen are partially dependent on how rich in nitrogen the fertilizer is. For example, 1.22 pounds of anhydrous ammonia must be applied to provide one pound of nitrogen to the soil.

Not all of the nitrogen applied to the landscape as fertilizer is taken up by crops. Some of it returns to the Uncompahgre River as agricultural runoff. There are 65,000 acres of irrigated farmland in the Uncompahgre River Basin. Approximately 55,870 acres or 87% of irrigated lands drain into the Uncompahgre River downstream of Dry Cedar Creek in Montrose. The calculated annual nitrogen contribution was 19.06 lbs per irrigated acre downstream of Montrose from 1995 to 2007, based on the assumption that all nitrogen introduced to the river originated from crop fields.

In 2011, farmers in the Uncompahgre Valley were predicted to spend $112.8/acre to fertilize corn with nitrogen (Fruita, Colorado Coop). The 2011 cost for anhydrous ammonia was 47 cents/pound ($940 per ton). The return of 19.06 pounds of nitrogen per acre to the river is the equivalent of 23.3 pounds of anhydrous ammonia fertilizer because the fertilizer is only 82% nitrogen. Thus, $10.94/acre of the fertilizer cost was wasted since 12% of the fertilizer did not reach the crop but returned to the Uncompahgre River to flow downstream.

The loss of $10.94 per acre is an overestimate. Fertilizers other than anhydrous ammonia are used in the Uncompahgre River and crops other than corn are grown in the basin. Nitrogen loading from confined feedlots may be a relatively large contributor per acre. However no data are available to determine the actual loading from feedlots. Urban runoff would also contribute nitrogen, however no data are available. Regardless, irrigators that fertilize a large number of acres are losing a substantial amount of money when nitrogen is not utilized in plant growth but escapes to the Uncompahgre River via runoff and return flows. Increasing irrigation efficiency could decrease the amount of nitrogen reaching the river and decrease operating costs to the farmer.

6.13.3 Summary Uncompahgre River in Delta

The Uncompahgre River is a hard-used River between Montrose and Delta. In Montrose, the Uncompahgre River is a trout stream with relatively few water quality problems. By the time the Uncompahgre River reached Delta the temperature, dissolved solids, nutrients, bacteria, calcium, manganese, sulfate, iron, aluminum and selenium levels increased - often by orders of magnitude. Elevated hardness, selenium, nutrient and sulfate levels in Delta decrease the relative value of the mainstem Uncompahgre River in Delta to Society due to increased monies that would be required to bring the river water within water quality levels for some parameters for some uses.

Increased dissolved salts concentrations occur in the lower Uncompahgre River due to changes in geology, natural plant cover and land use. Metal loading attributable to Red

Mountain Creek in the basin headwaters did not increase metal concentration in the Uncompahgre River near Delta in any measurable way. The increase in total aluminum and total iron concentrations in the Uncompahgre River below Montrose were likely due to agricultural and urban runoff.

Water quality in the Uncompahgre River improved in 1990 when Uncompahgre River water users instituted a winter water program that removed water from irrigation canals in winter months. The change in water management resulted in a significant decrease in dissolved solids, total suspended solids and dissolved salts in the Uncompahgre River in Delta.

Summary: Tributaries to the Uncompahgre River from Montrose to Delta

1. The Uncompahgre River in Delta has high levels of dissolved solids, total iron, aluminum, selenium phosphorus and nitrogen that may be impairing uses of the river.
2. Changes in winter water use resulted in decreased levels of solids and salts in the Uncompahgre River in Delta since 1990.
3. Selenium is a known impairment in the Uncompahgre River. Activities that decrease deep percolation of groundwater can reduce selenium loads.
4. Year round warm water flows in the Fifth Street Ditch in Delta indicated that reduction in water applied to lawns in urbanized areas of the Uncompahgre River Basin may also be a method to reduce contaminate loading to the Uncompahgre River in urbanized areas.

7.0 Summary & Conclusions

The Uncompahgre River flows for 77 miles from Como Lake in the San Juan Mountains in southwest Colorado to the confluence with the Gunnison River in Delta, Colorado. The word Uncompahgre is an English pronunciation of a Ute Indian word roughly meaning "red water spring" or “dirty water.” The water quality in the mainstem Uncompahgre River is influenced by a variety of issues, but five of these issues appeared to be the most important:

1. local geology
2. inputs from Red Mountain Creek
3. inputs from many types and numbers of tributaries
4. the presence and operation of Ridgway Reservoir
5. agricultural influence on water quality

7.1 Influences on Water Quality

Geology

The geology of the Uncompahgre Watershed is complex mixture of sedimentary deposits and igneous intrusions that have a great influence on water quality. Remnants of mineral-rich volcanic materials in the mountains led to naturally elevated levels of metals like iron, zinc and aluminum in headwater tributaries. The geology in the lower portion of the watershed is dominated by Mancos shale deposits. The Mancos shale in particular, is the primary contributor of dissolved mineral salts (hardness) and selenium to the Uncompahgre River downstream of Ouray. The Uncompahgre River had higher hardness levels than many other mountain streams at any given elevation. Hardness is particularly beneficial in headwater streams, as calcium and manganese mitigate metals toxicity. In the lower Uncompahgre River, elevated hardness levels can be detrimental to both wildlife and human endeavors.

Inputs from Red Mountain Creek

Red Mountain Creek drains water from the Red Mountain Massive which is rich in minerals and acid-producing pyrite. Red Mountain Creek also flows through the Red Mountain mining district which has an extensive network of abandoned and inactive mines, adits, tunnels, and waste rock piles. The acidic, metal-laden water in Red Mountain Creek is derived from both natural and man-made sources. Low pH levels and high metal concentrations eliminated most aquatic life including trout in Red Mountain Creek. Dissolved aluminum, cadmium, copper, iron, lead and zinc are each toxic to a wide variety of aquatic life.

The reclamation goal for the CERCLA project in Red Mountain Creek is based on a reduction of zinc in Red Mountain Creek. This reclamation goal has not yet been realized. Data developed since the CERCLA case was settled demonstrated that in addition to zinc and copper, acidity, iron and aluminum also exceeded levels that are lethal to aquatic life. The copper, iron, aluminum and acidity loadings contribute more to the total toxicity in Red Mountain Creek than the zinc loading to the system.

Dilution water

Inputs from numerous tributaries and the Gunnison River via the Gunnison Tunnel and South Canal provide relatively clean flows to the Uncompahgre River, thus diluting the overall concentration of pollutants. In Ouray, flows from Canyon and Oak Creeks reduce acidity and lower metals concentration in the Uncompahgre River despite carrying measurable metals loads.

Water from the Gunnison River is diverted to the mainstem Uncompahgre River during irrigation season to support local water demands. When flowing, the imported water supply contributes dilution water that decreases the dissolved solids concentration in the Uncompahgre River.

Ridgway Reservoir

Water quality in the Uncompahgre River improved downstream of Ridgway Reservoir compared to upstream of the impoundment, because Ridgway Reservoir functions as a metals sink for the Uncompahgre River. More than 90% (1.4 million pounds) of all metals entering Ridgway Reservoir remain in the Reservoir. This metal loading is the equivalent to the sinking of one world war II US Navy Submarine in Ridgway Reservoir each year. The impact of this metal reduction is immediate and far-reaching. Metal concentrations downstream of Ridgway Reservoir were often less than detection limits and were much lower than the existing stream standards applied to the stream reach for all metals save iron. The Colorado Water Quality Control Commission adopted a site-specific total iron standard and temporary modification of 1,500 ug/L and 1673 ug/L, respectively for the Uncompahgre River from Ridgway Reservoir to Montrose. However, the total iron in the mainstem Uncompahgre River was less than the chronic Table Value Standard in 43 of 44 measurements for a six year time period for which data are available. Metal contamination was not an issue below the Reservoir and the segment from the Reservoir to Montrose had the best water quality in the entire Uncompahgre River system.

The operation of Ridgway Reservoir did have a negative influence on the aquatic life downstream of the Reservoir. When the spillway is shut, reservoir operations require that water be released from a release structure at the bottom of the dam, resulting in severe gas bubble trauma in trout, which occurs. Temperature fluctuations and low winter flows due to storage obligations may also be impacting the fitness of trout populations below the reservoir.

Agricultural influence on water quality

Agricultural use of Uncompahgre River lands data back to over a century. About 65,000 acres of land are irrigated in the basin for a variety of uses. Confined animal feed lots are also present in the basin.

7.2 Water Quality Summary

The mainstem Uncompahgre River seems to always be dismissed as a naturally degraded waterway. Indeed, this very report begins in the same manner, emphasizing the negative connotation of the river's very name. The idea is however false. The Uncompahgre River downstream of Ridgway Reservoir is a "gem" of a stream. The river flows through an open pastoral valley of ranches and isolated business ventures downstream of the reservoir all the way to Montrose. A naturally reproducing brown trout cruise the water column all the way from the reservoir to a point downstream of Montrose, belaying the idea that the Uncompahgre River is somehow a degraded system from source to mouth. Much of the Uncompahgre River does have serious water quality issues Upstream of Ridgway Reservoir, acidic water and metals including copper, aluminum and iron derived from the mountains limit aquatic life in the mainstem Uncompahgre River. Below Montrose, the river is laden with salts and selenium.

Evaluation of water quality along the entire length of the Uncompahgre River, however, reveals variations in water quality due to anthropogenic influences. For example, each year Ridgway Reservoir traps millions of pounds of metals and sediment. As a result, water quality below the Reservoir is nearly pristine. Metal concentrations were often less than detection limits and nutrient levels were close to levels typical of undisturbed mountain streams. Water quality degrades, downstream of Montrose due to both natural erosion and as runoff from urban development and agriculture practices contribute nutrients, selenium, dissolved solids, and bacteria to the Uncompahgre River.

The metal loading upstream of Ridgway and the dissolved solids loading downstream of Montrose can be ameliorated to various degrees. Neither section will likely become pristine river reaches, but the value of both stream reaches to the community could be improved.

The following sections are reiterations of water quality summaries of each segment of the Uncompahgre River evaluated as part of this report.

Uncompahgre River source to Red Mountain Creek

The Uncompahgre River above Red Mountain Creek was not pristine. Metal concentrations exceeded the chronic Colorado Table Value Standards for cadmium, copper, lead and zinc. Aluminum concentrations exceeded the applicable hardness based chronic Table Value Standard that would be applied to the Uncompahgre River upstream of Red Mountain Creek if and when the Colorado Water Quality Control Commission adopts aluminum standards for the Uncompahgre River basin. The water quality of the mainstem Uncompahgre River improved, however, as the stream flowed downstream to the juncture with Red Mountain Creek.

A naturally reproducing trout population inhabits the Uncompahgre River just upstream of the river's confluence with Red Mountain Creek, although numbers and growth may be negatively impacted due to elevated metals. The current aquatic biota found in this stream reach could be designated as the reclamation goal for the Uncompahgre River downstream of Red Mountain Creek following implementation of meaningful recovery programs within the Red Mountain Creek Basin. The water quality regime in the Uncompahgre River downstream of the confluence with Red Mountain Creek would have to be similar to the water regime upstream of Red Mountain Creek to realize such an objective.

Red Mountain Creek Source to confluence with the East Fork of Red Mountain Creek

Red Mountain Creek from the source to the confluence with East Fork Red Mountain Creek is a typical headwater stream system. Zinc and pH did not attain chronic Table Value Stream Standards for aquatic life and would be expected to induce some degree of toxic impact to a wide variety of aquatic biota. However, small stream channel size and flow and low temperature regimes probably precluded natural colonization by fish. The zinc in upper Red Mountain Creek was considered to be either natural background or the result of non-point source loading.

Red Mountain Creek East Fork of Red Mountain Creek to Uncompahgre River

Metal concentrations and acidity make Red Mountain Creek one of the most contaminated waters in Colorado. Nearly 100 years of mining activity along with natural contamination and poor habitat result in a stream nearly devoid of aquatic life. The stream acidity along with dissolved aluminum, cadmium, copper, iron, lead and zinc all were at levels acutely lethal to aquatic life. Copper, iron and aluminum concentrations were more toxic to aquatic life than the cadmium, lead or zinc concentrations in Red Mountain Creek.

The State of Colorado and Newmont Mining Company selected zinc as the measure of compliance in Red Mountain Creek at a point "below Red Mountain Tailings Number 4 and above the confluence with Grey Copper Gulch" (Price 2008). The compliance objective is a concentration of 1,500 ug/L dissolved zinc or less from samples collected on six days from August 15 through September 15 at a flow from 1380 gallons per minute to 1,690 gallons per minute. To date, Newmont Mining has not met that objective, although Newmont Mining Company did complete the all activities included in the settlement agreement between the State of Colorado and the mining company.

Monitoring results from1985 to 2007 failed to detect any decrease of zinc on an annual basis. However, dissolved zinc concentrations appeared to decrease at the compliance-monitoring site in the month of May from 1985 to 2007. Dissolved zinc may also have decreased for the months of March and April. A more robust data set would be needed to validate the March and April decreases in zinc over the last 20 plus years. Reclamation projects implemented by Newmont may be the cause of the reduced zinc loading in March, April and May prior to the onset of spring snowmelt, although adequate data to verify this observation were not collected. The existing CERCLA remedy was based on reducing the zinc concentrations in Red Mountain Creek. However, aluminum, iron and copper likely contribute the largest amount of toxicity to mainstem Red Mountain Creek. Thus, the existing CERCLA remedy based on zinc criteria does not accurately describe or address the contaminants most responsible for the degraded conditions in the basin.

Red Mountain Creek may never have been a pristine stream. Past studies including Nash (2002) and Runkel et al. (2007) all indicated the natural loading of metals to Red Mountain Creek was of a magnitude sufficient to decrease numbers and kinds of aquatic life that could be present. However much of the current metal loading to Red Mountain Creek is attributable to a low number of sources (MFG, 1991, Runkel et al. 2002). Treatment of a low number of metal sources could reduce metal loading in the Uncompahgre River downstream of Red Mountain Creek to the point brown trout could survive. However, such a treatment scheme would not result in Red Mountain Creek attaining current chronic Table Value Standards or even pre-mining conditions. Treatment would be aimed at improving water quality in the mainstem Uncompahgre River in Ouray.

Uncompahgre River from Red Mountain Creek to Canyon Creek in Ouray

Water quality was poor in the Uncompahgre River downstream of the Red Mountain Creek confluence to Canyon Creek in Ouray. Metal concentrations and acid levels in the Uncompahgre River mainstem from the confluence of Red Mountain Creek to the Canyon Creek confluence were lower than those in Red Mountain Creek but still exceeded applicable stream standards. Aluminum, copper and iron concentrations were acutely toxic to brook trout and brown trout and pH was low enough to eliminate trout reproduction. Copper appeared to be the metal that limited aquatic life in the Uncompahgre River from Red Mountain Creek to Canyon Creek more than cadmium, lead and zinc. Reduced numbers of brook trout and brown trout may be able to tolerate the cadmium, lead and zinc regimes currently present in the Uncompahgre River from Red Mountain Creek to Canyon Creek if other parameters such as pH, aluminum, copper and iron were not present in lethal concentrations.

The operation of the Ouray Hydropower Station also influenced water quality in the Uncompahgre River. The hydro station is located on the mainstem Uncompahgre River above Canyon Creek. Most of the year, the hydro dam traps metal-laden sediments from the upper watershed. The sediment is periodically flushed out of the dam to maintain storage capacity. During flushing operations, metals concentrations increased downstream of the dam. Copper and lead concentrations resulting from the release may have been acutely toxic to fish. The flushing process did not add any metals on an annual loading basis. However, the flushing operations may cause instantaneous, acutely toxic conditions that prevent fish colonization. This stream reach could be considered for inclusion on the WQCC 303d list for a wide variety of constituents including pH, aluminum, cadmium, copper, iron, lead and zinc.

Canyon Creek and Oak Creek

Water quality in Canyon Creek infrequently violated metal stream standards for pH, cadmium, copper, lead, zinc, total iron and aluminum near the confluence with the Uncompahgre River. However, brook trout maintain a naturally reproducing population in the lower reaches of Canyon Creek. Metal concentrations in the lower end of Canyon Creek were less than in the mainstem Uncompahgre River where the two waters merge. As a result Canyon Creek waters diluted the metal concentrations in the Uncompahgre River. Canyon Creek could be used as a surrogate to describe what aquatic life conditions could be like if mainstem Uncompahgre River pH and metal regimes were similar to those in Canyon Creek. Canyon Creek may actually represent a cold water class 1 system and warrant a change in aquatic life use as designated by the Colorado Water Quality Control Commission even though the stream is currently on the 303 d list.

Oak Creek is a pristine Colorado Mountain stream. Neither metals or nutrients concentrations even approached applicable stream standards or concentrations typical of small mountain waterways. Oak Creek diluted the metal loading of the Uncompahgre River through Ouray. Oak Creek was also designated as a class 2 cold water stream segment by the WQCC. The designation of Oak Creek warrants a change to a class 1 cold water segment.

Uncompahgre River from Canyon Creek to Ouray USGS gage station

The Uncompahgre River was a stream in transition from Oak Creek to the USGS gage in Ouray. Metal concentrations were often higher at the Ouray USGS station compared to upstream the site near Oak Creek. The decreased metal concentration at Oak Creek was attributable to the operation of the Ouray Hydropower Station which removed metal laden water from the Uncompahgre River upstream of Canyon Creek and then discharged the same water with the same metal loading downstream of the Oak Creek. Water quality data at the Ouray USGS gage station provides a more accurate description of the water quality regime in this stream reach because all of the flow from the Uncompahgre River upstream of Canyon Creek has been returned to river.

Flows from both Oak and Canyon Creeks provide dilution water and additional hardness to the Uncompahgre River. Copper, iron and aluminum concentrations would either be acutely or chronically toxic, reducing both numbers and kinds of species present.. Lead toxicity may not be an issue in this stream reach. The low lead and zinc concentrations would permit limited brook and brown trout colonization in the mainstem if copper, iron and aluminum concentrations were reduced from the system. The Uncompahgre River mainstem is not likely to support an aquatic life assemblage sensitive to metals in Ouray.

Uncompahgre River from USGS Ouray Gage to Ridgway Reservoir

Water quality improved in the Uncompahgre River from Ouray to Ridgway Reservoir. Metals such as copper, lead and zinc, normally associated with metal contaminated streams decreased to concentrations lower than chronic Table Value Standards in most samples. Cadmium concentrations violated chronic stream standards in the upper portion of this reach, but not in the downstream end of the segment. Total aluminum and total iron concentrations throughout this stream reach exceeded various stream standards and may have been toxic to trout. The impacts from iron can be attributed to habitat loss as deposits of this metal cover the stream substrate. Concentrations of all metals except aluminum decreased in spring months due to the dilution effects of snow melt waters. In contrast, aluminum concentrations increased during spring snowmelt months as the metal appeared to re-suspend and flow towards Ridgway Reservoir during periods of elevated stream flows in the months of May and June each year.

Much of the stream substrate in this section is covered with fine black sediments in areas of low velocity and in backwaters and eddies,. These sediments fill the interstitial spaces of the gravel and cobble thus eliminating the physical habitat needed by aquatic invertebrates and the areas where trout eggs could incubate. These deposits are extensive. The magnitude of these sediments is such that aquatic life in the below Ouray would be reduced in numbers and species even of all metals were removed from the water column. These same fine black sediments are found in Canyon Creek where a reproducing brook trout population is present. The Canyon Creek sedimentation was not as extensive as that found in the mainstem Uncompahgre River. Restoration of the

Uncompahgre River would have to include efforts to reduce the loading of these fine sediments. The source of the fine sediments is not known, but probably originates from a variety of sources including canyon Creek, Skyrocket Creek and others.

Ridgway Reservoir

Ridgway Reservoir is the pivotal control point for water quality in the Uncompahgre River. Ridgway Reservoir acts as a sink for metals. As a result, metals toxicity is not a water quality concern downstream of the Reservoir. The amount of iron and aluminum stored in Ridgway Reservoir, nearly 3 million lbs/year, is equivalent to sinking a World War Two submarine to the bottom of the Reservoir every year. Without the reservoir, the metals in the Uncompahgre River would continue to flow downstream and limit aquatic life in the system.

The aquatic community below the reservoir was distinctly better than the community above the reservoir, but the trout fishery could be improved. Macroinvertebrate species richness was higher than above the reservoir, but still low compared to most Colorado mountain streams. The trout population found downstream of the Reservoir would not exist in the river without the presence of the reservoir. However, trout numbers in the Uncompahgre River remain lower than other rivers of similar size in Colorado. Possible causes of reduced trout numbers and macroinvertebrate taxa are gas bubble trauma, low winter flows and altered temperature regime. Sediment deposits appeared to be an issue reducing aquatic macroinvertebrate species in the Uncompahgre River reach immediately downstream of Ridgway Reservoir.

The Uncompahgre River from Colona to Montrose

The Uncompahgre River from Ridgway Reservoir to Montrose transitioned from a forested mountain stream to one where agriculture and increasing urban development fill an ever-widening river valley. Stream temperatures were appropriate to support trout populations. The concentrations of dissolved cadmium, copper, lead and zinc were far less than the existing chronic Table Value Standards and in many cases, less than detection limits. Total aluminum concentrations frequently exceeded the chronic Table Value Standard that would be applied to the Uncompahgre River basin if and when the WQCC adopts aluminum standards. In general the water quality was better in this segment than in any other mainstem river reach from the source to the confluence with the Gunnison River. The site-specific total iron standard and existing temporary modification for iron are not appropriate for this stream reach and should be removed by the WQCC.

The Uncompahgre River in Montrose, Highway 90 Bridge to LaSalle Road

Agriculture and increasing urban development begin to exert a larger influence on the Uncompahgre River in Montrose. The dissolved solids increase as the stream flows downstream towards LaSalle Road. High dissolved solids concentrations can diminish the economic and ecological value of the Uncompahgre River. In general the water quality was still better than standards applied to this segment.

The Uncompahgre River from Highway 90 to the LaSalle Road Bridge was designated as a class 2 warm water stream. However, stream temperatures are low enough to support trout populations near LaSalle Road and a reproducing brown trout population inhabits this stream reach. In order to set in place additional protection of ambient stream conditions, this segment warrants a change in designation from a class 2 warm to a class 1 cold water stream with Tier 2 temperature standards.

Tributaries to the Uncompahgre River from Montrose to Delta

The water chemistry of the Uncompahgre River between Montrose and Delta is degraded by the poor water quality in Cedar Creek, Loutsenhizer Arroyo, Dry Creek and other small tributaries as exemplified by the Fifth Street Ditch in Delta. Each of these tributaries contributed different combinations of contaminants to the mainstem Uncompahgre River. Dissolved solids, nutrients, selenium, iron and aluminum concentrations were higher in Dry Cedar Creek (dissolved solids only), Cedar Creek, Loutsenhizer Arroyo and Dry Creek than in the mainstem Uncompahgre River. The relatively high water temperature and dissolved solids, in these tributaries was in-part attributable to naturally arid, salt-laden, erodible lands in the lower basin. However, intense agricultural land use contributed to increased nutrient, bacterial, dissolved solids, aluminum and iron loads.

Uncompahgre River in from Montrose to Delta

The Uncompahgre River is used hard by human society in the 20 mile stream reach from Montrose to Delta. The Uncompahgre River is a healthy trout stream in Montrose. As the river continued downstream to Delta, temperatures, dissolved solids, nutrients, calcium, manganese, sulfate, iron, aluminum and selenium increased, often by orders of magnitude. Sources of aluminum and iron concentrations measured in Delta are probably not from the metals-rich headwater streams like Red Mountain Creek. Rather, the sources of aluminum and iron in the mainstem Uncompahgre River in Delta are a function of local geology and agricultural use of land and water and urban runoff. An increase in dissolved solids would be expected in the lower Uncompahgre River due to changes in geology and land use. The dewatering of irrigation canals resulted in a significant reduction in total dissolved solids and total suspended solids in the mainstem Uncompahgre River starting in 1991. The dewatering program provided an indication that negative impacts of agricultural activities on water quality can be mitigated. One interesting anomaly was observed. The total iron concentrations in the Uncompahgre River appeared to increase in the spring, summer and fall months in Delta since 1991 while total dissolved salts and total suspended solids decreased.

7.3 Recommendations

The Uncompahgre River water quality varies throughout the watershed. A variety of steps could be instituted to improve water quality along the length of the basin. The following section outlines changes in the regulatory system, data gaps and projects that could increase understanding and health of the Uncompahgre River.

1. Changes to WQCC segmentation, classifications, water quality standards and 303d listings

   The Colorado Water Quality Control Commission (WQCC) divided the mainstem Uncompahgre River and tributaries into a series of stream segments according to existing or potential “uses” of water in the stream and then assigning an appropriate suite of water quality standards to protect these uses. The initial set of stream segments and stream standards has been modified through time as the WQCC acknowledged proposals from various entities or the Water Quality Control Division staff that better described actual uses and conditions. Results of the analyses presented in this report have indicated that the current segmentation system and stream standards warrant further examination and some additional changes. The recommended changes are listed below.

a) ***Re-segmentation of Uncompahgre River segment COGUUR3a***
Uncompahgre River segment COGUUR3a includes the mainstem Uncompahgre River from the point where Red Mountain Creek enters the river to the Highway 90 Bridge in Montrose. Ridgway Reservoir is a separate segment, COGUUR3b. Water quality (metal concentrations) differs by orders of magnitude in the mainstem Uncompahgre River upstream and downstream of Ridgway Reservoir. Upstream metal concentrations were toxic to sensitive aquatic life in some parts of this stream reach and the water was too acidic to support aquatic life.

Downstream of Ridgway Reservoir, metal concentrations are often below detection limits and are well below the applicable aquatic life class 1 Table Value Standards and/or site specific standards applied to the segment by the WQCC. Inclusion of data collected below of the Reservoir underestimates the influence of metal concentration found upstream of the impoundment. Likewise, inclusion of data above of the Reservoir provides the impression that metal concentrations are much higher than what are actually present. Segment 3a should be re-segmented based on localized conditions to better reflect ambient water quality. At a minimum, we recommend dividing this segment into two segments: Uncompahgre River from Red Mountain Creek to Ridgway Reservoir and Uncompahgre River from below Ridgway Reservoir to Highway 90 Bridge in Montrose.

b) Reclassification of Uncompahgre River segment COGUUR4a
Uncompahgre River segment COGUUR4a includes “the mainstem Uncompahgre River from the Highway 90 Bridge in Montrose to the La Salle Road Bridge.” Segment COGUUR4a is listed as a warm water class 2 aquatic life reach. However, the presence of a reproducing trout population and a cold water temperature regime indicate that this segment may meet coldwater class 1 criteria with Tier 2 temperature standards.

c) Reclassification of Uncompahgre River segment COGUUR5
Uncompahgre River segment 5 includes “all tributaries to the Uncompahgre River from the source to a point immediately below the confluence with Dexter Creek” with some exceptions. Segment 5 is listed as a class 2 cold water stream system. A class 2 aquatic life designation is an indication that the aquatic life in a stream segment is impaired by either natural or nonreversible human actions. Many of the tributaries in this segment warrant class 1 cold water designation. Canyon Creek supports a naturally reproducing brook trout population with multiple age classes and Dexter Creek contains a sustainable trout population. Oak Creek is a pristine stream but does not contain fish. However, thousands of small, fishless, headwater streams in Colorado were classified as class 1 coldwater systems when the WQCC first applied use designations in the 1970s. These small Uncompahgre Basin tributaries must be treated in the same manner as headwater systems throughout Colorado and receive the same level of protection. The aquatic life classification of several tributaries included in segment 5 needs to be reconsidered by the WQCC to insure that the correct designated aquatic life use is applied.

d) Reclassification of Uncompahgre River segment COGUUR10
Uncompahgre River segment COGUUR10 includes “all tributaries to the Uncompahgre River from a point immediately below the confluence with Dexter Creek to the South Canal” with some exceptions. Segment 10 was designated as a class 2 cold water stream system. Several tributaries, including Dallas Creek, included in Segment 10 appear to be more representative of a class 1 aquatic life system. The aquatic life classification of several tributaries included in segment

COGUUR10 needs to be reconsidered by the WQCC to insure that the correct designated aquatic life use is applied.

e) ***Reclassification of Uncompahgre River Segment COGUUR12***
Uncompahgre River Segment COGUUR12 includes all tributaries to the mainstem Uncompahgre River from the South Canal to the confluence with the Gunnison River. Segment 12 was designated as a class 2 warm water system. Dry Cedar Creek appears to be more representative of class 1 warm water aquatic life system. The classification and standards for Dry Cedar Creek needs to be reconsidered by the WQCC to insure that the correct designated aquatic life use is applied.

f) ***Adoption of Aluminum Standards***
Aluminum toxicity is a major concern in the Uncompahgre River Watershed. However, aluminum standards have not been adopted by the WQCC for any stream reach in the Uncompahgre River Basin. As a result, point-source aluminum discharges to the river are not regulated via TMDLs or discharge permits. Aluminum standards should be developed by the WQCD or other entity and adopted by the WQCC.

g) ***Elimination of temporary modification from stream reaches where ambient water quality meets Colorado WQCC Table Value Standards.***
A temporary modification for cadmium of 1.1 ug/L was adopted by the WQCC for existing COGUUR 3a (the Uncompahgre River from a point downstream of Red Mountain Creek to the Highway 90 bridge in Montrose). Cadmium concentrations meet the current WQCC chronic Table Value Standard in the mainstem Uncompahgre River from a point downstream of Ridgway Reservoir to the Highway 90 Bridge in Montrose. The cadmium temporary modification is not appropriate for the Uncompahgre River downstream of Ridgway Reservoir to the Highway 90 Bridge and should be removed since this river reach meets the current Table Value Standard. The cadmium temporary modification should also be removed from that portion of the mainstem Uncompahgre River upstream of Ridgway Reservoir where the river meets the current Table Value Standard.

A temporary modification for total iron of 1,673 ug/L has been adopted by the WQCC for existing COGUUR 3a (the Uncompahgre River from a point downstream of Red Mountain Creek to the Highway 90 bridge in Montrose). Total iron concentrations meet the current WQCC chronic Table Value Standard in the mainstem Uncompahgre River from a point downstream of Ridgway Reservoir to the Highway 90 Bridge in Montrose. The total iron temporary modification is not appropriate for the Uncompahgre River downstream of Ridgway Reservoir to the Highway 90 Bridge and should be removed since this river reach meets the current Table Value Standard. Likewise the existing site specific total iron standard of 1,500 ug/L is not appropriate for that portion of the Uncompahgre River from a point downstream of Ridgway Reservoir to the Highway 90 Bridge in Montrose since the segment meets the current Table Value Standard. The current table value standard of 1,000 ug/L is appropriate and should be adopted for the Uncompahgre River from Ridgway Reservoir to the Highway 90 Bridge.

2. Filling Data Gaps

Additional water quality data would assist in developing an adequate regulatory framework that reflects ambient water quality and designing projects to improve water quality in the Uncompahgre River basin. Sampling programs have been described throughout the preceding report. A list of sampling needs includes:

a. ***A more intense sampling program is needed in Red Mountain Creek***
   This program should include a sampling site at the mouth of Red Mountain Creek. Sampling by Newmont Mining should also be expanded to include additional parameters such as hardness, dissolved cadmium, copper, lead, aluminum and iron. The current sampling program as agreed to by the State of Colorado and Newmont Mining results only in the analysis of zinc. However, copper, aluminum, and iron contribute more to the toxicity of Red Mountain Creek than zinc. More information is needed for cadmium, copper, lead, aluminum and iron to better understand the contamination in Red Mountain Creek and define improvements needed to define appropriate restoration strategies for Red Mountain Creek.

b. ***Special study to document the influence of the Ouray Hydropower Station flushing events.***
   The influence of the flushing operations at the Ouray Hydropower Station on the metals regime of the Uncompahgre River requires further examination. A series of samples should to be analyzed for dissolved and total metals during two of the upcoming flushing operations. Each sample should be analyzed for calcium, cadmium, copper, iron, lead, magnesium, zinc, pH and suspended solids to allow for a determination of the toxic impacts of the flushing operation in the Uncompahgre River from Ouray to Ridgway Reservoir.

c. ***Documentation of metal and sediment loads from summer storms***
   The influence of episodic metal loadings associated with summer storm events needs to be quantified in the Uncompahgre River in the stream reach extending from Ouray to Ridgway. This sample program would include collection of samples during and after storm events. Multiple sites should be established to evaluate metals loads from major tributaries.

d. ***Fall and winter substrate sampling***
   A fall and winter stream substrate sampling program is needed in the mainstem Uncompahgre River from Ouray to Ridgway to determine the source of fine sediments that may be limiting aquatic macroinvertebrates and fish populations in that stream reach.

e. ***Temperature monitoring***
   Temperatures regimes need to be clarified for the Uncompahgre River in Montrose to assure that temperature standards and the aquatic life classification for this stream reach protect the existing aquatic assemblage. Temperature loggers should be installed upstream and downstream of La Salle Road.

f. ***Nutrient loading study***
   Nitrogen and phosphorus levels introduced to the mainstem Uncompahgre River from these tributaries are much higher than in most western Colorado streams and rivers. A sampling program designed to better understand the influence of confined feedlots on nutrient loadings to the Uncompahgre Basin would allow for design of appropriate control measures. The influence of confined feedlot operations needs to be determined in the Uncompahgre River from Montrose to Delta including tributaries such as Dry Cedar Creek, Cedar Creek, Loutsenhizer Arroyo and Dry Creek. Waters fro m these four tributaries, especially The Loutsenhizer Arroyo, degrade the water quality of the mainstem Uncompahgre River.

3. Next Steps

a. ***Amend reclamation goals from zinc-based in Red Mountain Creek to Brown and Brook Trout colonization of the Uncompahgre River in Ouray.***

Red Mountain Creek was and remains a source of acid and metal loading to the mainstem Uncompahgre River that degrades the aquatic life in the river. The compliance goal is based on zinc concentrations in Red Mountain Creek at the compliance point below Tailings Pile 4. This compliance goal has not been achieved. Treatment or restoration of all anthropogenic contaminant sources in Red Mountain Creek would not likely result in a stream that meets applicable chronic stream standards. However, a reclamation goal of a brown or brook trout fishery in Ouray could serve as a reclamation objective for Red Mountain Creek. Reclamation projects targeted at 4 or 5 number of key sources could allow brown trout and brook trout to colonize the mainstem Uncompahgre River below Red Mountain Creek. A field experiment using temporary artificial wetlands without rooted aquatic plants could test the efficacy of this proposal. The potential exists for using hydropower to provide power for any such reclamation projects. Reclamation goals for Red Mountain Creek need to be established for copper, aluminum, iron and acidity as these parameters contribute more to the toxicity in Red Mountain Creek than zinc.

b. ***Increased participation in best management practices that contribute to soil health.***

Improving water quality in tributaries to the lower Uncompahgre River necessitates the treatment of nonpoint loading sources. The solution is not to eliminate agricultural activities or the creation of onerous regulations and controls that increase costs and decrease options. One option is to increase irrigation efficiency and decrease the amount of water applied to irrigated lands. Lining and piping of irrigation water, use of spray and drip irrigation and surge irrigation are all activities that reduce the total amount of water applied to irrigated lands and the amount of return water to natural waterways.

c. ***Increased participation in water conservation efforts that minimize deep percolation of groundwater into the Mancos Shale.***

A more holistic view of water quality management is warranted in the Uncompahgre River downstream of Montrose where current activities only target salt and selenium reductions. Reducing or altering the way water is used for irrigation of both crops and home lawns could reduce contaminant loads to the Uncompahgre River. Municipal entities such as Montrose, Olathe and Delta could adopt regulations to encourage xeriscaping in existing neighborhoods and developments while requiring xeriscaping on previously non-irrigated lands.

The End

8.0 Works Cited

Baker, J. P., and C. L. Schofield. 1982. Aluminum toxicity to fish in acidic waters. Water, Air and Soil Pollution 18:289-309.

Besser, J.M., A.L. Allert, D. Hardesty, C.I. Ingersoll, T.W. May and K. J. Leib. 2001. Evaluation of metal toxicity in stream affected by abandoned mine lands. Upper Animas river Watershed, Colorado. Biological Science Report. USGS/BRD/BSR 200-0001. USGS. Columbia, Missouri.

Barlaup, B. T., A. Hindar, E. Kleiven, and R. Hogberget. 1996. Incomplete mixing of limed water and acidic runoff restricts recruitment of lake spawning brown trout in Hovvatn southern Norway. Environmental Biology of Fishes 53:47-63.

Brinkman, S. and J. Woodling (2005). Zinc toxicity to the mottled sculpin (*Cottus bairdii*) in high-hardness water. Environmental Toxicology and Chemistry 24: 1515-1517.

Brinkman, S., P.H. Davies, D. Hansen, N. Vieira. 2006. Arkansas River Research study. Final Report. Period April 1994 to December 30, 2005. Colorado Division of Wildlife. Fort Collins, Colorado.

Butler D.L. and K.J. Leib. 2002. Characterization of selenium in the lower Gunnison River Basin, Colorado, 1988-2000. U.S. Geological Survey. Water-Resources Investigation Report 02-41-51. Denver, Colorado.

Carter and Burgess. 2007. Tri-county, Ridgway Reservoir Water Study Final Report.

Cleveland, L., E. E. Little, S. J. Hamilton, D. R. Buckler, and J. B. Hunn. 1986. Interactive toxicity of aluminum and acidity to early life stages of brook trout. Transactions of the American Fisheries Society 115:610-620.

Craft, D. and J. Miller. 2001. Reservoir sediment-water microcosm simulation: pre-impoundment predictions vs. observed water quality at Ridgway Reservoir, Ridgway, Colorado. National Technological Information Service. Springfield Virginia.

Colorado Water Quality Control Commission. 2010. 5 CCR 1002-93, REGULATION #93. COLORADO'S SECTION 303(D) LIST OF IMPAIRED WATERS AND MONITORING AND EVALUATION LIST. Denver, Colorado.

Davies, P. H., J. P. Goettl, J. R. Sinley, and N. F. Smith. 1976. Acute and chronic toxicity of lead to rainbow trout (Salmo gairdneri), in hard water and soft water. Water Research 10:199-206.

Daye, P. G. 1980. Attempts to acclimate embryos and alevins of Atlantic salmon, *Salmo salar*, and rainbow trout, *S. gairdneri,* to low pH. Canadian Journal of Fisheries and Aquatic Science 37:1038-1038.

Dalzell, D. J. B., and N. A. A. Macfarlane. The toxicity of iron to brown trout and effects on the gills: a comparison of two grades of iron sulfate. Journal of fish biology 55(2):301-315.
Decker, C., and R. Menendez. 1974. Acute toxicity of iron and aluminum to brook trout. Proceedings of the West Virginia Academy of Science 46(2):159-167.

Freeman, R. A., and W. H. Everhart. 1971. Toxicity of aluminum hydroxide complexes in neutral and basic media to rainbow trout. Transactions of the American Fisheries Society 100:644-658.

Herbert, D.W., J.S. Alabaster, M.C. Dart and R Loyd. 1961. The effect of shina-clay wastes on trout streams. International Journal of Air and Water Pollution. 5:56-74.

Herbert, D.W. and J.C. Merkens. 1961. The effects of suspended mineral solids on the survival of trout. International Journal of Air and Water Pollution. 5:46-55

Ikuta, K. S., T. Shikama, S. Oda, and N. Okumoto. 1992. Acid tolerance of eyed embryos and larvae in salmonid fishes. Bulletin of National Research Institute of Aquaculture 21:39-45.

Hunter, J. B., S. L. Ross, and J. Tannahill. 1980. Aluminum pollution and fish toxicity. Journal of the Water Pollution Control Federation 79:413-420.

Johnson, S. 2002 . Use Attainability Analysis, Aquatic Life Use – Idarado NRD Site. Colorado Department of Public Health and the Environment, Water Quality Control Division. Denver, Colorado.

Kowalski, Dan. 2009. Macroinvertebrate samples

Mackey, K. 2000. Combined assessment, analytical results report, Canyon Creek Watershed, Ouray County, Colorado. Colorado Department of Public Health and Environment. Hazardous Materials and Waste Management Division. Denver, Colorado.

Martin, Lori. 2003-2004. CDOW. Delta irrigation ditches

McKim, J. M. and D. A. Benoit (1971). "Effects of long-term exposure to copper on survival, growth and reproduction of brook trout (*Salvelinus fontinalis*)." Journal fisheries research board of Canada. 25(5): 655-662.

MFG. 1990. Technical Memorandum Red Mountain Creek Basin Study Low Flow Conditions. Draft for Review McCulley, Frick and Gilman. Boulder, Colorado.

MFG. 1991. Technical Memorandum Red Mountain Creek Basin Study Flow Sping 1990 High Flow Conditions Volume I. McCulley, Frick and Gilman. Boulder, Colorado.

Nash, J.T., 2002, Hydrogeochemical investigations of historic mining districts, Central Western Slope of Colorado, including influences on surface water quality: U.S. Geological Survey Digital Data Series 73, 168 p.

Newcomb, T.W. and T.A. Flagg. 1983. Some effects of Mount St. Helens ash on juvenile salmon smolts. US National Marine Fisheries Service Revew 45:8-12.

O’Grady, M. 2005. Combined assessment analytical results report upper Uncompahgre River watershed Ouray and San Juan Counties, Colorado. Colorado Department of Public Health and the Environment, Hazardous Materials and Waste Management Division. Denver, Colorado.

Price, C. 2001. Sampling of the May, 2001 sediment release from Ouray Hydro Dam. Report released by Colorado Department of Public Health and the Environment, Hazardous Materials and Waste Management Division. Denver, Colorado.

Price, C. 2008. Idarado Mine remediation measure of success. Report released by Colorado Department of Public Health and the Environment, Hazardous Materials and Waste Management Division. Denver, Colorado.

Runkel, R.L., Kimball, B.A., Walton-Day, K. and Verplank, P.L. 2005. Geochemistry of Red Mountain Creek, Colorado, under low-flow conditions, August 2002. Scientific Investigations report 2005-5101. USGS. Reston Virginia.

Runkel, R.L., Kimball, B.A., Walton-Day, K. and Verplank, P.L. 2007. A simulation based approach for estimating premining water quality: Red Mountain Creek, Colorado. Applied Geochemistry. 22:1899-1918.

Weiner, G. S., C. B. Schreck, and W. L. Hiram. 1986. Effects of low pH on reproduction of rainbow trout. Transactions of the American Fisheries Society 115:75-82.

Rockwell, Wilson. 1965. Uncompahgre Country. Sage Books. Denver, CO.
Rouse, J.V. 1970. Mine drainage and other sources of heavy metal pollution in the San Juan Mountains and other portions of the Colorado River basin: Denver, Federal Water Quality Am., Colorado River-Bonneville Basins Office, 22p; as quoted in Colorado Water Resources Circular 25.

Smith, R. A., R. B. Alexander, and G. E. Schwarz. 2003. Natural background concentrations of nutrients in streams and river of the conterminous United States. Environmental Science and Technology 37:3030-3047.

Stuller, J. 1997. Golf gets back to nature, inviting everyone to play. Smithsonain. 28:56-67.

Sutherland, A.B. and J.L. Meyer. 2007. Effects of suspended sediment on growth rate and gill condition of two southern Appalachian minnows. Environmental Biology of Fish. 80:389-403.

Thomas, J.C., K.J. Leib, and J.W. Mayo. 2008. Analysis of dissolved selenium loading for selected sits in the lower Gunnison River Basin, Colorado. 1978-2005. US Geological Survey. Scientific Investigations Report 2007-5287. Reston, Va.

Todd, J.W., J. Woodling, D.W. Reiser and G. Andes. 1982. Recovery of a Colorado stream affected by acid mine drainage. in. Issues and Technology in the management of impacted western wildlife. Proceedings of a national symposium. R. D. Comer, Joe Merino. Editors. Thorne Ecological Institute. Boulder, Colorado.

U.S. Geological Survey. 2004. Geology of Gunnison Gorge National Conservation Area, Montrose County, Colorado. Fact Sheet 3050-04.

WQCD, 2009. Total Maximum Daily Load Assessment Red Mountain Creek/Uncompahgre River, San Juan/Ouray/Montrose County, Colorado. Final Draft.

WQCD, 2009. Total Maximum Daily Load Assessment Gunnison River and Tributaries Uncompahgre River and Tributaries, Delta/Mesa/Montrose Counties, Colorado. Public Notice Draft.

WQCD, 2009. Use Attainability analysis Uncompahgre River.

9.0 Appendices

Appendix 1: Aquatic Toxicity

Aquatic toxicity is a broad subject that has been studied by many for decades. A discussion of the water quality of the Uncompahgre River will include a discussion of a variety of toxins including metals, acidity and suspended solids. Metal concentrations, acidity levels and suspended solids measurements are repetitively compared to contaminant levels that kill fish or aquatic macroinvertebrates as water quality in different stream reaches in the Uncompahgre River are analyzed. A repetitive explanation of the toxicity of each metal would make this report prohibitively long and dull. Accordingly, some of the toxicity data for each pollutant is presented in the following sections to give readers some background information concerning each contaminant. This presentation is not meant to be a complete review of the toxicity of each contaminant. The information presented was selected based on conditions in the Uncompahgre River Basin.

Metal toxicity

Understanding the toxicity of metals is not a straight forward process. A given level of any metal is not toxic to all aquatic life in all conditions. The toxicity of a given metal concentration changes based on water quality components including hardness and the species involved. Some of the toxicity data generated in laboratory studies throughout the world helps explain toxicity of metals for different metals in the metal regime of the Uncompahgre River. Toxicity data for all species does not exist for all metals. Thus, some conclusions concerning metals in the Uncompahgre River must be made in rather general terms limited to season and perhaps species.

Hardness

Cadmium, copper, lead and zinc toxicity to aquatic life is mitigated by hardness: the higher the hardness, the less toxic a given concentration of a metal. This mitigation occurs in part because calcium and magnesium (the principal components of hardness) competes with metals such as copper for uptake across gill membranes in fish. The 96h zinc LC50 for mottled sculpin (Cottus bairdii) is 156 ug/L at a hardness of 48 mg/L CaCO3 (Woodling et al., 2002) compared to a 96h LC50 of 439 ug/L at a hardness of 154 mg/L CaCO3 (Brinkman and Woodling, 2005).

Additionally, most metals form carbonate/bicarbonate complexes that reduce metal toxicity as alkalinity increases. Alkalinity usually increases as hardness increases. Stream standards for metals are established based on the hardness of the receiving water in question as a consequence of these relationships, but alkalinity is not considered in the calculations.

Metallic elements

Metallic elements are not all equally toxic. Silver can kill rainbow trout when present in the parts per trillion range, as demonstrated by a series of laboratory toxicity tests. Cadmium is lethal to trout at levels a thousand times greater then silver in parts per billion. Brown trout incurred a median 96h LC50 when exposed to concentrations of 10.1 ug/L cadmium at a hardness of 150 mg/L L $CaCO_3$ (Brinkman et al., 2005). Copper is less toxic than cadmium. Lethal in concentrations of parts per billion (McKim and Benoit, 1971), a mean copper LC50 of 100 ug/L for brook trout was determined at a hardness of 45 $CaCO_{3.}$ .Zinc is even less toxic. The 96h LC50 for brook trout was 2.0 mg/L an exposure in parts per million (Holcombe et al., 1979).

Different aquatic species also have different sensitivities to the same metal at a given hardness. The zinc 96h LC50 for mottled sculpin was 156 ug/L at a hardness of 48 mg/L $CaCO_3$ (Woodling et al., 2002). In comparison the zinc 96h LC50 was 871 ug/L for brown trout at hardness concentrations near 50 mg/L $CaCO_3$ (Brinkman and Woodling, in review). Brook trout are even less sensitive to zinc with a 96h LC50 of 2,000 ug/L at a hardness of 45 mg/L $CaCO_3$ (Holcombe et al. 1979).

The toxicity of a specific metal differs for various life stages of aquatic organisms. In general fish species tend to be most sensitive to metal toxicity as newly hatched larvae and fry. Fish are insensitive to metal pollution in the egg stage and comparatively less sensitive at older life stages. For example, the juvenile brook trout copper 96h LC50 was 30 ug/L at a hardness of 43 mg/L as $CaCO_3$ while the 14 month-old brook trout 96h LC50 was 100 ug/L at a mean hardness of 45 mg/L as $CaCO_3$ (McKim and Benoit, 1971).

Cadmium

Cadmium concentrations of 2.58 ug/L induced 30% mortality to brown trout at a mean hardness of 75 mg/L CaCO3 in 30 day exposure laboratory tests while a concentration of 1.3 ug/L resulted in no mortality (Brinkman et al., 2006). In the same study, cadmium toxicity decreased as the hardness increased when exposure to 6.5 ug/L did not induce a lethal response in brown trout in a 30-day laboratory study at a hardness concentration 150 mg/L CaCO3.

Copper

Brown trout and brook trout exhibit different toxicity to copper. The brown trout 96-h LC50 was 27 ug/L and 30 ug/L in two different toxicity tests at hardness concentrations near 50 mg/L CaCO3 (Brinkman and Woodling in press). In laboratory tests, a copper concentration of 29 ug/L was lethal to fifty percent of brook trout at a hardness of 180 mg/L as CaCO3 (Besser et al., 2001). In another test, the juvenile brook trout copper 96h LC50 was 30 ug/L at a hardness of 43 mg/L as CaCO3. Older brook trout were less sensitive to copper where the 96h LC50 was 100 ug/L at a mean hardness of 45 mg/L as CaCO3 (McKim and Benoit, 1971). Brook trout may be more sensitive to copper at a given hardness than brown trout based on the results of these two studies.

Copper toxicity also varies in an inverse relationship to hardness as recognized in the current hardness based Colorado chronic Table value Standard. The hardness relationship included in the chronic Colorado Table Value Standard was designed with the premise that alkalinity increases when hardness concentrations increase. Copper has been shown to exert a relatively greater toxicity at low alkalinity levels. Analyses of the relationship of copper to hardness and other water quality parameters resulted in the creation of the Copper biotic ligand model whereby measurements of other parameters including pH, calcium, magnesium, sodium, sulfate, chloride, alkalinity and dissolved organic carbon (EPA 2007).

Lead

In two laboratory toxicity tests, the 96h lead LC50 for rainbow trout was found to be 1,320 ug/L and 1,470 ug/L at a hardness of 353 mg/L as CaCO3 (Davies et al., 1976). Chronic toxicity of lead to rainbow trout in relatively hard waters was found at much lower concentrations. The tails of rainbow trout turned black at led exposure of 31.6 ug/L with a hardness of 353 mg/L as CaCO3 (Davies et al., 1976),), but blacktail did not develop in 18.2 ug/L lead at the same hardness. Fish with blacktail would not die, but sublethal chronic toxicity reduces overall fitness of the fish population in question. Rainbow trout did not exhibit chronic toxic impacts (blackened tails) at lead concentrations of 4.1 ug/L in low hardness water (28 mg/L as CaCO3) in the Davies et al. (1976) study.

Zinc

In 96 hour toxicity tests, zinc concentrations between 392 ug/L to 871 ug/L induced 50% mortality to brown trout at a mean hardness of 54 mg/L CaCO3 (Brinkman and Woodling being prepared). In comparison, Brook trout can tolerate dissolved zinc concentrations of 800 ug/L at a hardness of about 50 mg/L as CaCO3 (Holcombe, et al., 1979).

Iron

Dissolved iron is toxic to aquatic life. Iron occurs in a dissolved fraction at pH values less than 7.0, a common condition in the upper Uncompahgre River,. However total iron is the form that is commonly regulated because iron precipitates at pH levels normally associated with Colorado streams (pH > 7.0). Iron precipitation typically results in loss of suitable substrate habitat for aquatic organisms such as insects. Toxicity to fish may result at concentrations in the several mg/L range due to iron settling on the gills and suffocating fish.

Data are sparse concerning direct toxicity of total iron to fish since little iron is present in the dissolved form at pH regimes greater than 7.0. Iron toxicity to brook trout increased in a laboratory toxicity test as pH decreased from pH 7 to pH 6 to pH 5.5, where LC50 concentrations were 1,750 ug/L, 480 ug/L and 410 ug/L, respectively (Decker and Menendez, 1974). The lethality of iron to trout increased as pH decreased while the water became more acidic. The total iron brown trout LC50 was to 28,000 ug/L at a pH of 7.6 and hardness of 287 mg/L CaCO3 (Dalzell and Macfarlane 2005). Direct toxicity to fish would not be expected in pH regimes greater than 7.0 unless total iron is present in concentrations greater than tens of milligrams per liter. Direct iron toxicity may be an issue in the higher elevation sections of the Uncompahgre River Basin where tributaries contribute acidic or basic flows to the mainstem resulting in complex changes in both the amount of iron present, pH and river flows.

Aluminum

Aluminum toxicity is an issue many associate with acid rain in northeastern United States and Canada, not the mountainous areas of the west. Aluminum is naturally released from acidic ore bodies in Colorado’s mountains that have been impacted by mining activities and is present in the Mancos shale, a formation exposed in much of the Uncompahgre River basin from Ridgway to Delta. Aluminum toxicity is an issue in the upper Uncompahgre River Basin where acid mine drainage conveys aluminum and other metals into rivers and streams.

The acidity or pH of water influences aluminum toxicity. Aluminum is more soluble in acidic and basic waters than in circumneutral (ph 5 to pH 9) waters (US EPA criteria). The minimum solubility of aluminum occurs at a pH of 5.5 (Freeman and Everhart, 1971). At pH levels less than 5.5, dissolved aluminum is present as cationic polymers while at higher pH levels dissolved aluminum is present as monomeric anions. Depending on pH and other factors, 1,500 ug/L total aluminum can be more toxic than a concentration of 5,000 ug/L total aluminum (Freeman and Everhart 1971).

Much of the research into aluminum toxicity was performed in acidic conditions due to loss of fisheries associated with acidification of freshwater systems. Aluminum concentrations of 200 ug/L reduced survival of brook trout at pH levels of 4.2 to 5.6 (Baker and Schofield, 1982). Aluminum was most toxic to brook trout “in oversaturated solutions” when pH levels were 5.2 to 5.4. Low concentrations of aluminum prove lethal to trout once water pH is less than 5.5.

Few studies are available concerning the effects of aluminum on trout in waters with pH greater than 7.0 (basic waters). Growth of juvenile brook trout was reduced at a pH of 7.2 and an aluminum concentration of 300 ug/L (Cleveland et al., 1986) and a mean hardness of 8 mg/L $CaCO_3$. In the same study, fish exposed to 300 ug/L aluminum at a pH of 7.2 were less active than fish exposed to a pH of 7.2 and no aluminum.

Freeman and Everhart (1971) reported that a concentration of 520 ug/L total aluminum induced 50% mortality in rainbow trout at a pH that varied from 6.5 to 7.0 and a hardness of about 50 mg/L as $CaCO_3$ after a 44 day exposure. No mortality was observed at the same aluminum concentration at a pH of 8.0 although “continued exposure under these conditions would undoubtedly produce high mortalities,” as feeding, growth and flight response had all decreased. Gundersen et al. (1994) reported 10% and 45% mortality to rainbow trout at an aluminum exposure of 1,500 ug/L after a 15-day exposure at hardness concentrations of 20 mg/L $CaCO_3$ and 103 mg/L $CaCO_3$, respectively. Continued exposure to aluminum concentrations at about 500 ug/L would be expected to induce both non-lethal chronic and lethal responses in pH regimes from about 7.0 to 8.0 and a relatively low hardness concentration of about 50 mg/L as $CaCO_3$.

The pH of water also influences aluminum toxicity. Aluminum toxicity increased in rainbow trout as pH increased from 7.0 to 9.0 (Freeman and Everhart 1971). The length of time required to induce a 50% lethal response decreased at an exposure of about 5.2 mg/L as pH increased from 7.0 to 9.0. The average time to a 50% lethality decreased from 38.9 days to 32 days to 7.46 days to 2.98 days at mean pH values of 6.8, 8.0, 8.5 and 8.99, respectively. Aluminum toxicity will have two peaks in the Uncompahgre River Basin, one at low pH levels found in the higher elevations the basin and one at lower elevations where pH increases to levels greater than 8.5

Aluminum has two main effects on fish, ion regulatory and respiratory failure (Alstad et al. 2005). Ion regulatory failure dominates at pH levels less than 4.5 while respiratory failure dominates at pH levels greater than 5.5. Aluminum binds to gill surfaces and mucous secretions fill the space between gill filaments resulting in hypoxia (Poleo et al. 1995). Ion regulatory failure may be the dominate form of lethality in the upper portions of the Uncompahgre River basin where pH regimes are less than 7 and hypoxia may be possible in lower elevations where pH regimes may be greater the 8.5.

Increased hardness (calcium and magnesium cations) decreases the toxicity of a given concentration of many metals. The same relationship could be anticipated for aluminum and increased hardness. Added calcium increased survival time of brown trout in pH regimes less than 5.5 and relatively low hardness concentrations less than 15 mg/L $CaCO_3$ (Alstad et al. 2005). The calcium added by Alstad et al. (2005) did not decrease the lethal effect of the aluminum exposure but only increased the time the test fish survived. Increased calcium did decrease aluminum toxicity in brown trout in low pH exposures (Brown 1981 and Brown 1983). The studies by Alstadt et al. (2005) and Brown (1981, 1983) were performed at lower pH regimes where ion regulatory failure may be the dominant form of lethality. Data are not available demonstrating that elevated hardness decreases aluminum toxicity in basic pH regimes where hypoxia may be the dominant form of lethality to fish. Differences in rainbow trout 96 h LC 50 total aluminum values were not significantly different at a hardness of 50 mg/L CaCO3 compared to 100 mg/L CaCO3 (Gundersen et al. 1994). Assuming calcium influences toxicity in the same manner in basic and acidic conditions is not supported by any experimental data. PH was the most important influence on 96 h aluminum LC 50 results to rainbow trout (Gundersen et al. 1994). Hardness probably is an important influence on aluminum toxicity but additional studies are needed to quantify the importance.

Aluminum solutions approach chemical equilibrium relatively slowly in some freshwater systems. Therefore actually determining what form of aluminum was present may be difficult. The longer time for aluminum to reach chemical equilibrium was an issue in the mainstem Uncompahgre River where tributaries either contributed acidic or basic flows to the mainstem river resulting in complex changes in both the amount of aluminum present, pH and ionic strength of the river flow.

Acidity, pH

The acidity of streams contaminated by metals may induce toxic impacts. The ore bodies found in the Uncompahgre Basin often produce acid water flows as streams or springs interact with rock, waste piles and other deposits. The acidity of water can be measured by pH a logarithmic scale ranging from 1 to 14. A pH of 7 is said to be neutral. Any pH level less than 7 is acidic and any greater than 7 is basic.

Survival of fish in acidic waters is of interest due not only to the influence of mining activities associated with acid producing ore bodies high in sulfur concentrations bit issues such as acid rain and coal mining operations. Older trout have been shown to survive at pH levels less than 5.0. Brown trout were shown to survive in acid waters where half the test fish died in 24 hours when exposed to water with a pH of 3.63, while half the rainbow trout died in 24 hours when exposed to pH of 3.83 (Ikuta 1992). Rainbow trout appeared to be less sensitive to acid water than brown trout. However acid tolerance is not as great in early trout stages (e.g. egg or fry stage). Rainbow trout eggs exposed to pH of 4.3 or less did not hatch (Daye 1980) while less than 1% of brown trout eggs hatched when exposed to pH levels of 4.0 to 4.8 (Barlaup et al. 1996). Fish populations may disappear over time from waters recently contaminated by acid wastes from reproductive failure and not direct mortality to adult or juvenile fish. Continued low pH regimes prohibit recolonization of fish.

Dissolved salts

The sum total of salts, organic compounds, metals, nutrients, etc. actually dissolved in water is measured using a total dissolved solids analysis. In brief, a volume of water is passed through a very fine filter that retains solids suspended in the fluid but allows all solids dissolved in solution to pass through the filter matrix. The remaining water is evaporated after filtering. Material remaining in the evaporation container is then weighed and constitutes all the salts, organics, metals, etc. that were dissolved in solution. These dissolved solids comprise part of the environment in which aquatic organisms must survive.

A total dissolved solids concentration of 1,000 mg/L can be considered to represent water that has a rather excessive level of dissolved material. This limit of 1,000 mg/L is not codified as statute, regulation or stream standard. Rather this level can be used to indicate when aquatic systems may be attaining a magnitude where the negative impacts to aquatic life assemblages could be expected.

Ammonia

The toxicity of ammonia and iron are related to pH of the water. The total ammonia fraction is not toxic, the unionized ammonia or NH3 is the toxic fraction. Exponentially more of the total ammonia fraction is present as unionized ammonia at pH levels in excess of 8.5. In contrast, the direct toxicity of total iron decreases as pH increases.

Suspended solids.

Most studies concerning lethality of suspended solids were performed using trout and salmon as the test species. The level of toxic response depends on both magnitude and duration of exposure, with an inverse relationship between magnitude and duration. For example, a total suspended solids exposure of 39,400 mg/L for 1.5 days resulted in a 90% mortality in juvenile Chinook and sockeye salmon (Newcomb and Flagg 1983). In contrast, brown trout incurred an 85% reduction in population size when exposed to 1,040 mg/L suspended solids for 361 days (Herbert et al. 1961) while rainbow trout exposed to 270 mg/L for 19 days incurred 80 % mortality to “sub-adults” (Herbert and Merkens 1961).

Appendix 2: WBID

WBID	Classification	Description
UN01	Aq Life Cold 1 Recreation E Water Supply Agriculture	All tributaries to the Uncompahgre River, including all wetlands, lakes and reservoirs, which are within the Mt. Sneffels and Uncompahgre Wilderness Areas.
UN02	Aq Life Cold 1 Recreation N Water Supply Agriculture	Mainstem of the Uncompahgre River from the source at Como Lake (Poughkeepsie Gulch) to a point immediately above the confluence with Red Mountain Creek.
UN03a	Aq Life Cold 1 Recreation E Water Supply Agriculture	Mainstem of the Uncompahgre River from a point immediately above the confluence with Red Mountain Creek to the Highway 90 bridge at Montrose.
UN03b	Aq Life Cold 1 Recreation E Agriculture	Ridgway Reservoir
UN04a	Aq Life Warm 2 Recreation E Agriculture	Mainstem of the Uncompahgre River from the Highway 90 bridge at Montrose to La Salle Road.
UN04b	Aq Life Warm 2 Recreation N Agriculture	Mainstem of the Uncompahgre River from La Salle Road to Confluence Park.
UN04c	Aq Life Warm 2 Recreation E Agriculture	Mainstem of the Uncompahgre River from Confluence Park to the confluence with the Gunnison River.
UN05	Aq Life Cold 2 Recreation E Water Supply Agriculture	All tributaries to the Uncompahgre River, including all wetlands, lakes and reservoirs, from the source to a point immediately below the confluence with Dexter Creek, except for specific listings in Segments 1 and 6 thru 9.
UN06a	Aq Life Cold 2 Recreation N Agriculture	Mainstem of Red Mountain Creek from the source to immediately above the confluence with the East Fork of Red Mountain Creek.
UN06b	Recreation N Agriculture	Mainstem of Red Mountain Creek from immediately above the confluence with the East Fork of Red Mountain Creek to the confluence with the Uncompahgre River. All tributaries to Red Mountain Creek within Corkscrew and Champion basins.
UN07	Aq Life Cold 2 Recreation N Water Supply Agriculture	Mainstem of Gray Copper Gulch from the source to the confluence with Red Mountain Creek.

UN08	Aq Life Cold 2 Recreation N Water Supply Agriculture	Mainstem of Mineral Creek from the source to the confluence with the Uncompahgre River.
UN09	Aq Life Cold 2 Recreation P Agriculture	Mainstem of Canyon Creek from its inception at the confluence of Imogene and Sneffles Creek to the confluence with the Uncompahgre River. Mainstem of Imogene Creek from its source to its confluence with Canyon Creek. Mainstem and all tributaries of Sneffels Creek from a point 1.5 miles above to its confluence with Canyon Creek.
UN10	Aq Life Cold 2 Water Supply Agriculture Nov 1 - April 30 Recreation N May 1 - Oct 31 Recreation P	All tributaries to the Uncompahgre River, including all wetlands, lakes and reservoirs, from a point immediately below the confluence with Dexter Creek to the South Canal near Uncompahgre, except for specific listings in Segments 1 and 11.
UN11	Aq Life Cold 1 Water Supply Agriculture Nov 1 - April 30 Recreation N May 1 - Oct 31 Recreation P	Mainstem of Coal Creek from the source to the Park Ditch, mainstem of Dallas Creek from the source of the East and West Forks to the confluence with the Uncompahgre River; mainstem of Cow Creek, including all tributaries, lakes and reservoirs, from the Uncompahgre Wilderness Area boundary to the confluence with the Uncompahgre River; Billy Creek; Onion Creek and Beaton Creek from their source to their confluences with Uncompahgre River; mainstem of Beaver Creek from source to the confluence with East Fork of Dallas Creek; and mainstem of Pleasant Valley Creek from the source to the confluence with Dallas Creek.
UN12	Aq Life Warm 2 Recreation N Agriculture	All tributaries to the Uncompahgre River, including all wetlands, lakes and reservoirs, from the South Canal near Uncompahgre to the confluence with the Gunnison River, except for specific listings in Segments 13, 14, 15a and 15b.
UN13	Aq Life Cold 1 Recreation E Agriculture	Mainstem of East Fork Dry Creek, Pryor Creek and West Fork Dry Creek from their sources to their confluence; mainstem of Spring Creek, West Fork Spring Creek and Middle Spring Creek from the source to Popular Road at the mouth of Spring Canyon, and mainstem of Mexican Gulch from the source to the Section line
UN14	Aq Life Warm 2 Recreation E Agriculture	Sweitzer Lake.
UN15a	Aq Life Warm 2 Recreation N Agriculture	Mainstem of Happy Canyon from West Canal to the confluence with the Uncompahgre River; mainstem of Horsefly Creek from the confluence with Wildcat Canyon to the confluence with the Uncompahgre River.
UN15b	Aq Life Warm 2 Recreation N Agriculture	Mainstem of Dry Creek from the confluence of the East and West Forks to immediately above the confluence with Coalbank Canyon Creek.

WQCC, Regulation 35 - Classifications and Numeric Standards for Gunnison and Lower Dolores River Basins (http://www.cdphe.state.co.us/op/wqcc/).

Appendix 3: Stream Standards and Temporary Modifications

Stream Segment (WBID)	Classification	Numeric Standards						
		Physical and Biological	Inorganic (mg/L)		Metals (ug/L)			Modifications
COGUUN01: Mainstem of Gray Copper Gulch from the source to the confluence with Red Mountain Creek.	Aq Life Cold 1 Recreation E Water Supply Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH=6.5-9.0 E.Coli=126/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=WS	As(ac)=340 As(ch)=0.02(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=WS(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50 Mn(ac/ch)=TVS Mn(ch)=WS(dis) Hg(ch)=0.01(tot)	Ni(ac/ch)=TVS Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
COGUUN02: Mainstem of the Uncompahgre River from the source at Como Lake (Poughkeepsie Gulch) to a point immediately above the confluence with Red Mountain Creek.	Aq Life Cold 1 Recreation N Water Supply Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH=6.5-9.0 E.Coli=630/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=WS	As(ac)=340 As(ch)=0.02(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=WS(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ac/ch)=TVS Mn(ch)=WS(dis) Hg(ch)=0.01(tot)	Ni(ac/ch)=TVS Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
COGUUN03a: Mainstem of the Uncompahgre River from a point immediately above the confluence with Red Mountain Creek to the Highway 90 bridge at Montrose.	Aq Life Cold 1 Recreation E Water Supply Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH=6.5-9.0 E.Coli=126/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=WS	As(ac)=340 As(ch)=0.02(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS	Cu(ac/ch)=TVS Fe(ch)=WS(dis) Fe(ch)=1500(Trec) Pb(ac/ch)=TVS Mn(ac/ch)=TVS Mn(ch)=WS(dis) Hg(ch)=0.01(tot)	Ni(ac/ch)=TVS Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
COGUUN03b: Ridgway Reservoir	Aq Life Cold 1 Recreation E Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH=6.5-9.0 E.Coli=126/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10	As(ac)=340 As(ch)=7.6(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS	Cu(ac/ch)=TVS Fe(ch)=1500(Trec) Pb(ac/ch)=TVS Mn(ac/ch)=TVS Hg(ch)=0.01(tot)	Ni(ac/ch)=TVS Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
COGUUN04a: Mainstem of the Uncompahgre River from the Highway 90 bridge at Montrose to La Salle Road.	Aq Life Warm 2 Recreation E Agriculture	D.O.=5.0 mg/l pH=6.5-9.0 E.Coli=126/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.5 NO_3=100	As(ac)=340 As(ch)=100(Trec) Cd(ac/ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=2250(Trec) Pb(ac/ch)=TVS Mn(ac/ch)=TVS Hg(ch)=0.01(tot) Ni(ac/ch)=TVS	Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	Temporary Modifications. NH_3(ac/ch)=TVS(old) Expiration date of 12/31/2011.
COGUUN04b: Mainstem of the Uncompahgre River from La Salle Road to Confluence Park.	Aq Life Warm 2 Recreation N Agriculture	D.O.=5.0 mg/l pH=6.5-9.0 E.Coli=630/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.5 NO_3=100	As(ac)=340 As(ch)=100(Trec) Cd(ac/ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=2250(Trec) Pb(ac/ch)=TVS Mn(ac/ch)=TVS Hg(ch)=0.01(tot) Ni(ac/ch)=TVS	Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS Zn(ac/ch)=TVS	Temporary Modifications. NH_3(ac/ch)=TVS(old) Se(ch)=20 Expiration date of 12/31/2011.
COGUUN04c: Mainstem of the Uncompahgre River from Confluence Park to the confluence with the Gunnison River.	Aq Life Warm 2 Recreation E Agriculture	D.O.=5.0 mg/l pH=6.5-9.0 E.Coli=126/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.5 NO_3=100	As(ac)=340 As(ch)=100(Trec) Cd(ac/ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=2250(Trec) Pb(ac/ch)=TVS Mn(ac/ch)=TVS Hg(ch)=0.01(tot) Ni(ac/ch)=TVS	Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS Zn(ac/ch)=TVS	Temporary Modifications. Se(ac/ch)=20 Expiration date of 12/31/2011.

Stream Segment (WBID)	Classification	Numeric Standards						
		Physical and Biological	Inorganic (mg/L)		Metals (ug/L)			Modifications
COGUUN05: All tributaries to the Uncompahgre River, including all wetlands, lakes and reservoirs, from the source to a point immediately below the confluence with Dexter Creek, except for specific listings in Segments 1 and 6 thru 9.	Aq Life Cold 2 Recreation E Water Supply Agriculture	D.O.=5.0 mg/l D.O.(sp)=7.0 mg/l pH=6.5-9.0 E.Coli=126/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=WS	As(ac)=340 As(ch)=0.02-10(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac/ch)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=WS(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ac/ch)=TVS Mn(ch)=WS(dis) Hg(ch)=0.01(tot)	Ni(ac/ch)=TVS Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac)=TVS Zn(ch)=TVS(sc)	
COGUUN06a: Mainstem of Red Mountain Creek from the source to immediately above the confluence with the East Fork of Red Mountain Creek.	Aq Life Cold 2 Recreation N Agriculture	D.O.=5.0 mg/l D.O.(sp)=7.0 mg/l pH=6.5-9.0 E.Coli=630/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.05 NO_3=100	As(ac)=340 As(ch)=150 Cd(ac/ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ac/ch)=TVS Hg(ch)=0.01(tot) Ni(ac/ch)=TVS	Se(ac/ch)=TVS Ag(ac/ch)=TVS Zn(ac)=TVS Zn(ch)=TVS(sc)	
COGUUN06b: Mainstem of Red Mountain Creek from immediately above the confluence with the East Fork of Red Mountain Creek to the confluence with the Uncompahgre River. All tributaries to Red Mountain Creek within Corkscrew and Champion basins.	Recreation N Agriculture	D.O.=3.0 mg/l pH=ambient E.Coli=630/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005					
COGUUN07: Mainstem of Gray Copper Gulch from the source to the confluence with Red Mountain Creek.	Aq Life Cold 2 Recreation N Water Supply Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH=6.5-9.0 E.Coli=630/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=WS	As(ac)=340 As(ch)=0.02-10(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac/ch)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=WS(dis) Fe(ch)=2450(Trec) Pb(ac/ch)=TVS Mn(ch)=655 Mn(ac/ch)=TVS Hg(ch)=0.01(tot)	Ni(ac/ch)=TVS Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ch)=TVS	
COGUUN08: Mainstem of Mineral Creek from the source to the confluence with the Uncompahgre River.	Aq Life Cold 2 Recreation N Water Supply Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH=6.5-9.0 E.Coli=630/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=WS	As(ac)=340 As(ch)=0.02-10(Trec) Cd(ch)=0.4 CrIII(ac/ch)=50(Trec) CrVI(ac/ch)=TVS Cu(ch)=5	Fe(ch)=WS(dis) Fe(ch)=1000(Trec) Pb(ch)=4 Mn(ac/ch)=TVS Mn(ch)=WS(dis) Ni(ac/ch)=TVS	Hg(ch)=0.01(tot) Ni(ch)=50 Se(ac/ch)=10 Ag(ch)=0.1 Zn(ch)=50	
COGUUN09: Mainstem of Canyon Creek from its inception at the confluence of Imogene and Sneffles Creek to the confluence with the Uncompahgre River. Mainstem of Imogene Creek from its source to its confluence with Canyon Creek. Mainstem and all tributaries of Sneffels Creek from a point 1.5 miles above to its confluence with Canyon Creek.	Aq Life Cold 2 Recreation P Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH=6.5-9.0 E.Coli=205/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.05 NO_3=100	As(ac)=340 As(ch)=0.02-10(Trec) Cd(ch)=0.4 CrIII(ac/ch)=50(Trec) CrVI(ac/ch)=TVS Cu(ch)=5	Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ac/ch)=TVS Hg(ch)=0.01(tot) Ni(ac/ch)=TVS	Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	Fish Ingestion
COGUUN10: All tributaries to the Uncompahgre River, including all wetlands, lakes and reservoirs, from a point immediately below the confluence with Dexter Creek to the South Canal near Uncompahgre, except for specific listings in Segments 1 and 11.	Aq Life Cold 2 Water Supply Agriculture Nov 1 to April 30 Recreation N May 1 to Oct 31 Recreation P	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH=6.5-9.0 Nov 1 to April 30 E.Coli=630/100ml May 1 to Oct 31 E.Coli=205/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=WS	As(ac)=340 As(ch)=0.02-10(Trec) Cd(ac)=TVS(tr) Cd(ch)=0.4 CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ac)=WS(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)= WS(dis) Mn(ac/ch)= TVS Hg(ch)=0.01(tot)	Ni(ac/ch)=TVS Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	Water + Fish Standards

Stream Segment (WBID)	Classification	Numeric Standards						
		Physical and Biological	Inorganic (mg/L)		Metals (ug/L)			Modifications
COGUUN11: Mainstem of Coal Creek from the source to the Park Ditch, mainstem of Dallas Creek from the source of the East and West Forks to the confluence with the Uncompahgre River; mainstem of Cow Creek, including all tributaries, lakes and reservoirs, from the Uncompahgre Wilderness Area boundary to the confluence with the Uncompahgre River; Billy Creek; Onion Creek and Beaton Creek from their source to their confluences with Uncompahgre River; mainstem of Beaver Creek from source to the confluence with East Fork of Dallas Creek; and mainstem of Pleasant Valley Creek from the source to the confluence with Dallas Creek.	Aq Life Cold 1 Water Supply Agriculture Nov 1 to April 30 Recreation N May 1 to Oct 31 Recreation P	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH=6.5-9.0 Nov 1 to April 30 E.Coli=630/100ml May 1 to Oct 31 E.Coli=205/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=WS	As(ac)=340 As(ch)=0.02(Trec) Cd(ac)=TVS(tr) Cd(ch)=0.4 CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ac)=WS(dis) Fe(ch)=1030(Trec) Pb(ac/ch)=TVS Mn(ch)= WS(dis) Mn(ac/ch)= TVS Hg(ch)=0.01(tot)	Ni(ac/ch)=TVS Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
COGUUN12: All tributaries to the Uncompahgre River, including all wetlands, lakes and reservoirs, from the South Canal near Uncompahgre to the confluence with the Gunnison River, except for specific listings in Segments 13, 14, 15a and 15b.	Aq Life Warm 2 Recreation N Agriculture	D.O.=6.0 mg/l pH=6.5-9.0 E.Coli=630/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10	As(ac)=340 As(ch)=100(Trec) Cd(ac/ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=1200(Trec) Pb(ac/ch)=TVS Mn(ac/ch)= TVS Hg(ch)=0.01(tot) Ni(ac/ch)=TVS	Se(ac/ch)=TVS Ag(ac/ch)=TVS Zn(ac/ch)=TVS	Temporary modification: Se(ch)=existing ambient quality. Expiration date of 12/31/2011.
COGUUN13: Mainstem of East Fork Dry Creek, Pryor Creek and West Fork Dry Creek from their sources to their confluence; mainstem of Spring Creek, West Fork Spring Creek and Middle Spring Creek from the source to Popular Road at the mouth of Spring Canyon, and mainstem of Mexican Gulch from the source to the Section line dividing Section 19 and 30, T49N, R9W.	Aq Life Cold 1 Recreation E Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH=6.5-9.0 E.Coli=126/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.05 NO_3=100	As(ac)=340 As(ch)=7.6(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ac/ch)= TVS Hg(ch)=0.01(tot) Ni(ac/ch)=TVS Se(ac/ch)=TVS	Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
COGUUN14: Sweitzer Lake.	Aq Life Warm 1 Recreation E Agriculture	D.O.=6.0 mg/l pH=6.5-9.0 E.Coli=126/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.5 NO_3=100	As(ac)=340 As(ch)=7.6(Trec) Cd(ac/ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ac/ch)= TVS Hg(ch)=0.01(tot) Ni(ac/ch)=TVS	Se (ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
COGUUN15a: Mainstem of Happy Canyon from West Canal to the confluence with the Uncompahgre River; mainstem of Horsefly Creek from the confluence with Wildcat Canyon to the confluence with the Uncompahgre River.	Aq Life Warm 2 Recreation N Agriculture	D.O.=5.0 mg/l pH=6.5-9.0 E.Coli=630/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.5 NO_3=100	As(ac)=340 As(ch)=100(Trec) Cd(ac/ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ac/ch)= TVS Hg(ch)=0.01(tot) Ni(ac/ch)=TVS	Se (ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS Zn(ac/ch)=TVS	
COGUUN15b: Mainstem of Dry Creek from the confluence of the East and West Forks to immediately above the confluence with Coalbank Canyon Creek.	Aq Life Warm 2 Recreation E Agriculture	D.O.=5.0 mg/l pH=6.5-9.0 E.Coli=126/100ml	NH_3(ac/ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=.005	S=0.002 B=0.75 NO_2=0.5 NO_3=100	As(ac)=340 As(ch)=100(Trec) Cd(ac/ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ac/ch)= TVS Hg(ch)=0.01(tot) Ni(ac/ch)=TVS	Se (ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS Zn(ac/ch)=TVS	

Notes: TVS = Table Value Standard, ac = acute, ch = chronic, dis = dissolved, tot = total

Aquatic Life Temperature Standards

CLASS 1 COLD WATER BIOTA	CLASS 1 WARM WATER BIOTA	CLASS 2
Rivers & Streams: **Tier I[a]:** June-Sept = 17.0 (ch), 21.7(ac) Oct –May = 9.0 (ch), 13.0 (ac) **Tier II[b]:** Apr-Oct =18.3 (ch), 23.9 (ac) Nov-Mar =9.0 (ch), 13.0 (ac) **Lakes & Res:** Apr-Dec = 17.0 (ch), 21.2 (ac) Jan-Mar = 9.0 (ch), 13.0 (ac) **Large Lakes & Res[c]:** Apr-Dec = 18.3(ch), 23.8 (ac) Jan-Mar = 9.0(ch), 13.0 (ac)	**Rivers & Streams:** **Tier I[d]:** Mar-Nov = 24.2(ch), 29.0 (ac) Dec-Feb= 12.1(ch), 14.5(ac) **Tier II[e]:** Mar-Nov= 27.5(ch), 28.6(ac) Dec-Feb=13.8 (ch), 14.3 (ac) **Tier II[If]:** Mar-Nov = 28.7 (ch), 31.8 (ac) Dec-Feb = 14.3 (ch), 15.9 (ac) **Lakes & Res:** Apr-Dec = 26.3 (ch), 29.5 (ac) Jan-Mar = 13.2 (ch), 14.8 (ac)	Same as Class 1

Temperature Definitions

[a] Cold Stream Tier I temperature criteria apply where cutthroat trout and brook trout are expected to occur.

[b] Cold Stream Tier II temperature criteria apply where cold-water aquatic species, excluding cutthroat trout or brook trout, are expected to occur.

[c] Large Cold Lakes temperature criteria apply to lakes and reservoirs with a surface area equal to or greater than 100 acres surface area.

[d] Warm Stream Tier I temperature criteria apply where common shiner, Johnny darter, or orangethroat darter are expected to occur.

[e] Warm Stream Tier II temperature criteria apply where brook stickleback, central stoneroller, creek chub, finescale dace, longnose dace, Northern redbelly dace, razorback sucker, or white sucker are expected occur, and none of the more thermally sensitive species in Tier I are expected to occur.

[f] Warm Stream Tier III temperature criteria apply where warm-water aquatic species are expected to occur, and none of the more thermally sensitive species in Tiers I and II are expected to occur.

Source; Basic Standards, Rule #31 (http://www.cdphe.state.co.us/op/wqcc/Standards/RegsCurrent/31_2012%2801%29.pdf)

Appendix 4: Water Quality Limited Stream Segments

WBID	Segment Name	Portion	M&E Parameter	303(d) Impairment
UN02†	Uncompahgre River from the source at Como Lake (Poughkeepsie Gulch) to a point immediately above the confluence with Red Mountain Creek	all		Cd, Cu, Zn
UN03a†	Uncompahgre River from a point immediately above the confluence with Red Mountain Creek to the Highway 90 bridge at Montrose	all		Cd, Cu, Fe-Trec
UN04a	Uncompahgre River, HWY 90 to La Salle Road	all	sediment	
UN04b	Uncompahgre River, La Salle Road to Confluence Park	all	sediment	Se*
UN04c	Uncompahgre River, Confluence Park to Gunnison River	all	sediment	Se*
UN06a†	Red Mountain Creek, from the source to immediately above the confluence with East Fork Red Mountain Creek	all		Zn (sculpin)
UN07	Gray Copper Gulch from source to Red Mountain Creek	all	Fe(Trec)	
UN08	Mineral Creek, source to Uncompahgre River	all	Cd, Cu, Zn	
UN09	Canyon Creek, Imogene Creek, Sneffels Creek	all	Zn	
UN09	Canyon Creek, Imogene Creek, Sneffels Creek	Canyon Creek	Pb	
UN10	All tributaries to the Uncompahgre River from Dexter Creek to the South Canal	Alkali Creek	Se	
UN11	Coal, Dallas, Cow, Billy, Onion, Beaton, Beaver and Pleasant Valley Creeks	all		Se
UN14	Sweitzer Lake	all	D.O.	Se*
UN15b	Dry Creek from East and West Forks to Coalbank Canyon Creek	Dry Creek Watershed	sediment	

Listings marked with an asterisk (*) are carryover from the 1998 303(d) List

Segments marked with (†) were removed from the 2010 303(d) List due to the development of the Red Mountain Creek TMDL (WQCD 2009)

Source: Regulation 93 - 2010 303(d) and M&E Lists

Appendix 5: Water Quality Monitoring Stations

Source	Number	Name	Stream	lat	long
CDPHE		BELOW SILVER CREEK	Uncompahgre	37.9445310	-107.6272080
CDPHE		ABOVE MINERAL CREEK	Uncompahgre	37.96464100	-107.6263160
CDPHE		BELOW MINERAL CREEK	Uncompahgre	37.96534700	-107.6266590
CDPHE		BELOW LETCHER CREEK	Uncompahgre	37.95329400	-107.6274170
CDPHE		ABOVE RED MOUNTAIN CREEK	Uncompahgre	37.98840300	-107.6529530
CDPHE		ABOVE MICHAEL BREEN MINE	Uncompahgre	37.97202000	-107.6345950
CDPHE		BELOW MICHAEL BREEN MINE	Uncompahgre	37.97509400	-107.6361260
CDPHE		BELOW OLD LOUT MINE	Uncompahgre	37.95404800	-107.6273270
CDPHE		BELOW CANADA CREEK	Uncompahgre	37.94248200	-107.6261790
RW	3580	IDARADO COMPLIANCE	Red Mtn Cr	37.93820000	-107.6729000
RW	3582	ABV RED MTN CONF	Uncompahgre	37.98617000	-107.6483500
USGS	375621107373000	UPPER UNCOMPAHGRE RIVER (NR LAKE COMO)	Uncompahgre	37.93916200	-107.6247822
USGS	375422107423000	RED MTN C NR SOURCE AT RED MOUNTAIN, CO.	Red Mtn Cr	37.90610616	-107.7078389
USGS	375623107401000	RED MTN C AB GRAY COPPER GL NR IRONTON, CO	Red Mtn Cr	37.93971716	-107.6706160
USGS	375732107394000	RED MOUNTAIN C AB CRYSTAL LK NR IRONTON,CO	Red Mtn Cr	37.95888366	-107.6617269
USGS	375810107393000	RED CREEK NR OURAY	Red Mtn Cr	37.9694391	-107.658949
USGS	375916107385000	UNCOMPAHGRE R AB RED MTN C NR OURAY, CO.	Uncompahgre	37.9877723	-107.6489488
MFG		HENDRICK	Hendrick	37.96555	-107.660615
MFG		BROOKLYN	Brooklyn	37.944564	-107.667328
MFG		GRAY COPPER	Gray Copper	37.940248	-107.668935
MFG		CORKSCREW	Corkscrew	37.931661	-107.680338
MFG		FULL MOON	Full Moon	37.948531	-107.671617
MFG		ALBANY	Albany	37.946511	-107.665067
MFG		MCINTYRE	McIntyre	37.929439	-107.68756
MFG		CHAMPION	Champion	37.922057	-107.694271
MFG		COMMODORE	Commodore	37.919994	-107.701449
MFG		CRYSTAL LAKE	Crystal Lake	37.959864	-107.662392
MFG		RED MOUNTAIN CR	Red Mountain Cr	37.988403	-107.652953
RW	392	POTTERS RANCH	Uncompahgre	38.07021	-107.43593
RW	393	BELOW RIDGEWAY RES	Uncompahgre	38.14326	-107.45478

RW	395	CR 24	Uncompahgre	38.10558	-107.44437
RW	3581	BELOW CANYON CR	Uncompahgre	38.01725	-107.67574
RW	3584	BELOW OAK CR	Uncompahgre	38.01817	-107.67449
RW	3585	AT MOUTH	Oak Cr	38.01789	-107.67588
RW	3586	USGS GAUGE	Uncompahgre	38.03938	-107.6815
RW	4134	AT MOUTH	Canyon Cr	38.074362	-107.4136
RW	4135	ABOVE CANYON CR	Uncompahgre	38.0215073	-107.39493
CDPHE	79	UNCOMPAHGRE RIVER AT RIDGWAY	Uncompahgre	38.1519444	-107.7519444
Price		ABOVE OURAY HYDRO	Uncompahgre	38.007529	-107.663835
Price		BELOW OURAY HYDRO	Uncompahgre	38.019438	-107.675893
USGS	9146020	UNCOMPAHGRE RIVER NEAR OURAY, CO	Uncompahgre	38.04332665	-107.6831154
USGS	9146200	UNCOMPAHGRE RIVER NEAR RIDGWAY, CO	Uncompahgre	38.183889	-107.745278
USGS	9147025	UNCOMPAHGRE RIVER BELOW RIDGWAY RESERVOIR	Uncompahgre	38.238056	-107.758611
Mackey		SNEFFELS CR BELOW ATLAS TAILINGS	Sneffels Creek	37.975543	-107.750616
Mackey		SNEFFELS CR BELOW GOVERNORS BASIN	Sneffels Creek	37.978915	-107.759729
Mackey		SNEFFELS CR ABOVE IMOGENE CR	Sneffels Creek	37.971886	-107.727766
Mackey		IMOGENE CR ABOVE CANYON CR	Imogene Creek	37.971142	-107.726794
Mackey		CONFLUENCE OF IMOGENE AND SNEFFELS	Canyon Cr	37.971853	-107.726638
Mackey		CANYON CR AT PPE OF CAMP BIRD TAILINGS	Canyon Cr	37.97201	-107.726075
Mackey		CANYON CR BELOW CAMP BIRD TAILINGS	Canyon Cr	37.973463	-107.724207
Mackey		CANYOU CR ABOVE UNCOMPAHGRE RIVER	Canyon Cr	38.019541	-107.676889
Mackey		CANYON CR 1.5 MI BELOW CAMP BIRD	Canyon Cr	37.987368	-107.705069
USGS	9147500	UNCOMPAHGRE RIVER AT COLONA, CO	Uncompahgre	38.331389	-107.778889
RW	508	CHIPETA	Uncompahgre	38.43642452	-107.8670476
RW	537	RIVER BOTTOM PARK	Uncompahgre	38.46781446	-107.8795102
RW	159	LA SALLE RD	Uncompahgre	38.30127141	-107.5445527
CDPHE	10664	DRY CEDAR AT MOUTH	Dry Cedar	38.45118333	-107.86255
CDPHE	10622	CEDAR CR NEAR MOUTH	Cedar Cr	38.51061667	-107.91235
CDPHE	10661	LOUTSENHIZER ARROYO NR MOUTH AT NORTH RIVER BRIDGE	Loutsenhizer Arroyo	38.66295	-107.9985667
CDPHE	55	UNCOMAHGRE AT DELTA	Uncompahgre	38.7405556	-108.0797222
RW	300	BILLY CR SWA	Uncompahgre	38.28848634	-107.7638163
RW	294	DRY CEDAR CR	Dry Cedar	38.45678311	-107.8723225

RW	539	IN TOWN	Uncompahgre	38.48473719	-107.8569725
RW	159	LA SALLE RD	Uncompahgre	38.30127141	-107.5445527
WQCD	10624	CEDAR CREEK JUST EAST OF MONTROSE	Cedar Cr	38.48543333	-107.74955
WQCD	10611	DRY CR NEAR MOUTH	Dry Cr	38.70061667	-108.0553333
WQCD	10636	HAPPY CANYON AT MOUTH	Happy Canyon	38.42548333	-107.8906833
WQCD	10627	MONTROSE ARROYO SOUTHEAST OF MONTROSE	Montrose Arroyo	38.4672	-107.8596833
WQCD	10631	SPRING CREEK AT JAY ROAD BRIDGE	Spring Cr	38.5334733	-107.9649517
WQCD	10605	UNCOMAHGRE R ABOVE OF WEST MONTROSE WWTP	Uncompahgre	38.50385	-107.9113
WQCD	10602	UNCOMAHGRE RIVER ABOVE DRY CREEK AT 17 ROAD BRIDGE	Uncompahgre	38.7027778	-108.0458333
WQCD	79	UNCOMPAHGRE RIVER AT RIDGWAY	Uncompahgre	38.1519444	-107.7519444

Appendix 6: Tables

Table 1. Water quality in the mainstem Uncompahgre River, June 22, 2004

Site	pH	Hardness	Al	Cd	Cu	Fe	Mn	Zn
Above Canadian Creek	7.2	68	350[a]	3.1*	23*	74	453	525*
Below Silver Creek		69	110	2.1*	17*	44	290	367*
Below Letcher Creek	6.9	68	88.4	1.9*	13*	95	262	341*
Below Old Lout Mine	7.2	77	68.4	2*	13.5*	99	276	339*
Above Mineral Creek	7.6	76	56	1.4*	10*	83	232	285*
Below Mineral Creek	7.1	56	85.7	1.1*	7.3*	249	148	211*
Above Michael Breen Mine	7.3	67	0	1.1*	13.4*	61	140	202*
Below Michael Breen Mine	7.6	61	0	.95*	8.5*	64	118	177*
Above Red Mountain Creek	7.5	60	0	1*	8.7*	206	135	197*

Data from O'Grady, 2005
All metals in ug/L and reported in dissolved fraction, except iron which is reported as total iron.
Hardness reported in mg/L as $CaCO_3$.
* = exceeded chronic table value stream standards as applied by WQCC.
All zinc measurements also exceeded recalculated standards protective of some level of brown trout, except one measurement at the "Below Michael Breen Mine."
Aluminum standards are not applied by the WQCC in the Uncompahgre River Basin, but "a" indicates the sample exceeded chronic aluminum criteria which was 288 ug/L at a hardness of 68 mg/L $CaCO_3$ which could be applied to the Uncompahgre River.

Table 2. Load Reduction Targets for Segment UN02

Metal	Assumed Background levels (ug/L)	Load from mine activity	Month	85% (ug/L)	Existing Load (lbs/day)	Load Reduction (lbs/day)	% Reduction (lbs/day)
Cu	7	44%	April	18.4	1.293	0.911	70%
			May	14	3.262	0.482	74%
Cd	1	23%	Mar	1.9	0.050	0.038	76%
			April	1.6	0.112	0.094	83%
			May	0.7	0.165	0.121	73%
Zn	57	73%	Mar	381	10.07	6.418	64%
			April	445	31.33	26.014	83%
			May	146	34.12	22.140	65%

Data from WQCD, 2009.

Table 3. Copper concentrations (ug/L) in tributaries to Red Mountain Creek

Gulch	Date	Site near Red Mountain Creek confluence		Stream sampling site closest to tributary headwater	
		Flow	**Copper**	**Flow**	**Copper**
Hendrick	9/301989	66	0	4.9	0
	6/15/1990	742	0	66	0
Crystal Lake=W	9/301989	331	0	0	0
	6/15/1990	140	0	0.31	0
Albany	9/301989	31	450	35	0
	6/15/1990	686	68	202	0
Full Moon=W	9/301989	294	0	160	0
	6/15/1990	4826	0	4003	0
Brooklyn	9/301989	9	15	31	5
	6/15/1990	35	0	225	5
Gray Cooper	9/301989	521	10	0.1	0
	6/15/1990	7493	53	191	53
Corkscrew	9/301989	121	190	0.03	6
	6/15/1990	3212	90	170	0
McIintyre=W	9/301989	29	0	5.4	0
	6/15/1990	522	0	76	0
Champion	9/301989	49	5000	0.13	15
	6/15/1990	1869	660	154	36
Commodore=W	9/301989	76	9	36	0
	6/15/1990	6768	7	5800	0
Red Mountain *	9/301989	189	4100	0.29	0
	6/15/1990	1730	870	4.2	0

Data from MFG (1991). Flow = gallons per minute.

Table 4. Red Mountain Creek trend analysis for monthly zinc values from 1985 to 2007 at CERCLA compliance point

Month	Linear Regression formula	R^2	Number of samples
Jan.	Dis Zn = 1297 + 0.0265*X	0.016	21
Feb.	Dis Zn = 2658 - 0.0056*X	0.001	17
Mar	Dis Zn = 5746 - 0.0961*X	0.134	23
Apr	Dis Zn = 6876 - 0.132*X	0.245	23
May	Dis Zn = 8365 - 0.1853*X	0.415	25
June	Dis Zn = 129.6 + 0.0194*X	0.0082	35
July	Dis Zn = 703 + 20.696*X	0.05	24
Aug	Dis Zn = 836 + 37.24*X	0.174	23
Sept	Dis Zn = 1948 - 0.0099*X	0.017	33
Oct	Dis Zn = 1887 + 2.008*X	0.002	22
Nov	Dis Zn = 1815 + 11.3*X	0.026	26
Dec	Dis Zn = 2258 - 3.97*X	0.001	22

Data Source = River Watch, MFG and Idarado
R^2 (R squared) is a statistical measure of how well a regression line approximates real data points. An R^2 of 1.0 (100%) indicates a perfect fit where as an R^2 of 0 indicates no. Relationship between variance and the estimate.

Table 5. Load Reduction Targets for Segment UR03a

Metal	Month	Ambient (ug/L)	TVS	Existing Load (lbs/day)	WLA, Historic Mining	Load Reduction (lbs/day)	% Reduction (lbs/day)
Cu	March	**175**	26	31.3	3.4	27.1	87%
	May	**19**	12	30.4	14.7	13.3	44%
	Sept	**64**	19	22.9	5.1	16.7	73%
	Dec	**191**	27	31.5	3.2	27.5	87%
Cd	March	**1.9**	1.1	0.332	0.018	0.159	48%
	May	**1.2**	0.6	1.832	0.210	1.052	57%
	Sept	**1.5**	0.8	0.531	0.046	0.263	50%
	Dec	**1.9**	1.1	0.317	0.016	0.151	48%
Fe (Trec)	March	**4802**	1500	856	101	615	72%
	May	**1932**	1500	3046	950	918	30%
	Sept	118	1500	42	210	n/a	0%
	Dec	**3129**	1500	515	93	293	57%

Data from Anthony, 2009.
Cu and Cd is 85th Percentile Data, Fe(Trec) is 50th Percentile Data

Table 6. May 5, 2001 Water Samples of Ouray Hydropower Dam Flushing Event

Analytes	Above Dam	Below Dam		Chronic Table Value Standard
	post- release	pre-release	post-release	
Flow (cfs)	95	95	100	
PH	5.9	6.3	6.3	
TSS	8	22	2,090	
Hardness	155	155	155	
Cadmium	1.8*	1.7*	5.3*	0.59
Copper	140*	140*	850*	13
Iron	3,260*	3,820*	14,700*	1,000
Lead	9.7*	12.2*	344*	4
Zinc	490*	460*	1,200*	180

Metals reported as the total fraction ug/L, not dissolved.
Source: CDPHE, 2001, Hardness calculated as mean from Colorado River Watch data collected at site upstream of Reservoir collected in April of 2006-2009. Hardness reported as mg/L $CaCO_3$.
* = indicates exceeds chronic Colorado Table Value Stream Standards.

Table 7. Water quality data summary, Uncompahgre River 300 feet upstream of Canyon Creek confluence and downstream of Ouray Hydropower Dam

Metal	Cadmium	Copper	Iron	Lead	Zinc
Median	1.56	124	3,839	10.1	454
Minimum	0	0	0	0	114
maximum	2.35	405	16,830	62	1,046
85th percentile	2.1	230	6,575	14.8	568
Number of samples	60	60	55	60	60
HAZMAT - Pre-Release below Hydro facility	1.7	140	3,820	12.2	460

Data from River Watch 1999-2002. Results presented as total metal concentrations ug/L

Table 8. Water quality in Canyon Creek, September 1999

Site	pH	Hardness	Al	Cd	Cu	Fe	Mn	Zn
Sneffels Creek below Governor Basin	7.18	55	131	0	0	142	14.1	19.7
Sneffels Creek below Atlas Tailings	7.14	59	108	0	2.5	82	111	77
Sneffels Creek above Imogene Creek	7.79	69	73.9	0	1.2	80.5	108	143*
Imogene Creek above Canyon Creek	7.05	417	68	1.4	14	268	117	334
Confluence of Imogene Creek and Sneffles Creek	7.5	237	108	0	7.1	177	121	228
Canyon Creek at PPE of Camp Bird Tailings	7.57	197	212	0	6	238	119	215
Canyon Creek below Camp Bird Tailings	7.76	196	977	1.1*	14.7	1220*	319	276*
Canyon Creek 1.5 miles downstream of Camp Bird	7.78	161	0	0	1.3	33	57	120
Canyon Creek above Uncompahgre River	7.8	175	404	0	3.4	353	76	116

All metals in ug/L and reported in dissolved fraction, except iron, which is reported as total iron. Hardness reported in mg/L as CaCO3. * = exceeded current chronic Table Value Standard as applied by Colorado Water Quality Control Commission. (data from Mackey, 2000)

Table 9. Total aluminum concentrations in Canyon Creek that that appeared adequate to induce a lethal toxic impact to trout in the stream

Date	pH	Hardness mg/L $CaCO_3$	Total aluminum ug/L
5/24/1999	7.65	90	1,223
9/13/1999	7.24	188	4,742
7/20/2000	7.48	284	2,803
9/12/2000	7.8	208	756
5/22/2001	7.64	72	601
2/25/2002	6.43	354	2,021
5/7/2002	7.04	144	901

Data Source: River Watch Data, 1999-2002

Table 10. Comparison of the Uncompahgre River Hazard Quotients downstream of Oak Creek to the Uncompahgre River at Ouray USGS flow station, frequency of Table Value Standard exceedances

Metal		**Below Oak Creek**	**Ouray USGS Gage**
Cadmium	Median H.Q.	0.99	1.3
	Number of samples	43	97
	Number of H.Q. > 1	21 (48%)	70 (72%)
	Number of H.Q. > 2	11 (26%)	14 (14%)
	Number of H.Q. > 3	3 (7%)	4 (5%)
Copper	Median H.Q.	0.68	0.32
	Number of samples	43	97
	Number of H.Q. > 1	18 (41%)	13 (13%)
	Number of H.Q. > 2	7 (16%)	5 (5%)
	Number of H.Q. > 3	3 (7%)	5 (5%)
Lead	Median H.Q.	0	0
	Number of samples	43	97
	Number of H.Q. > 1	2 (4.6%)	3 (3%)
	Number of H.Q. > 2	1 (2.3%)	3 (3%)
	Number of H.Q. > 3	0	2 (2.1%)
Zinc	Median H.Q.	0.63	0.7
	Number of samples	43	97
	Number of H.Q. > 1	14 (33%)	24 (25%)
	Number of H.Q. > 2	5 (12%)	2 (2%)
	Number of H.Q. > 3	0	0

A Hazard Quotient (H.Q.) greater than 1.0 indicates the value exceeds current Colorado chronic Table Value Standards.

Table 11. Uncompahgre River from Ouray to Ridgway Reservoir, number of times sample results exceeded Colorado chronic Table Value

Station		Cd	Cu	Pb	Zn	Hazard Quotient
USGS Ouray gage	Number of Samples > chronic standard	45	11	18	4	58
	N	58	57	58	58	58
County Rd 23 north of Ouray	Number of Samples > chronic standard	19	3	1	0	33
	N	41	40	41	41	41
Potter's Ranch south of Ridgway	Number of Samples > chronic standard	11	2	0	1	31
	N	43	42	43	44	44
County Road 24 upstream of Reservoir	Number of Samples > chronic standard	1	0	1	0	7
	N	34	39	35	40	40
USGS gage just downstream of Reservoir	Number of Samples > chronic standard	0	0	0	0	1
	N	41	41	41	41	41

Data from River Watch (2002-2007). N = total number of samples collected, Cd = cadmium, Cu = copper, Pb = lead, Zn = zinc. Divide the number of samples greater than the chronic standard by the N to get % of samples with HQ>1.

Table 12. Metal loads (pounds per day) entering and leaving Ridgway Reservoir on the 41 days for which data are available

Site	Aluminum	Cadmium	Copper	Iron	Lead	Zinc
Flow gage in Ouray	82,876	188	3130	110594	554	7,319
Flow gage upstream Ridgway	111,112	28.4	1,636	110,318	570	4,933
Flow gage downstream of Ridgway Reservoir	6,251	2.1	178	3,890	15.8,	544
Percent retained in Reservoir	94%	92%	89%	96%	92%	89%

Metal data from River Watch. Flow data from USGS gage stations. Results in pounds for the days when samples collected.

Table 13. Annual loading to Ridgway Reservoir, total aluminum, total cadmium, total copper, total iron, total lead and total zinc

Metal	Pounds entering Reservoir	Pounds leaving Reservoir	Pounds remaining in Ridgway Reservoir annually	Percent retention in Ridgway Reservoir
Aluminum	1,561,402	1,459	1,559,943	99.9
Cadmium	12.6	0.068	12.5	99.5
Copper	606	5.15	600.9	99.2
Iron	1,422,628	1,244	1,421,384	99.9
Lead	116.7	0.51	116.2	99.5
Zinc	1,735	13.2	1,721.8	99.2
Total	2,986,500	2,722	2,983,778	99.9

River Watch combined with USGS flow data. Results in pounds per year.

Table 14. Summary of metals data in the Uncompahgre River from Colona to Montrose

Parameter		Colona	Chipeta (above Montrose)	Town Park (in Montrose)
Cadmium	Median	***	***	***
	N	17	20	30
	Minimum	***	***	***
	maximum	1	0.21	***
	N > 0	1	7	***
Copper	Median.	3	1.25	1.1
	N	17	20	30
	minimum	1	***	***
	maximum	6	3	3.2
	N>0	17	13	20
Lead	Median	3.5	***	***
	N	17	20	30
	minimum	***	***	***
	maximum	6	6.9	6.8
	N>0	2	5	4
Zinc	Median	7	***	3.5
	N	17	20	30
	minimum	***	***	***
	maximum	26	38.7	45.8
	N>0	13	9	24

Metal results in ug/L

Table 15. Total aluminum and total iron in Uncompahgre River from Colona to Montrose

Parameter		Colona	Chipeta (above Montrose)	Town Park (in Montrose)
Total Aluminum	Median		226	253
	N		52	65
	minimum		***	***
	maximum		8,902	9,612
Total Iron	Median.	370	378	368
	N	12	106	106
	minimum	***	***	***
	maximum	3,500	5,603	7,653
	N>1,000	3	25	27

Results in ug/L. *** = below detection limits. USGS data from 1977 to 1996. Colorado River Watch data 1996 to 2009.

Table 16. Nutrient Data: Uncompahgre River from Colona to Montrose

Parameter		Colona	Chipeta (above Montrose)	Town Park (in Montrose)
Ammonia	Median	***	***	***
	N	1	20	25
	minimum		***	***
	maximum		560	360
	85th percentile		90	50
Nitrate (NO_3)	Median	160	98	114
	N	9	19	24
	minimum	90	***	***
	maximum	250	420	830
	85th percentile	290	136	360
Total Phosphorus	Median	30	19	20
	N	3	19	24
	minimum	***	***	***
	maximum	40	600	600
	85th percentile	37	100	120
TSS	Median		14,000	18,000
	N		21	26
	minimum		4,500	***
	maximum		414,000	492,000
	85th percentile		61,000	138,000

Results in ug/L. UR = mainstem Uncompahgre River. *** = below detection limits. USGS data from 1977 to 1996. Colorado River Watch data 1996 to 2009. USGS phosphorus data are orthophosphate not total phosphorus

Table 17. Summary water quality data: Uncompahgre River Tributaries from Montrose to Delta (1998 to 2008)

Parameter		Dry Cedar Creek	Cedar Creek	Dry Creek	Loutsenhizer Arroyo
E. coli (# Colonies/100 mL)	Median	19.9	227	142	241.1
	N	3	4	3	14
	minimum	6.3	62	16	107.1
	maximum	22.3	365	1299	686.7
	geomean	14	142	142.9	283
Nitrogen, ammonia (NH_3) + ammonium (NH_4) (ug/L)	Median.	50	80	70	70
	N	5	5	5	16
	minimum	0	50	0	30
	maximum	160	220	250	310
	N>0	4	5	4	16
Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N (ug/L)	Median	2,000	1,400	2,300	2,250
	N	5	5	5	17
	minimum	350	970	820	1,300
	maximum	4,300	3,500	5,600	14,000
	N>10,000	0	0	0	3
Phosphate Phosphorus as P (ug/L)	Median	41	92	63	550
	N	5	5	5	15
	minimum	18	31	0	25
	maximum	90	340	300	1,300
	N>0	4	5	4	15
pH	Median	8.07	8.41	8.16	8.07
	N	5	5	5	16
	minimum	7.6	8.25	6.58	6.75
	maximum	8.36	8.46	8.43	8.99
	N > 9	0	0	0	0
Hardness as $CaCO_3$ (mg/L)	Median.	1,200	760	450	665
	N	5	5	5	16
	minimum	1,900	430	240	380
	maximum	620	1,100	740	2,100
	N> 0	5	5	5	16
Sulfate as SO4 (mg/L)	Median	2,200	980	370	750
	N	5	5	5	16
	minimum	750	420	180	500
	maximum	2,600	1,100	620	3,300
	N> 250	5	5	3	16
Total iron (ug/L)	Median	360	3,640	3,135	6,500
	N	5	6	5	16
	minimum	19	14	110	270
	maximum	1,600	12,000	14,000	26,000
	N> 1,000	2	3	3	13
	85th percentile	1,570	10,460	9,545	14,000

Data from STORET and WQCD. geomean = geometric mean.

Table 18. Mean Total Dissolved Solids (mg/L) in Delta (WQCD Site 55) before and after 1991

Year	Mean		t-value	df	p	N		F-ratios	p - variance
	68-90	91-09				68-90	91-09		
Jan *	1,739	1,442	3.42	33	0.002	24	11	3.009	0.07
Feb *	1,733	1,307	3.2	31	0.003	20	13	1.45	0.5
Mar *[a]	1,854	867	2.48	31	0.019	26	7	17.1	0.002
April	947	867	0.9	33	0.4	23	12	1.44	0.54
May	973	818	1.01	37	0.32	28	11	2.87	0.08
June	964	880	0.7	37	0.47	28	11	2.8	0.09
July	1,263	1,114	1.28	34	0.21	25	11	3.64	0.04
Aug	1,401	1,245	1.35	35	0.18	26	11	1.00	.09
Sept **	1,288	1,097	1.72	36	0.09	32	6	2.76	0.07
Oct *	1,279	1,016	2.72	37	0.01	29	10	1.6	0.48
Nov *	1,682	1,324	3.2	34	0.003	29	7	3.1	0.15
Dec *	1,762	1,354	9.3	33	0	23	12	1.33	0.56

Table 19. Total aluminum in Uncompahgre River at Delta (WQCD Site 55) from 1978 to 2001

Date	Hardness mg/L $CaCO_3$	Total aluminum ug/L	Chronic Aluminum standard ug/L
12/4/1978		0	
5/7/1979	300	3,000	1,437
11/13/1979		*0	
6/3/1980	580	1,900	1,437
12/11/1980		*0	
5/4/1981	-	3,000	
11/2/1981		*0	
4/1/1998	340	2,800	1,437
12/1/1998		140	
6/18/2001	490	4,100	1,437

* = less than detection limits.
If hardness exceeds 220 mg/L $CaCO_3$ aluminum standard capped at 1,437 ug/L.

Table 20. The 50th percentile value of total iron measurements (ug/L) in the Uncompahgre River at Delta (WQCD Site 55)

Month	N	Minimum	Maximum	median
March	6	380	10,000	1,380
April	13	1,200	8,300	2,700*
May	10	0	21,000	2,650*
June	11	1,900	6,500	3,400*
July	11	510	8,500	3,500*
August	11	1,100	9,700	2,100

*= exceeds site specific total iron standard adopted by the WQCC.

Total iron standard achieved September through February.

Table 21. Comparison of mean Total Iron (ug/L) in Delta (WQCD Site 55) from 1975-1988 to 1991-2007

	Mean		**N (Sample Size)**	
Month	**1975-1988**	**1991-2007**	**75-88**	**91-07**
Jan	451	315	14	12
Feb	712	429	12	11
Mar	1358	5547	13	6
April	1929	4054	16	13
May	2797	6548	18	10
June	3597	4264	15	11
July	2819	5992	14	11
Aug	1474	3845	14	11
Sept	1162	2113	16	4
Oct	1054	1569	14	11
Nov	509	420	18	6
Dec	445	257	14	12

Data not available for 1989 and 1990.

Table 22. Monthly nitrogen loads in the Uncompahgre River at Delta

Month	Daily loading lb/day as N	Monthly loading lb/day as N
Jan	2,474.3	76,702.7
Feb	2,084.9	58,378.3
March	1,617.8	50,153.0
April	1,579.0	47,368.8
May	3,681.2	114,116.6
June	4,445.3	133,358.4
July	4,915.9	152,392.6
August	4,027.3	124,846.9
Sept	3,314.5	99,435.6
Oct	4,519.8	140,113.8
Nov	3,542.9	106,288.2
Dec	2,897.1	89,810.1
Total loading not corrected for input upstream of Montrose		1,192,965
Net loading corrected for input upstream of Montrose		1,078,455

Appendix 7: Figures

Figure 1. Dissolved cadmium (Cd) concentrations compared to Table Value Standards (TVS) in the Uncompahgre River above Red Mountain Creek

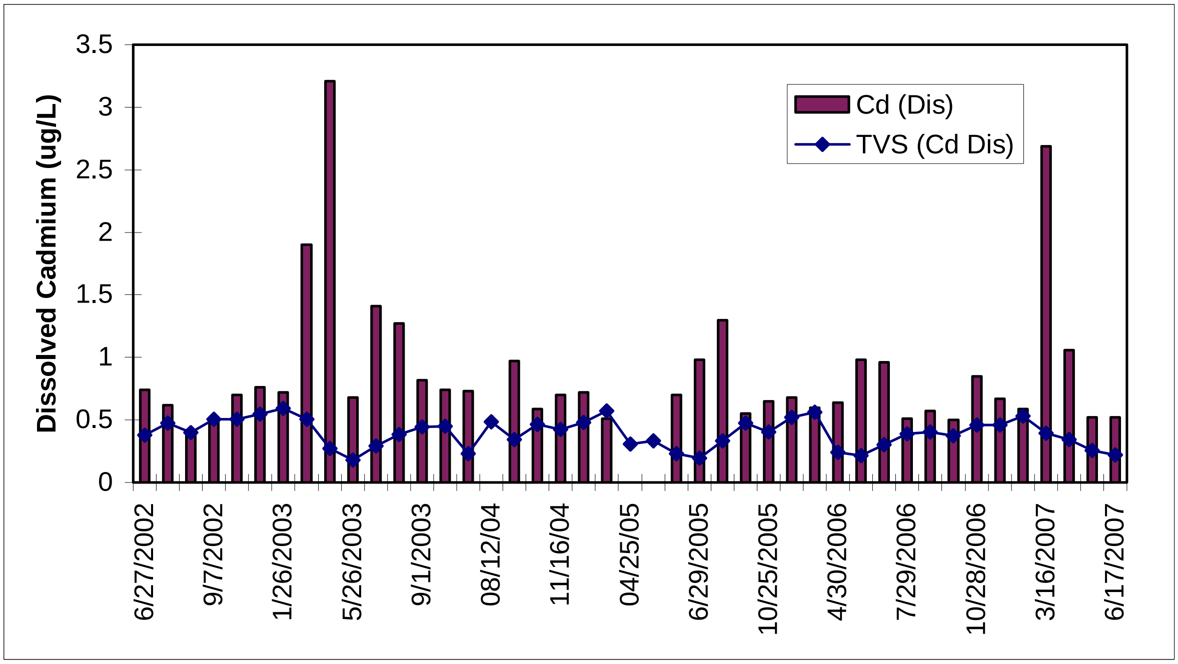


Figure 2. Dissolved copper (Cu) concentrations compared to Table Value Standards (TVS) in the Uncompahgre River above Red Mountain Creek

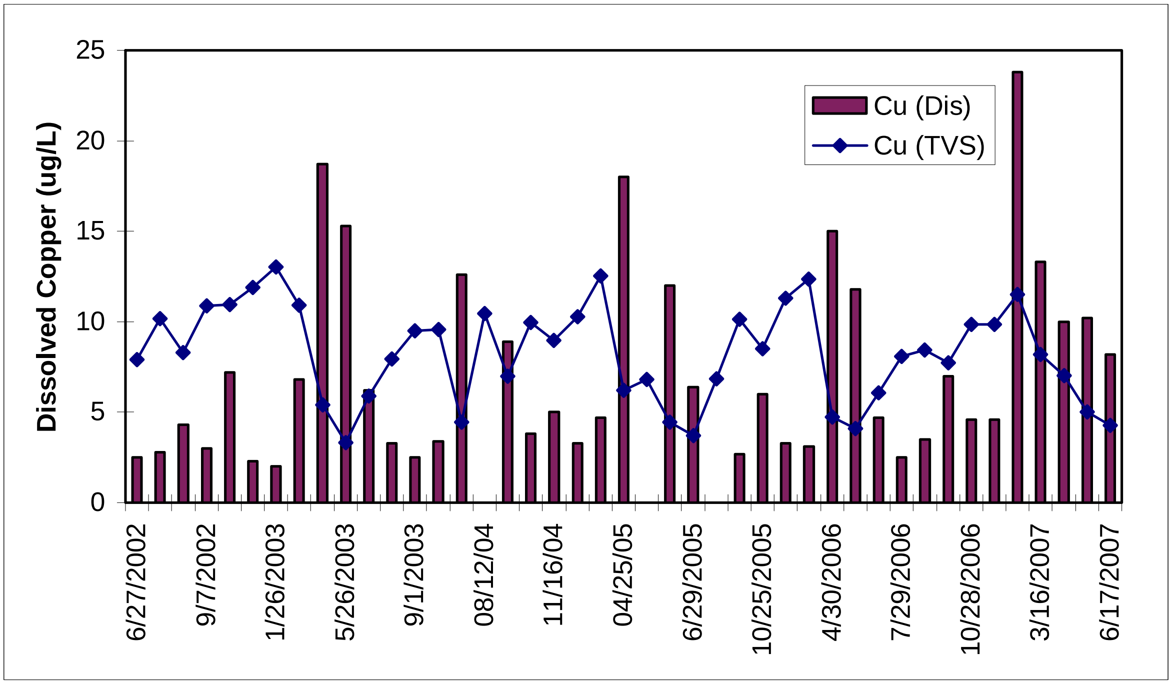


Figure 3. Dissolved Zinc (Zn) concentrations compared to Table Value Standards (TVS) in the Uncompahgre River above Red Mountain Creek

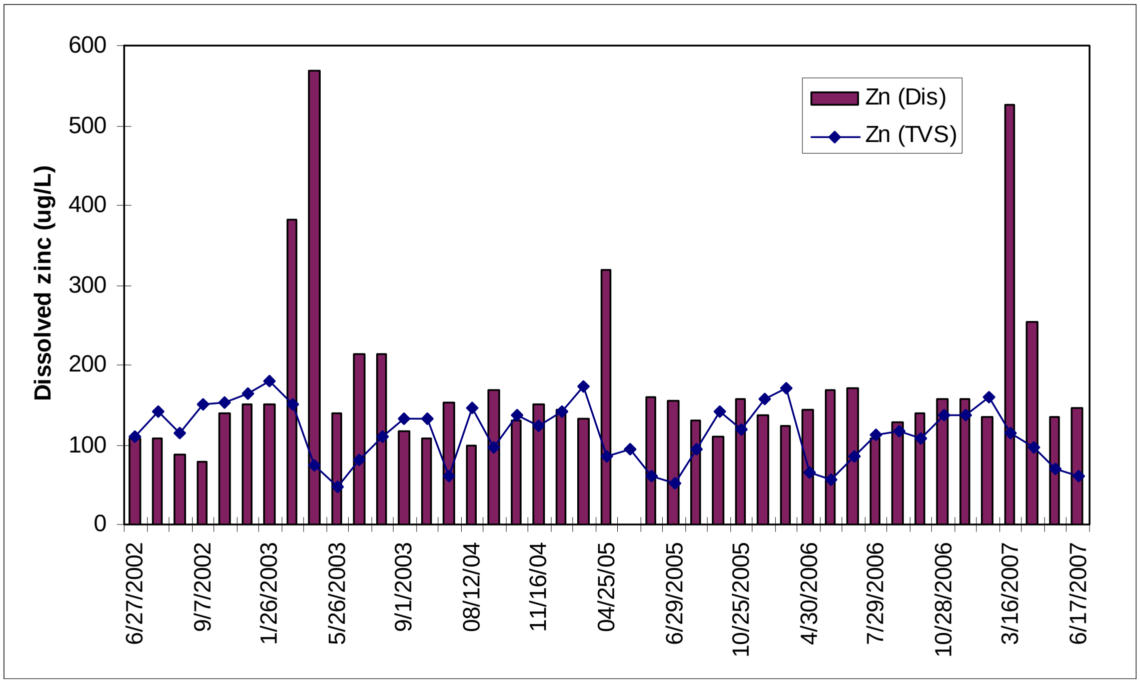


Figure 4. Dissolved Zinc (Zn) concentrations compared to a Recalculated Zinc Standards in the Uncompahgre River above Red Mountain Creek

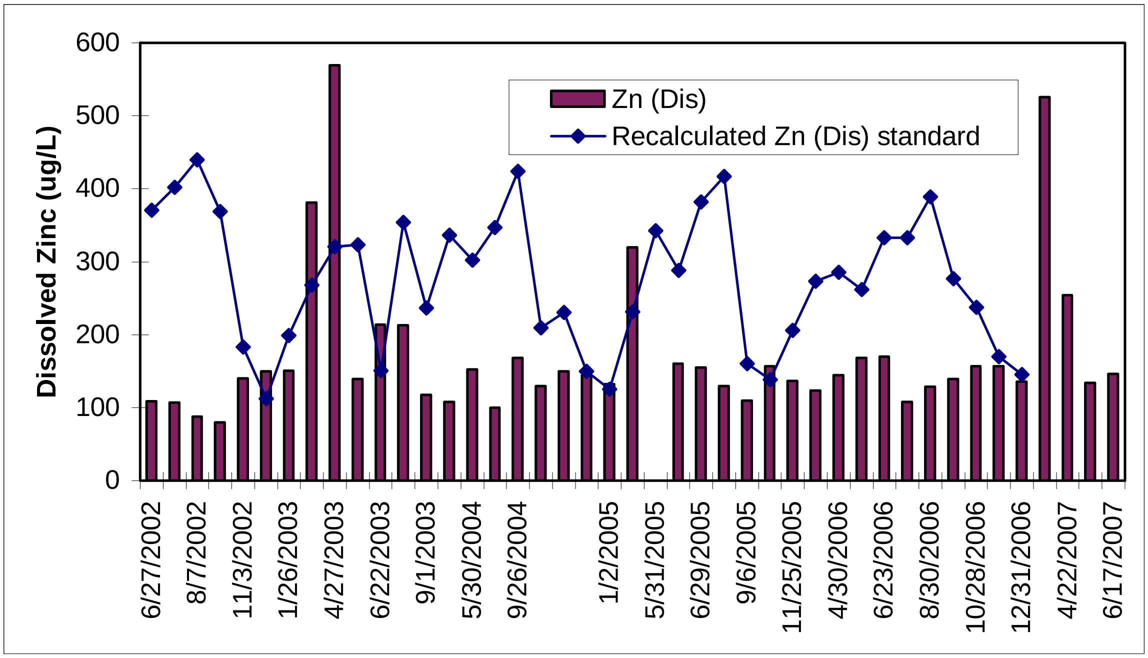


Figure 5. Dissolved Aluminum (Al) concentrations compared to Chronic Standards in the Uncompahgre River above Red Mountain Creek

Note: Aluminum standards have not been adopted in the Uncompahgre River Basin.

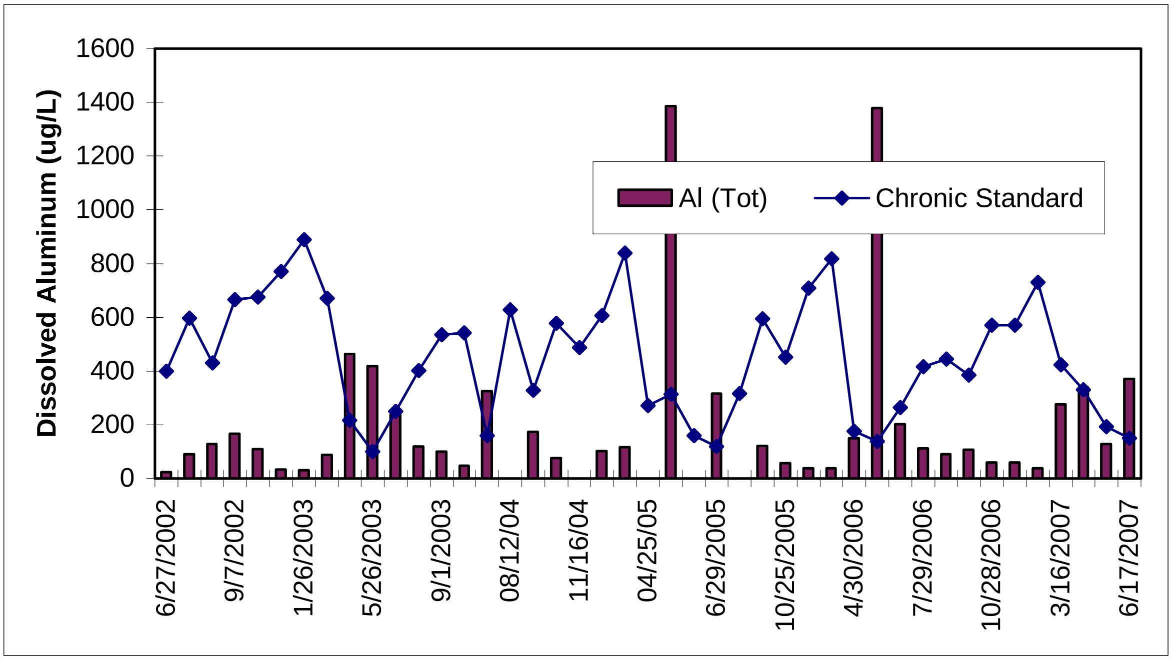


Figure 6. Dissolved Cadmium (Cd) concentrations compared to Table Value Standards (TVS) in Red Mountain Creek

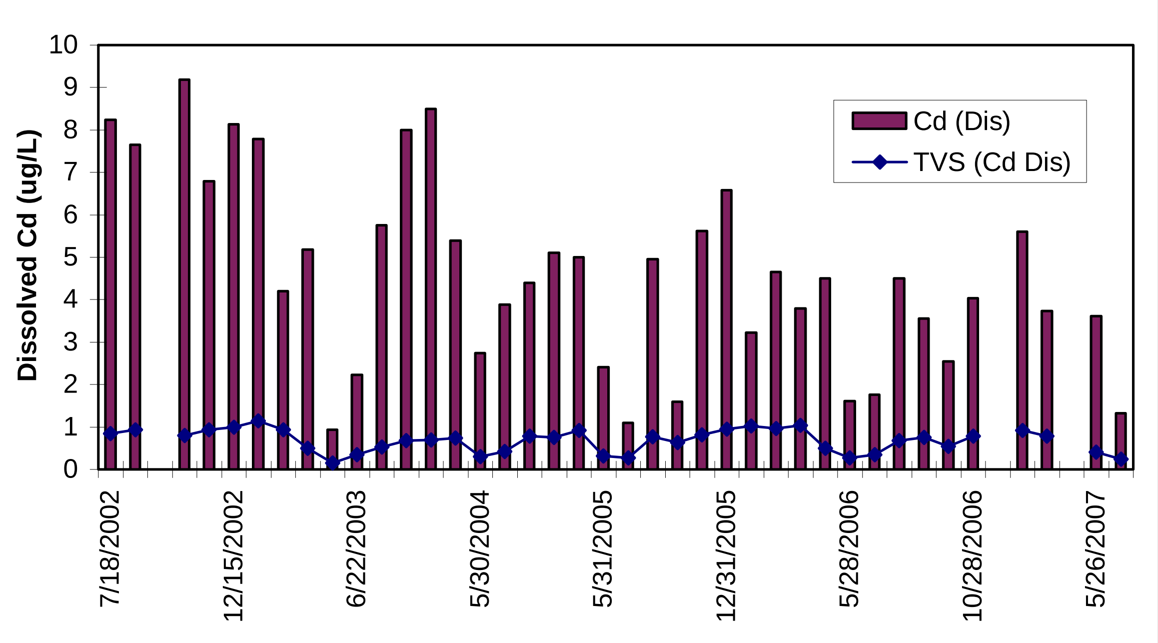


Figure 7. Dissolved Copper (Cu) concentrations compared to Table Value Standards (TVS) in Red Mountain Creek

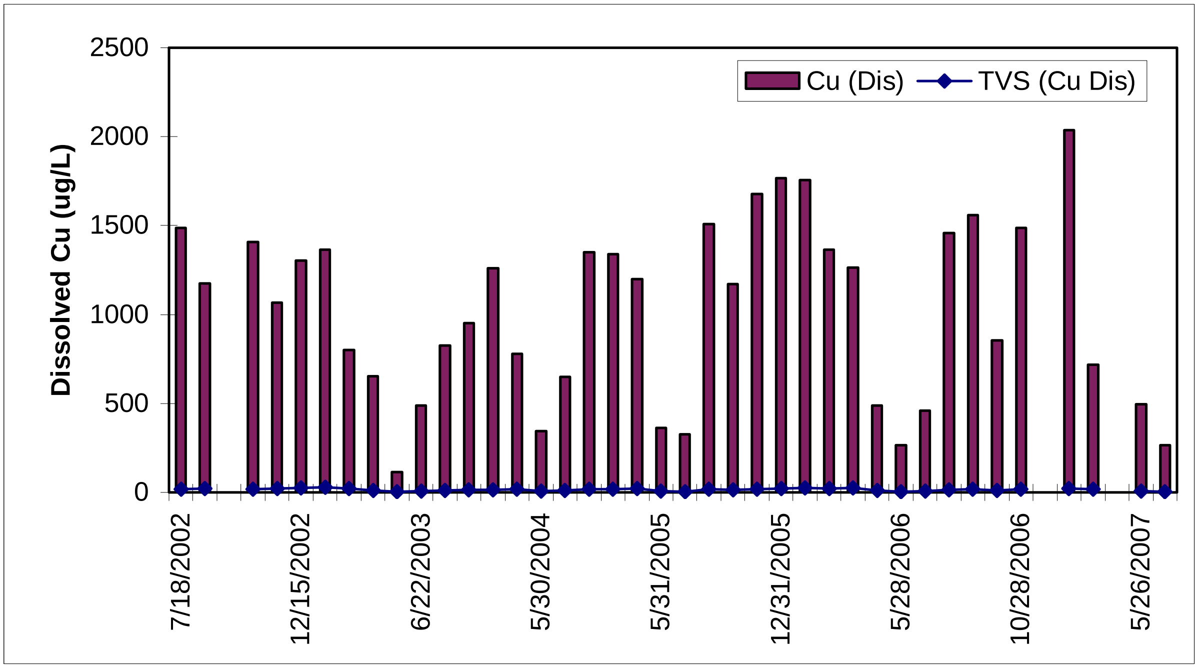


Figure 8. Dissolved Lead (Pb) concentrations compared to Table Value Standards (TVS) in Red Mountain Creek

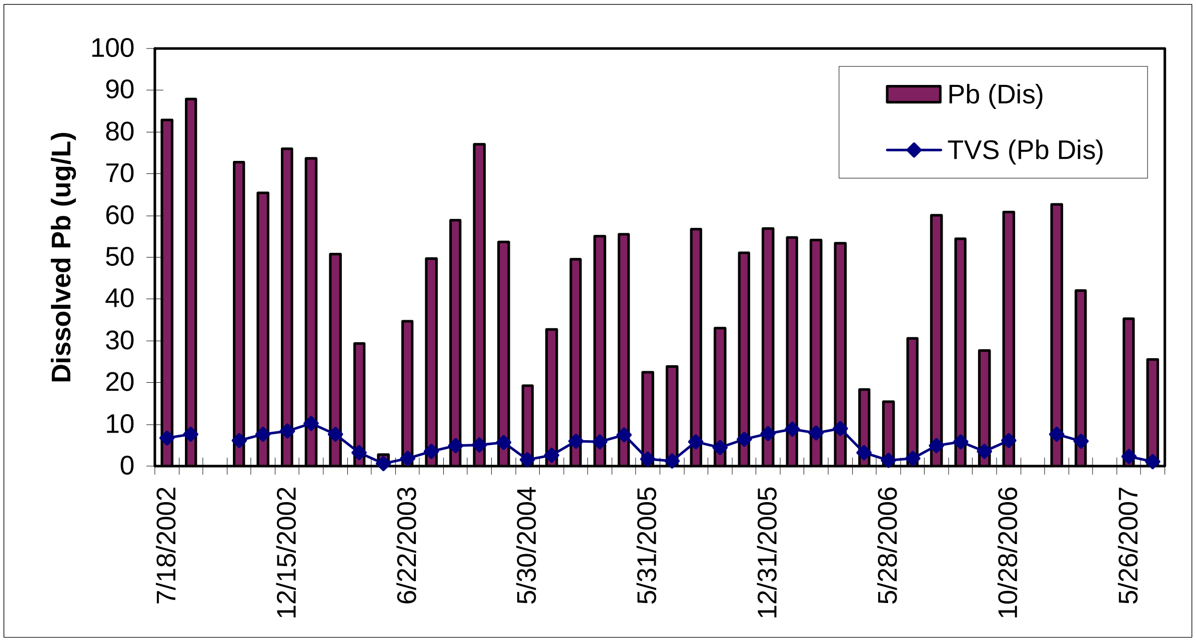


Figure 9. Dissolved Zinc (Zn) concentrations compared to Table Value Standards (TVS) in Red Mountain Creek

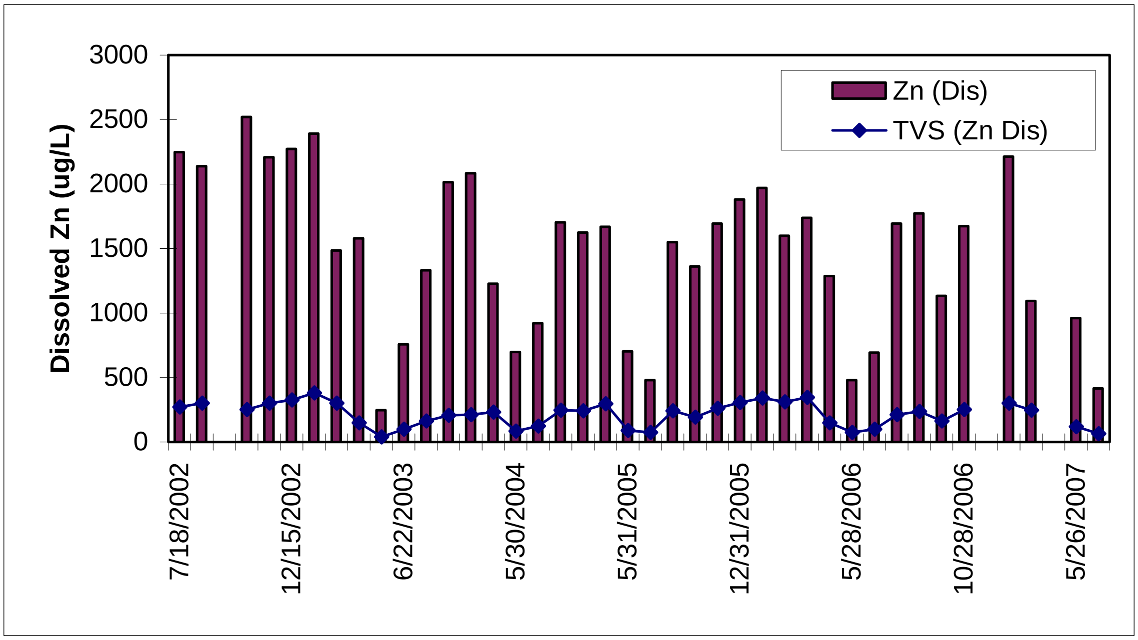


Figure 10. Dissolved Zinc (Zn) concentrations compared to a Recalculated Zinc Standards in Red Mountain Creek

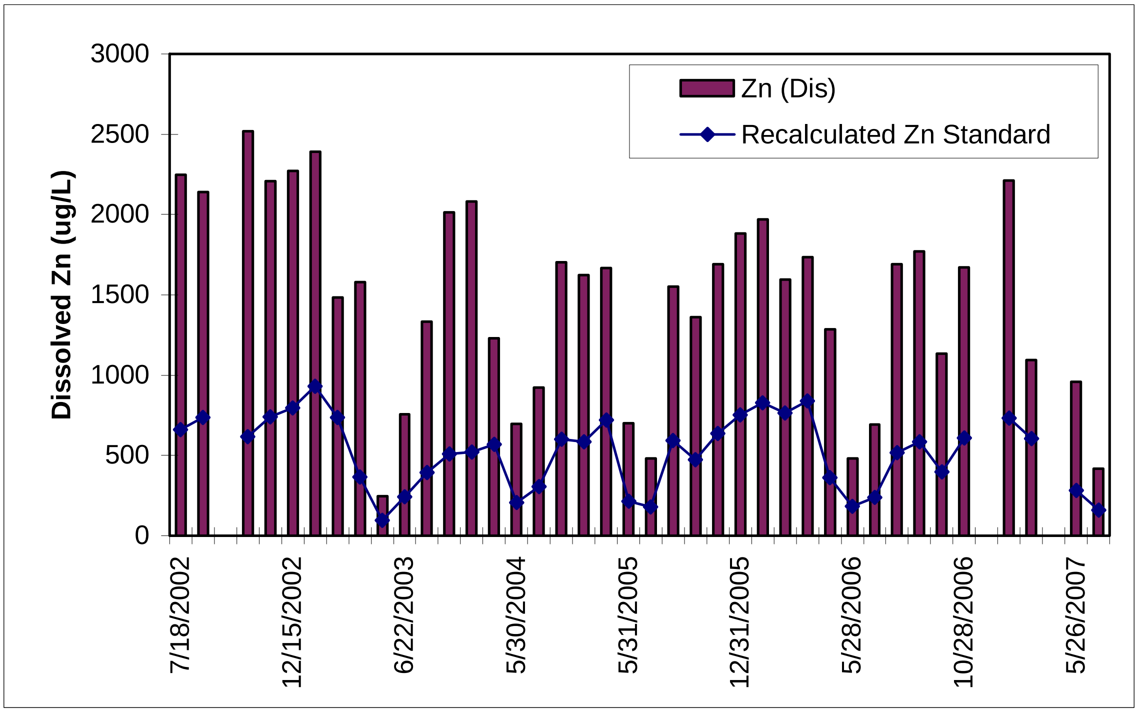


Figure 11. Hazard Quotients of Metals in Red Mountain Creek

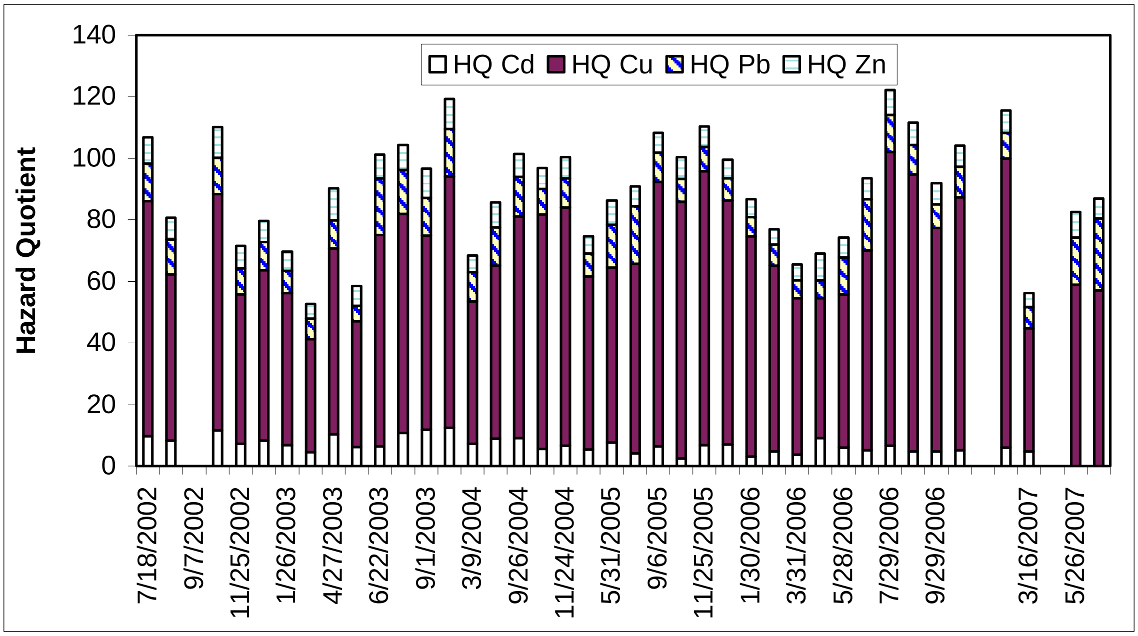


Figure 12. Total Aluminum (Al) concentrations compared to Table Value Standards (TVS) in Red Mountain Creek

Note: Aluminum standards have not been adopted in the Uncompahgre River Basin.

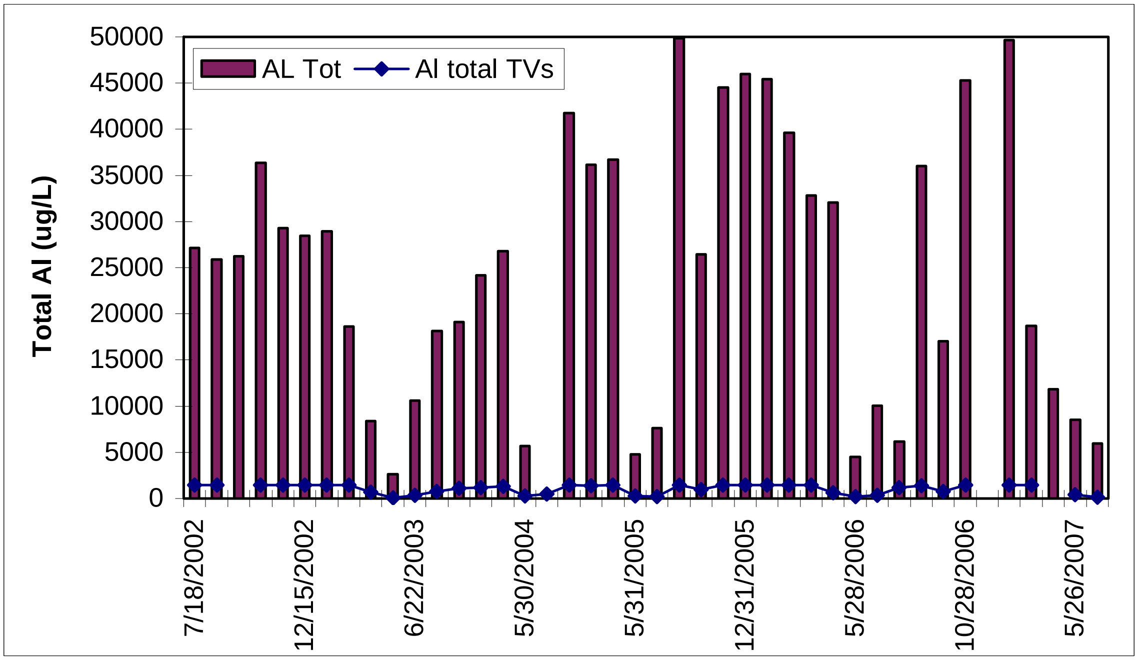


Figure 13. Total Iron (Fe) concentrations compared to Table Value Standards (TVS) in Red Mountain Creek

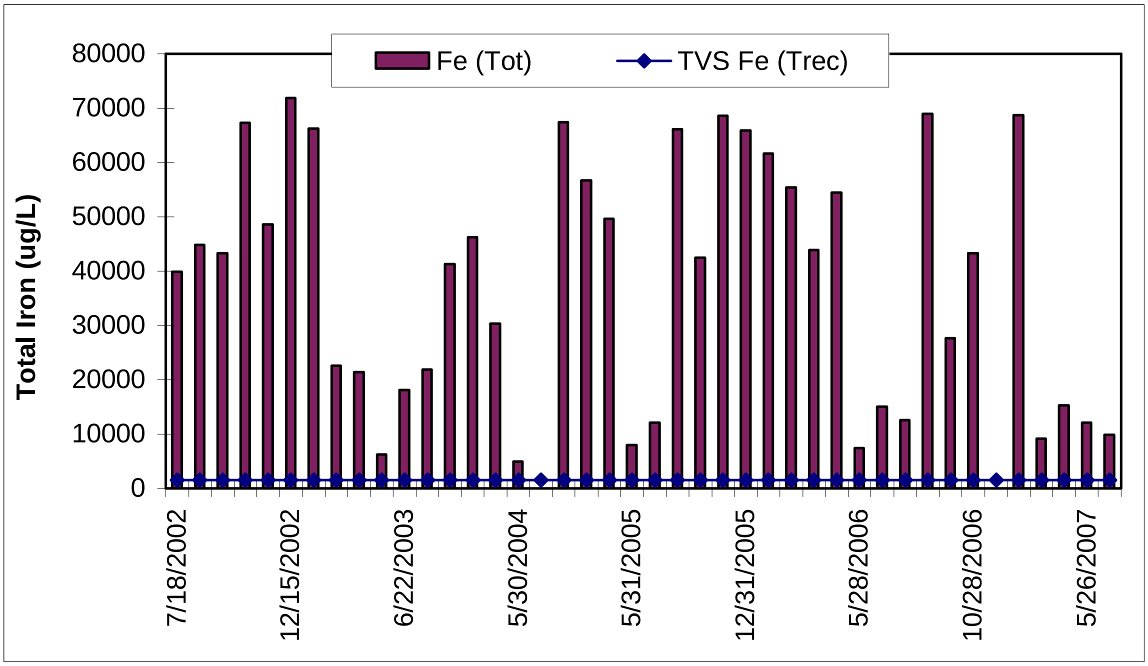


Figure 14. Zinc Loading at a Fall Low Flow Event in Red Mountain Creek

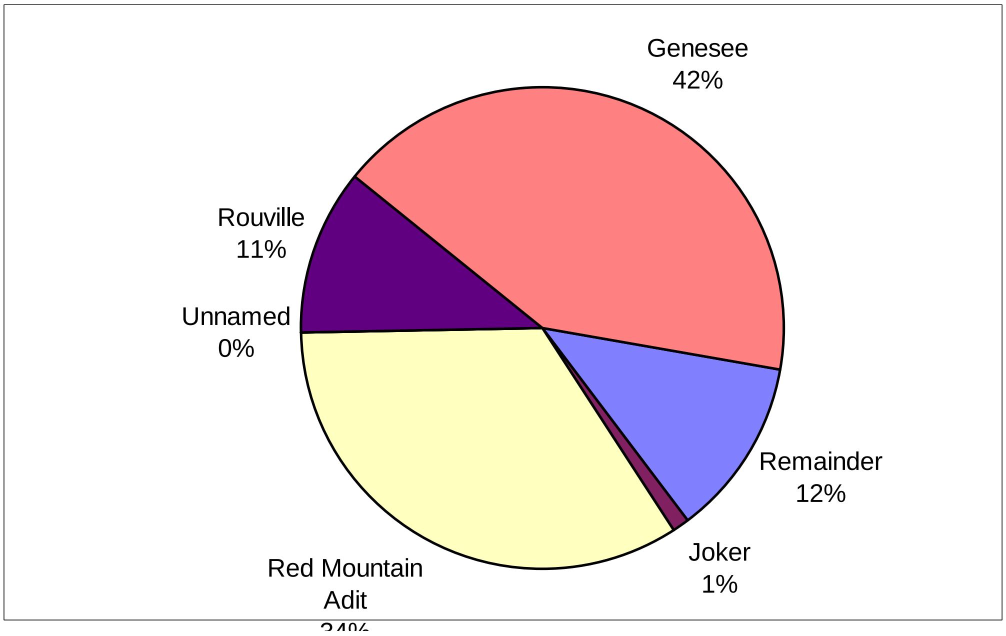


Figure 15. Zinc Loading at a Spring High Flow Event in Red Mountain Creek

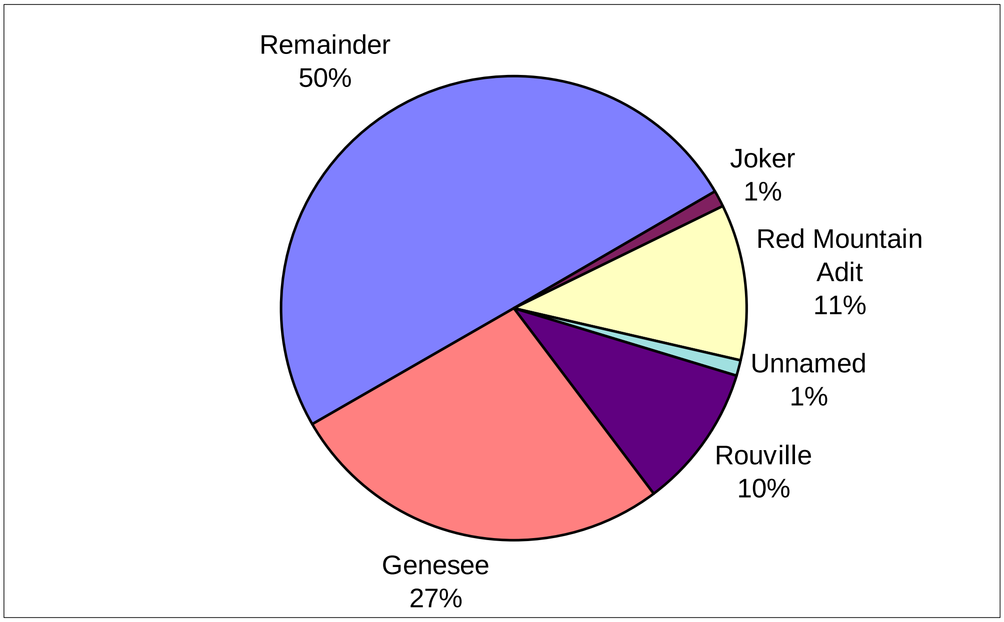


Figure 16. Dissolved Zinc (Zn) at Red Mountain Creek (1985 - 2008)

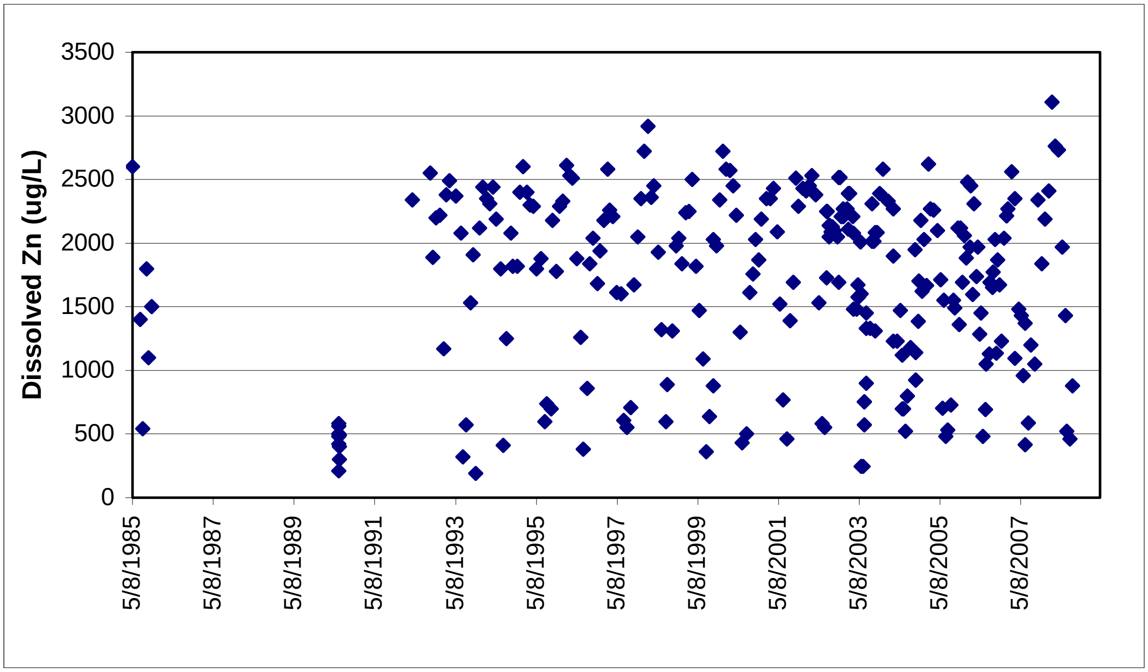


Figure 17. Dissolved Cadmium (Cd) compared to Table Value Standards (TVS) in the Uncompahgre River above Canyon Creek

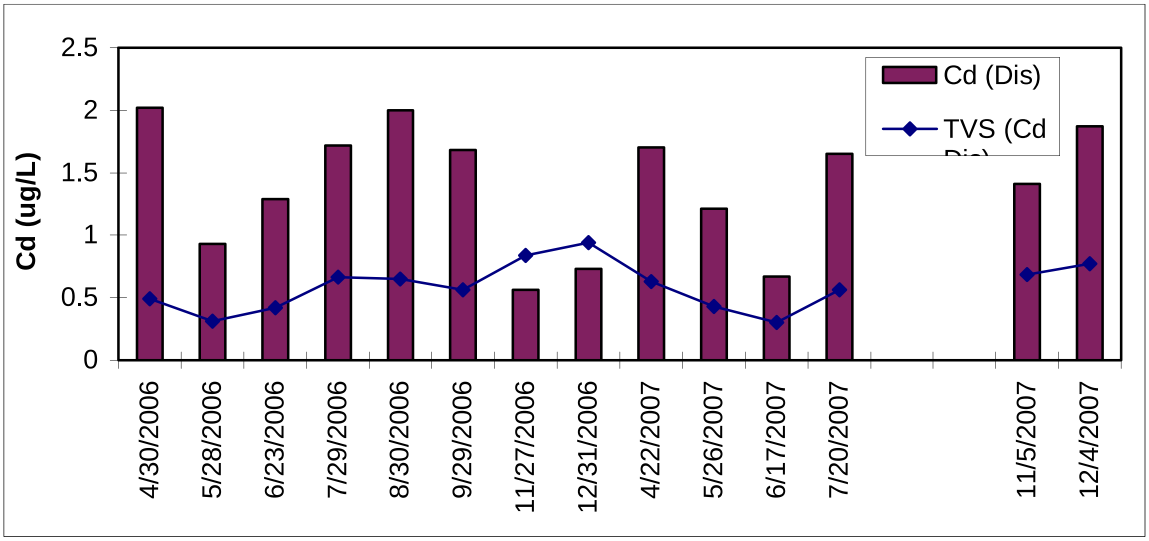


Figure 18. Dissolved Copper (Cu) compared to Table Value Standards (TVS) in the Uncompahgre River above Canyon Creek

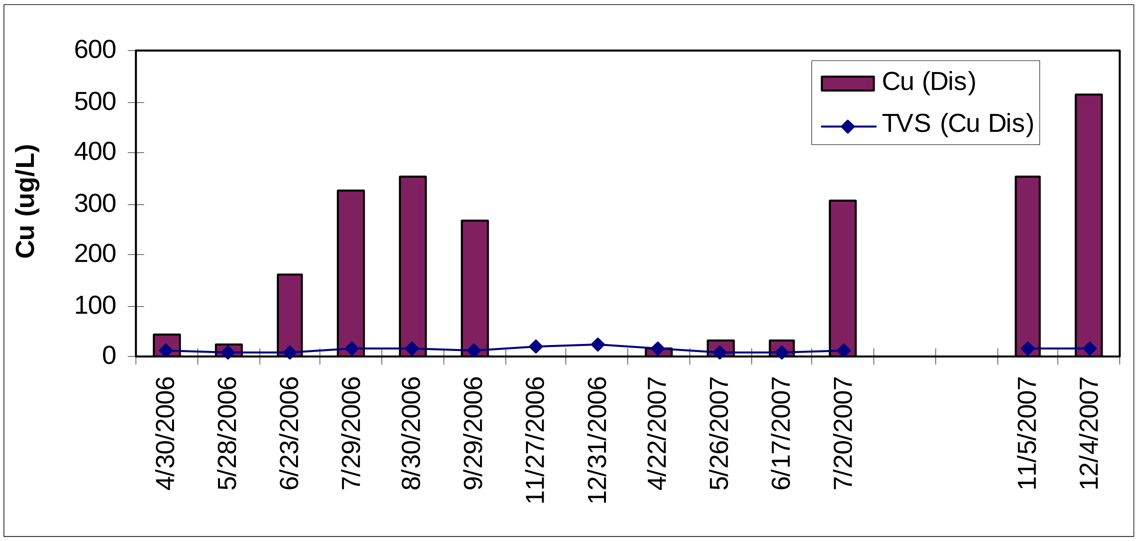


Figure 19. Dissolved Lead (Pb) compared to Table Value Standards (TVS) in the Uncompahgre River above Canyon Creek

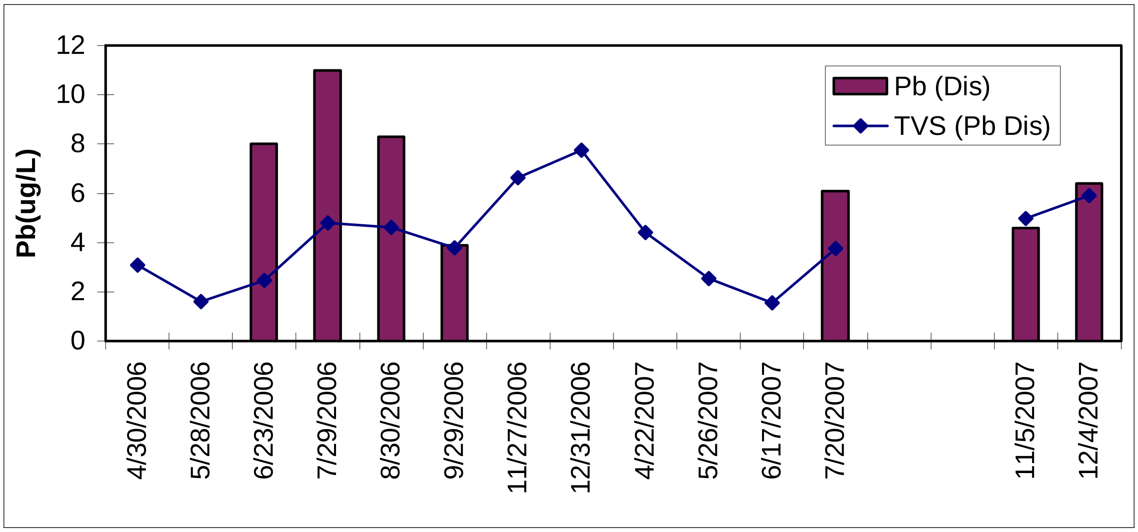


Figure 20. Dissolved Zinc (Zn) compared to Table Value Standards (TVS) in the Uncompahgre River above Canyon Creek

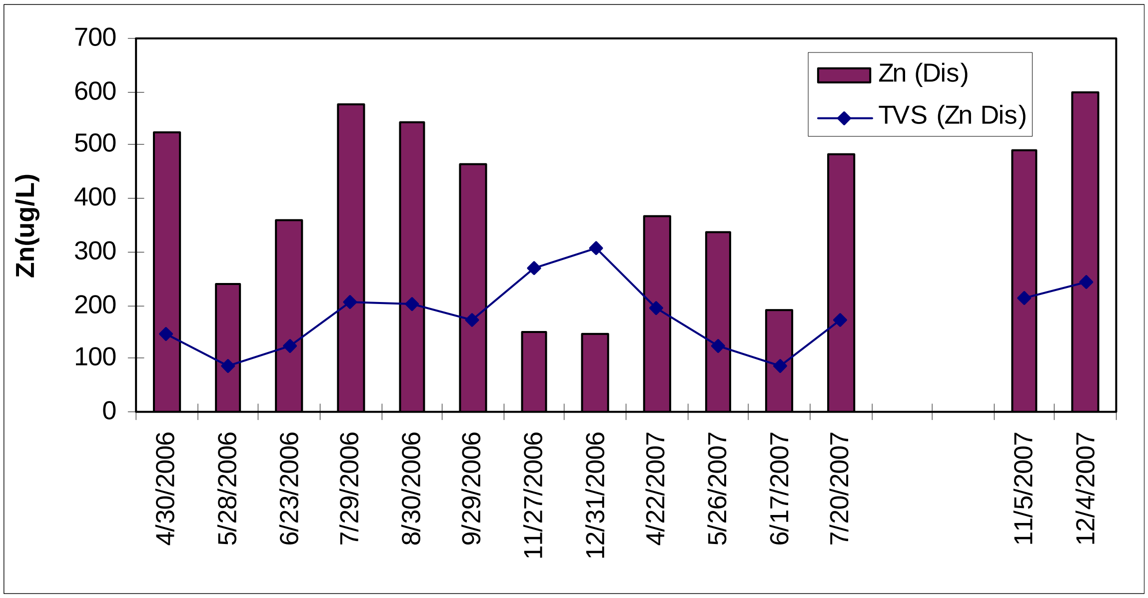


Figure 21. Dissolved Zinc (Zn) compared to Recalculated Zinc Standards in the Uncompahgre River above Canyon Creek

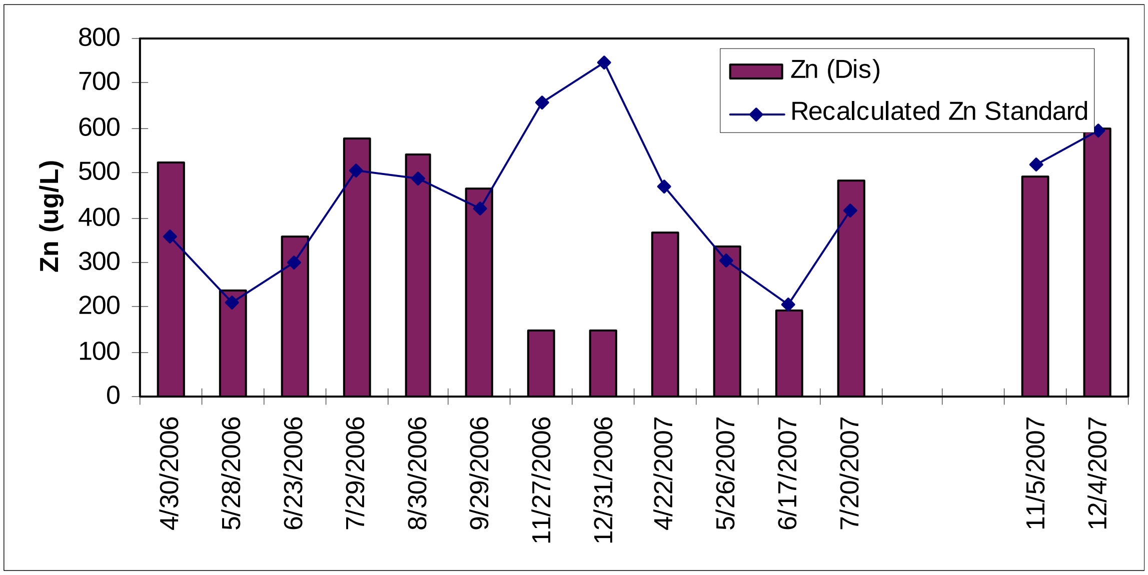


Figure 22. Hazard quotient, Uncompahgre River upstream of Ouray Hydro Dam (2006-2007)

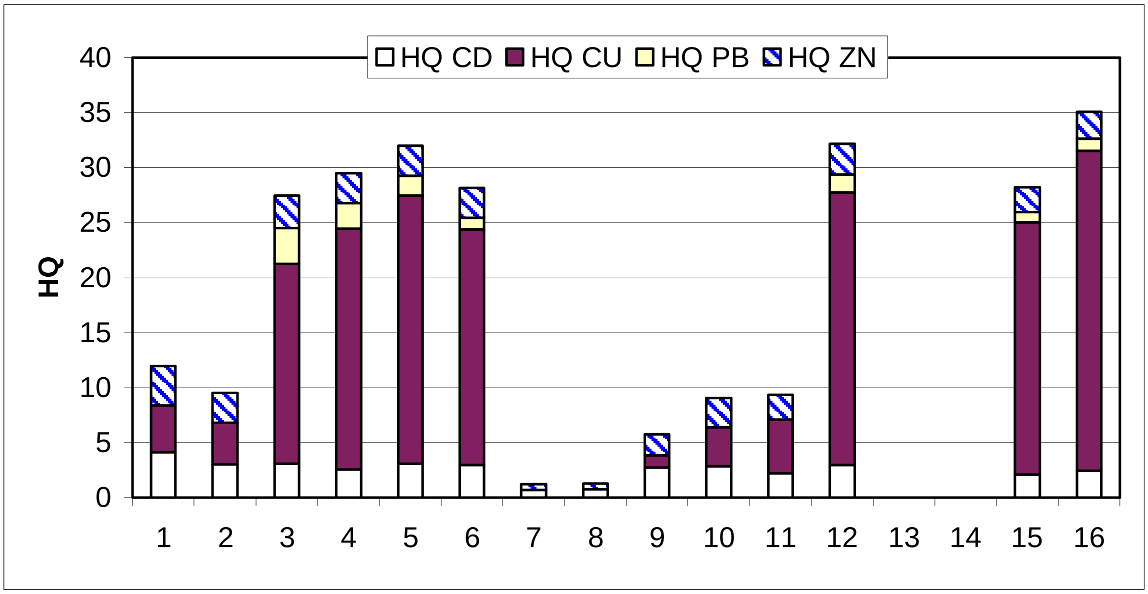


Figure 23. Dissolved Copper (Cu) and Hardness (CaCO3) in Uncompahgre River above Canyon Creek

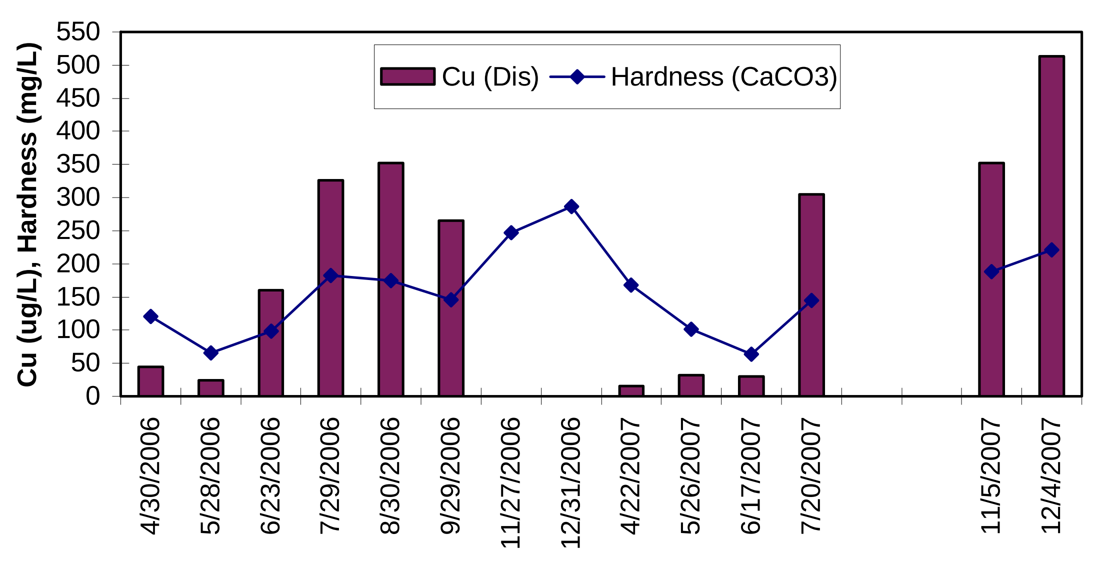


Figure 24. Total Aluminum (Al) compared to Table Value Standards (TVS) in the Uncompahgre River above Canyon Creek

Note: Aluminum standards have not been adopted in the Uncompahgre River Basin.

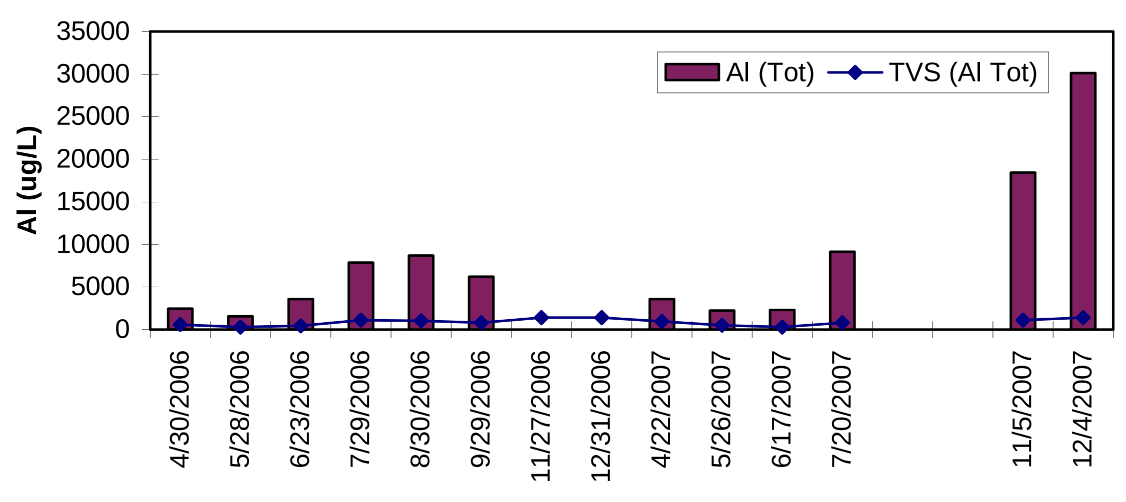


Figure 25. Dissolved Aluminum (Al) and pH in the Uncompahgre River above Canyon Creek

Note: Aluminum standards have not been adopted in the Uncompahgre River Basin.

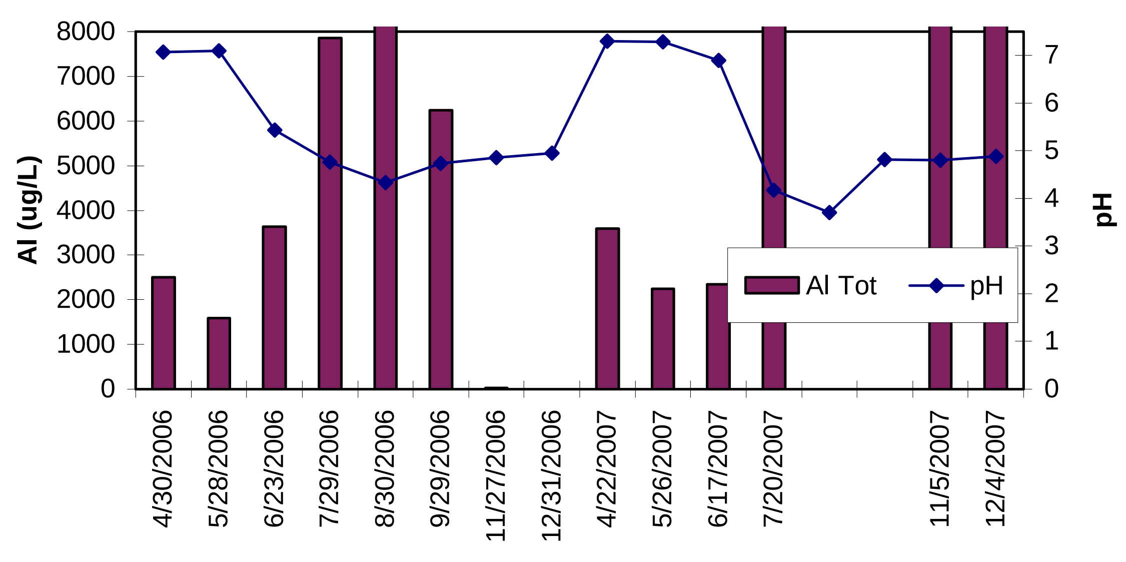


Figure 26. pH in Canyon Creek near mouth (1995 -2002)

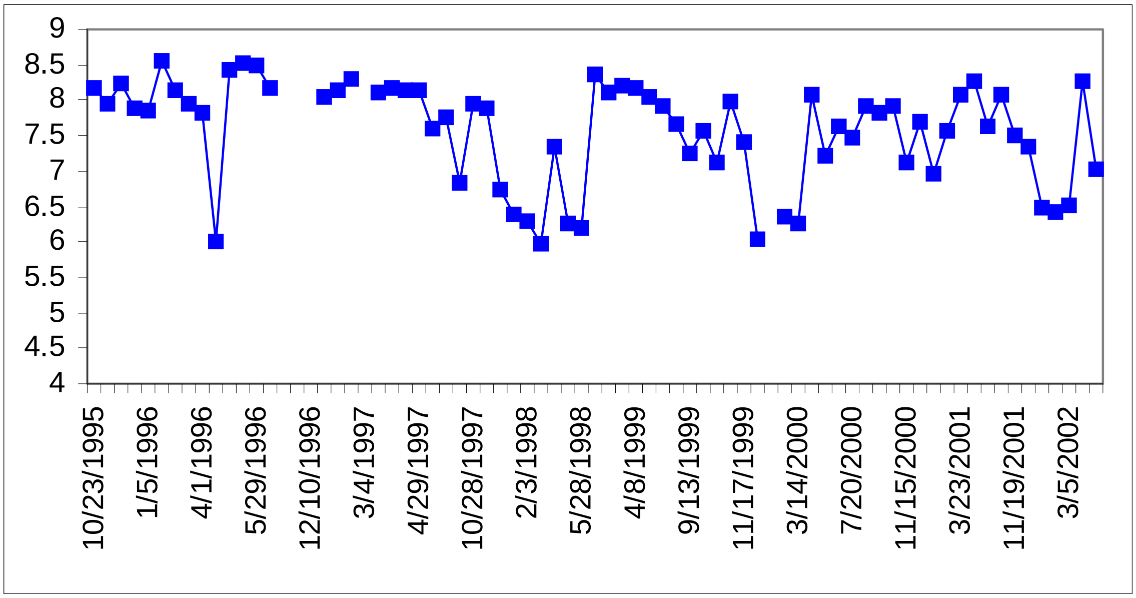


Figure 27. Hardness as $CaCO_3$ in Canyon Creek (1995 -2002)

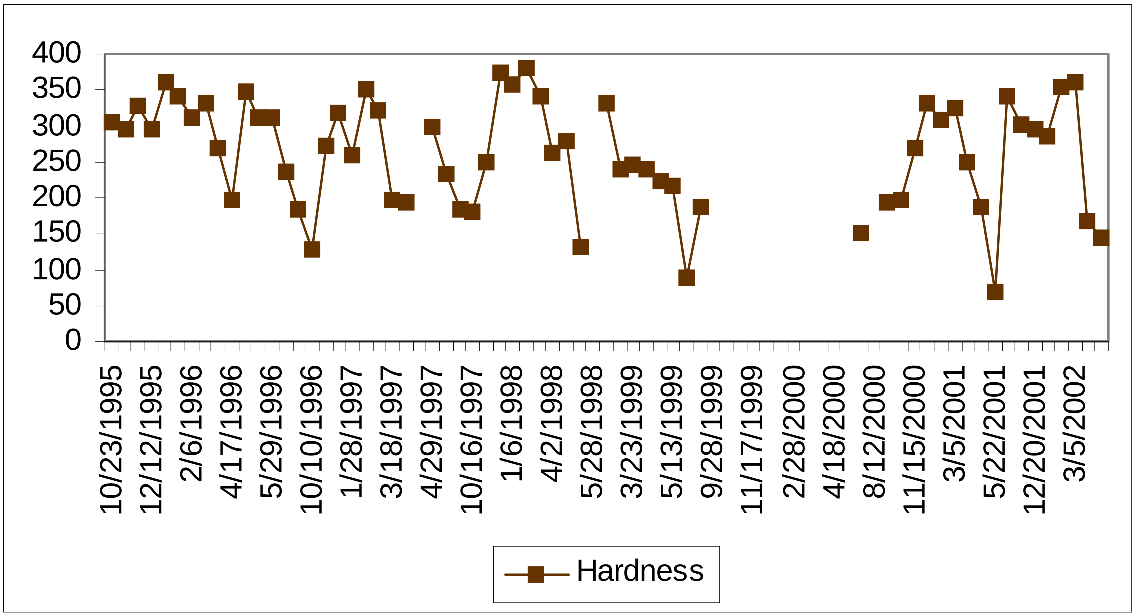


Figure 28. Dissolved Cadmium (Cd) in Canyon Creek compared to chronic Table Value Standards (1996 - 2001)

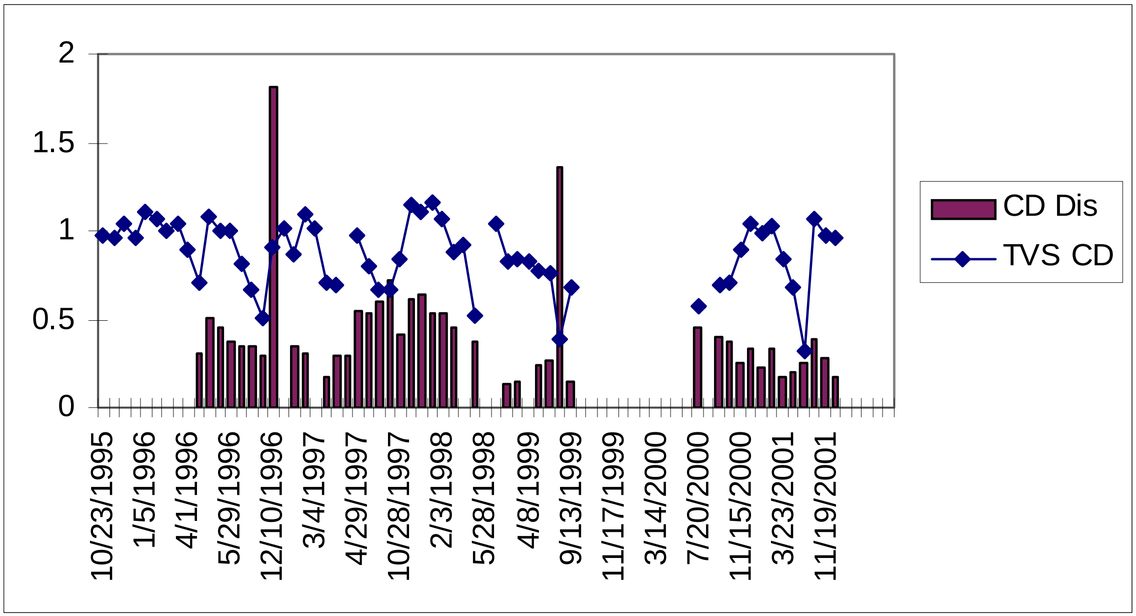


Figure 29. Dissolved Copper (Cu) in Canyon Creek compared to chronic Table Value Standard (1996 - 2001)

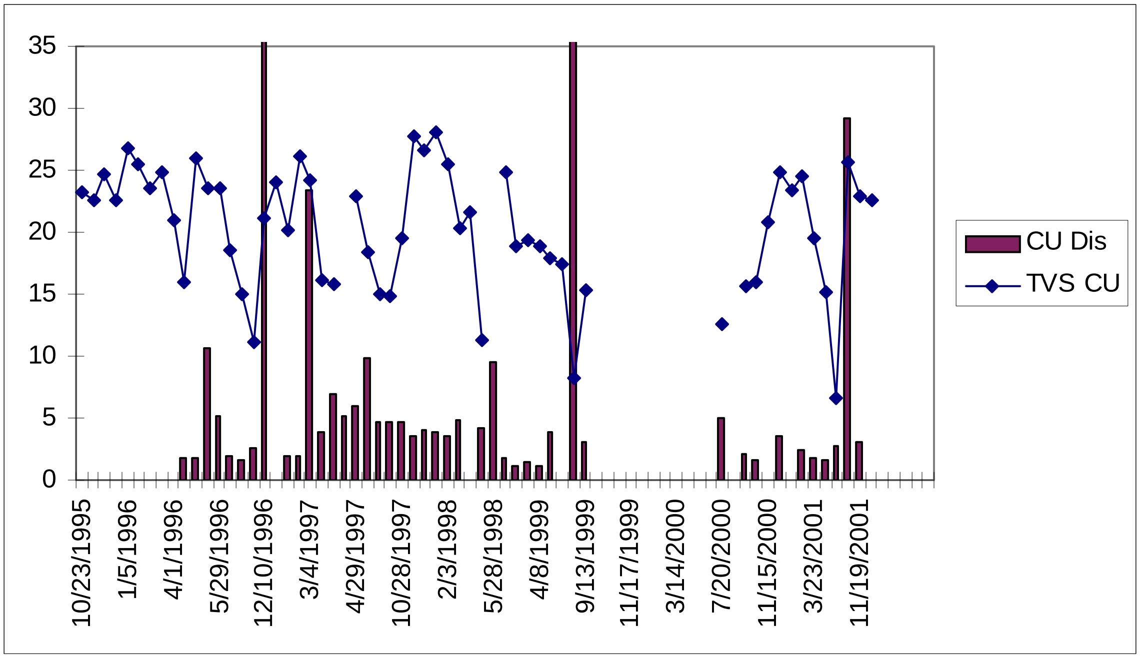


Figure 30. Dissolved Zinc (Zn) in Canyon Creek compared to chronic Table Value Standards (1996 - 2001)

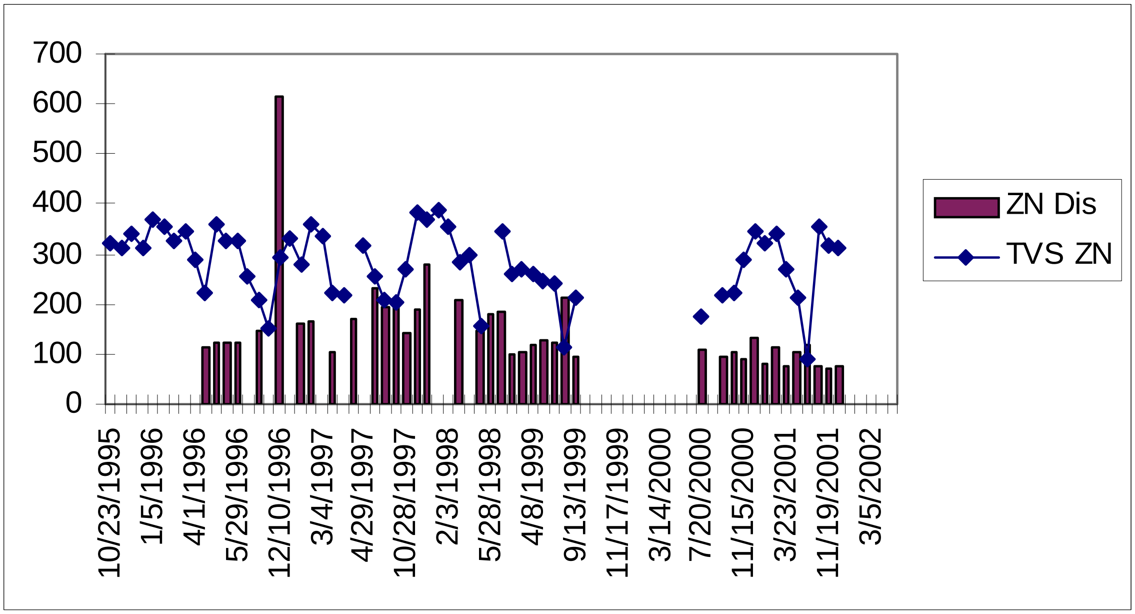


Figure 31. Hazard quotients in Canyon Creek (1996-2002)

Note: Numbers on X axis correspond to sample dates from 1996 to 2002 in Figure 30

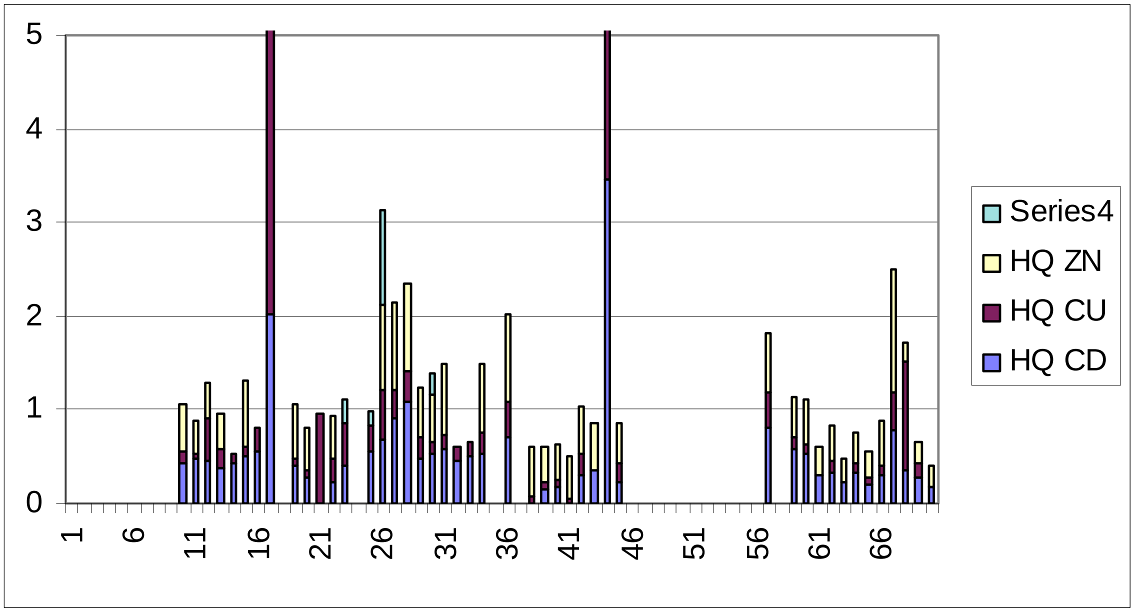


Figure 32. Dissolved Aluminum (Al) in Canyon Creek compared to chronic Table Value Standards (1996-2002)

Note: Aluminum standards have not been adopted in the Uncompahgre River Basin.

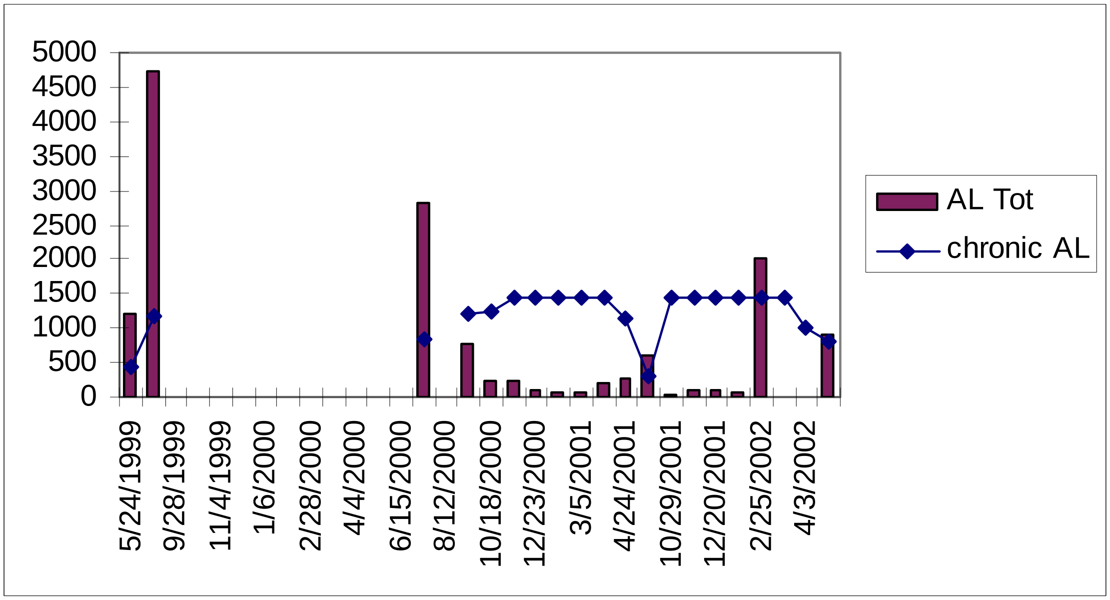


Figure 33. Dissolved Copper (Cu) compared to Table Value Standards (TVS) in the Uncompahgre River below Oak Creek in Ouray

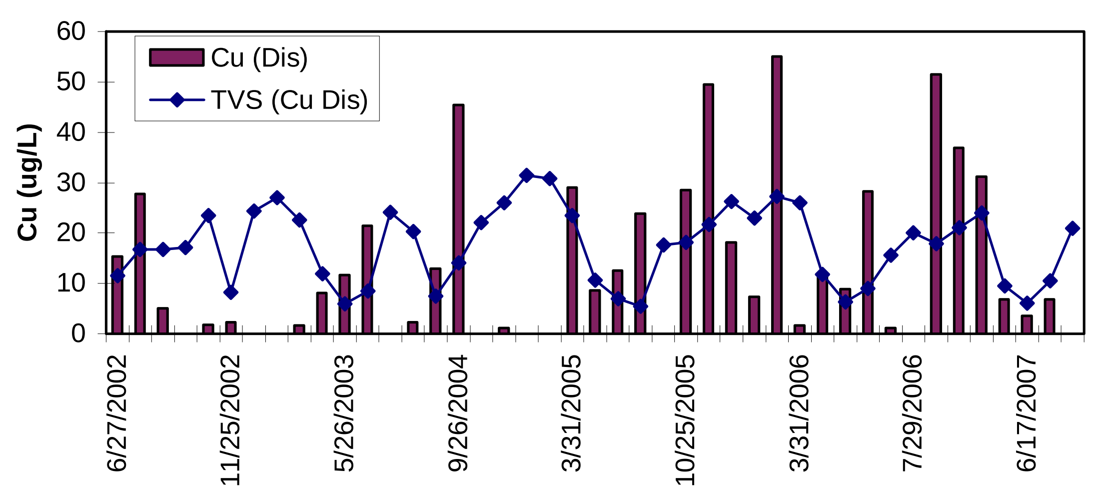


Figure 34. Dissolved Cadmium (Cd) compared to Table Value Standards (TVS) in the Uncompahgre River below Oak Creek in Ouray

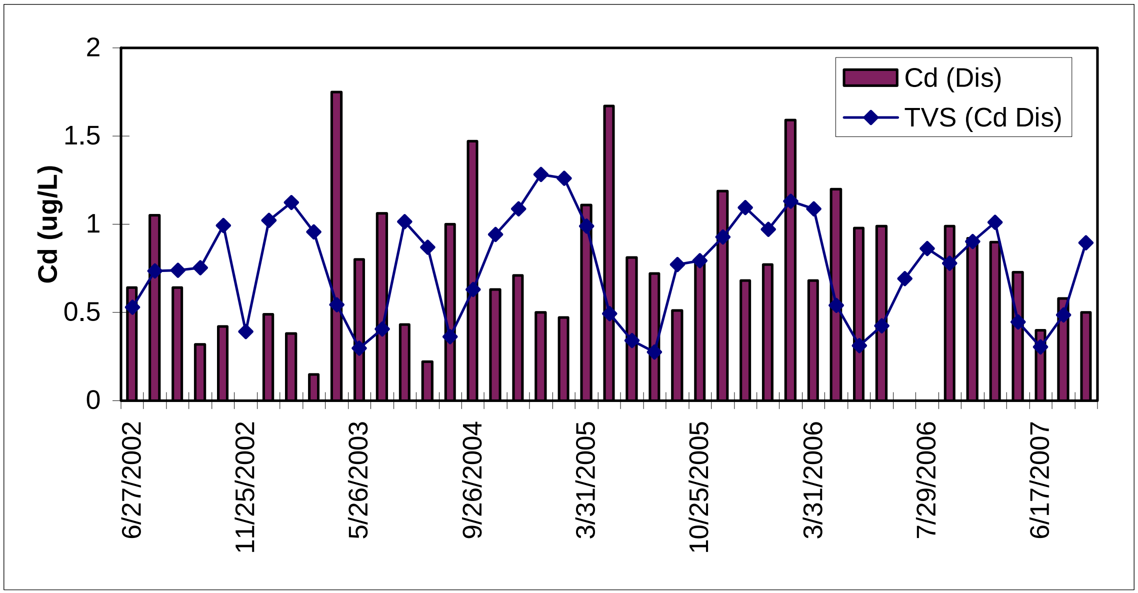


Figure 35. Relationship of Total Aluminum (Al ug/L) to flow (cfs) downstream of Ouray (Station 3586, Gage 09146020, 2002-2006)

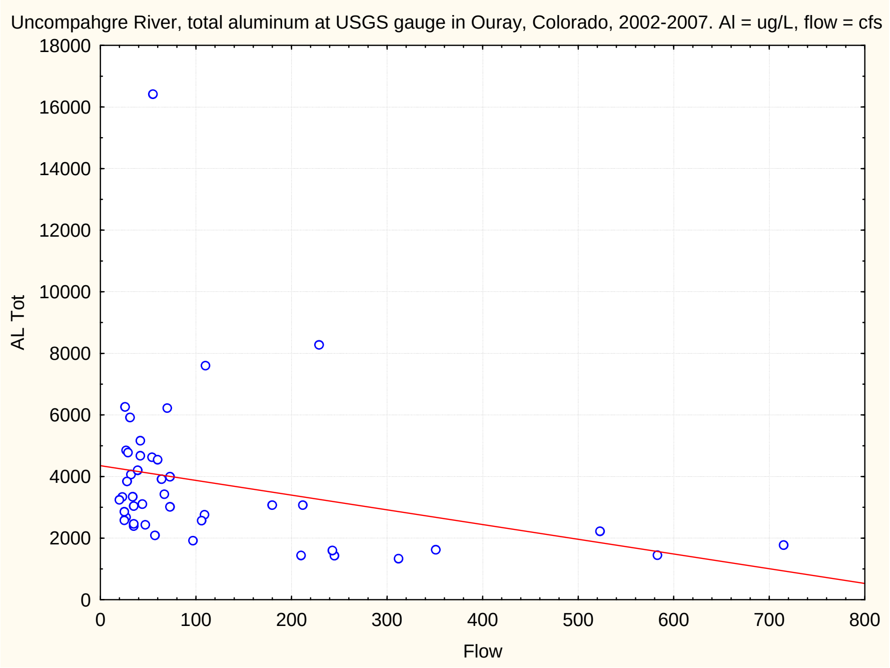


Figure 36. Relationship of Total Aluminum (Al ug/L) to flow (cfs) upstream of Ridgway Reservoir at County Road 24 (Station 395, Gage 9146200, 2002-2006)

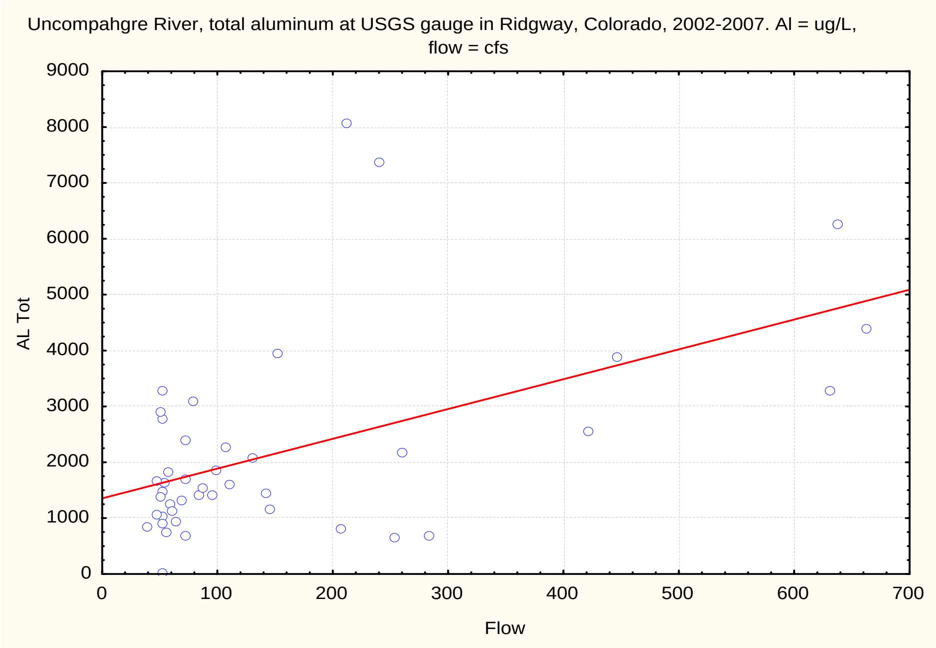


Figure 37. Total aluminum loading at two sites on Uncompahgre River, the USGS gage in Ouray and the USGS gage upstream of Ridgway Reservoir
(Data from Station 3586, Gage 09146020 and Station 395, Gage 9146200)

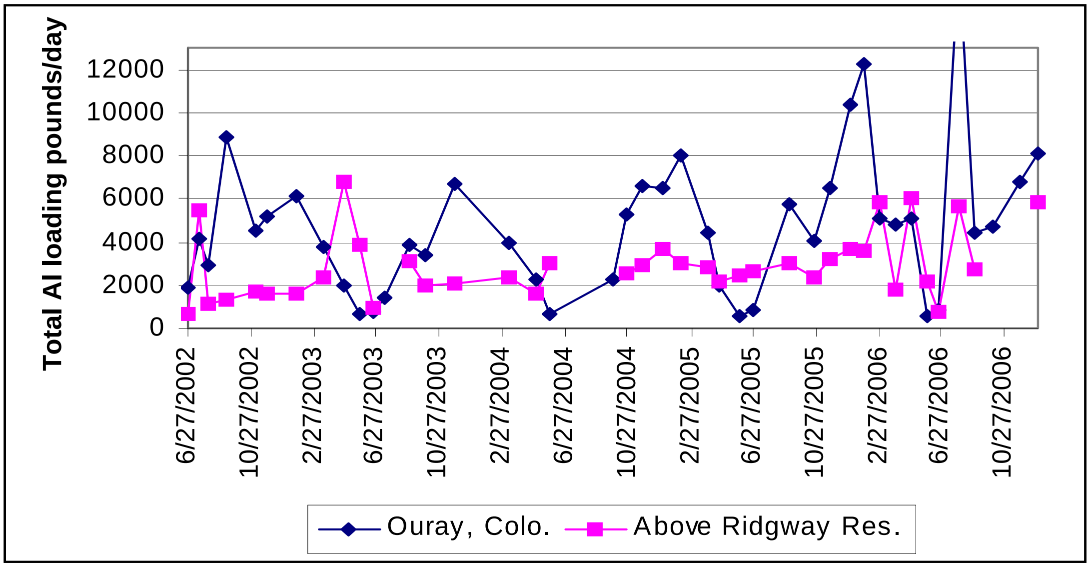


Figure 38. Total aluminum (ug/L) compared to the chronic Aluminum Table Value Standard, Uncompahgre River at Potter Ranch downstream of Ouray
Note: Aluminum standards have not been adopted in the Uncompahgre River Basin.

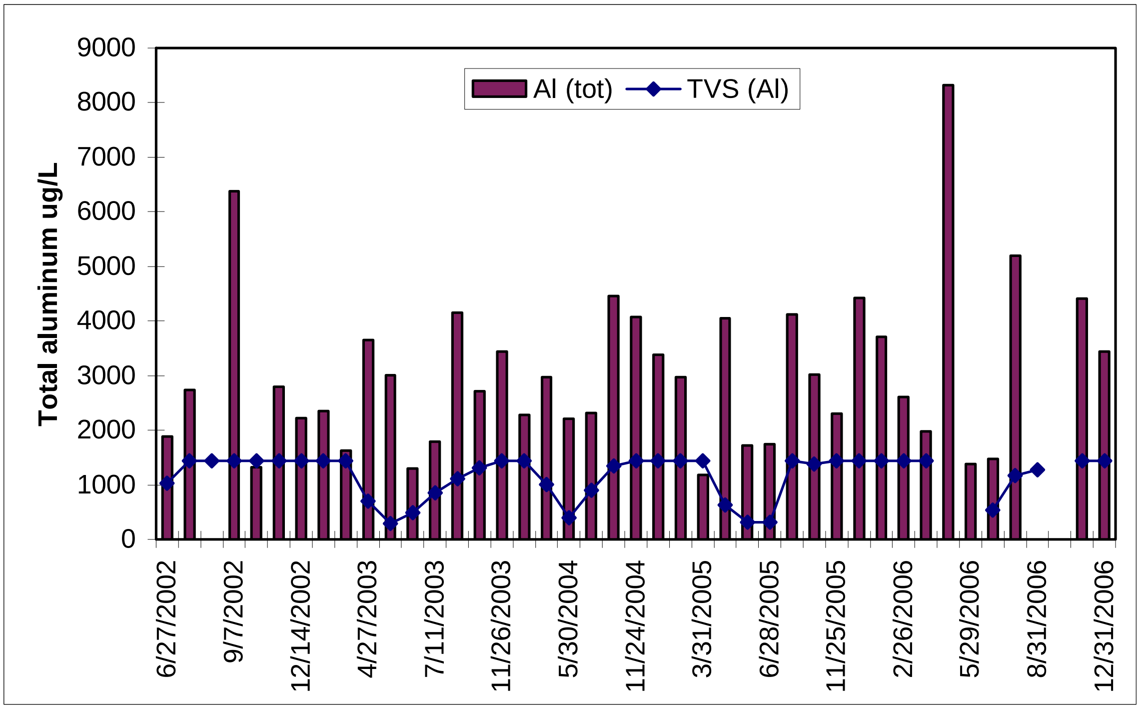


Figure 39. Total Aluminum (ug/L) compared to the chronic Aluminum Table Value Standard, Uncompahgre River at Potter Ranch downstream of Ouray

Note: Aluminum standards have not been adopted in the Uncompahgre River Basin.

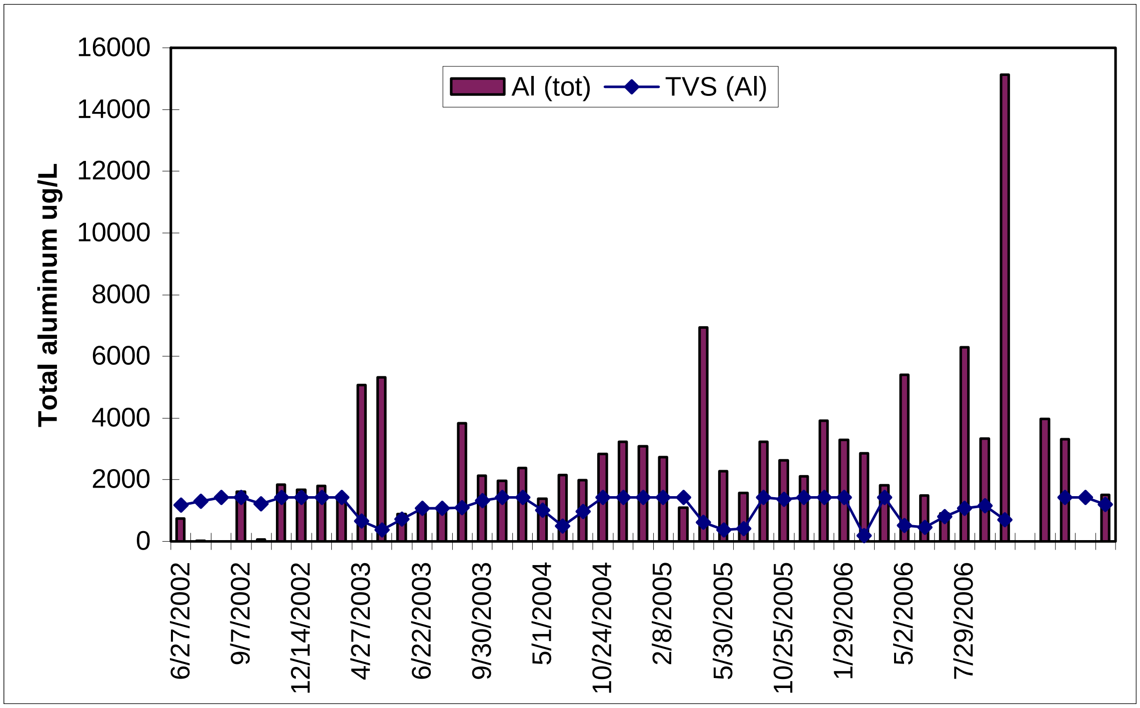


Figure 40. Total Aluminum (ug/L) compared to the chronic Aluminum Table Value Standard, Uncompahgre River at a sampling site upstream of Ridgway Reservoir

Note: Aluminum standards have not been adopted in the Uncompahgre River Basin.

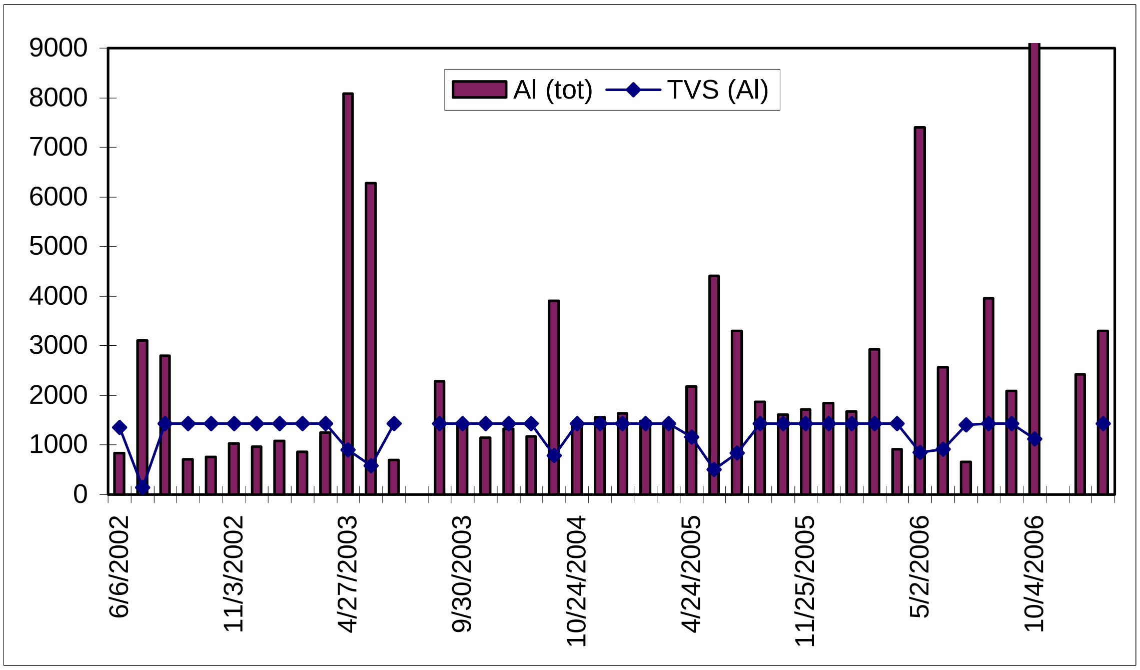


Figure 41. Water temperature C° Uncompahgre River at LaSalle Road
(2007 - 2009)

Figure 42. Sulfate (SO_4 mg/L) Uncompahgre River at LaSalle Road.
(2007 - 2009)

Figure 43. Hardness (mg/L as $CaCO_3$) in the Uncompahgre River at LaSalle Road (2007 - 2009)

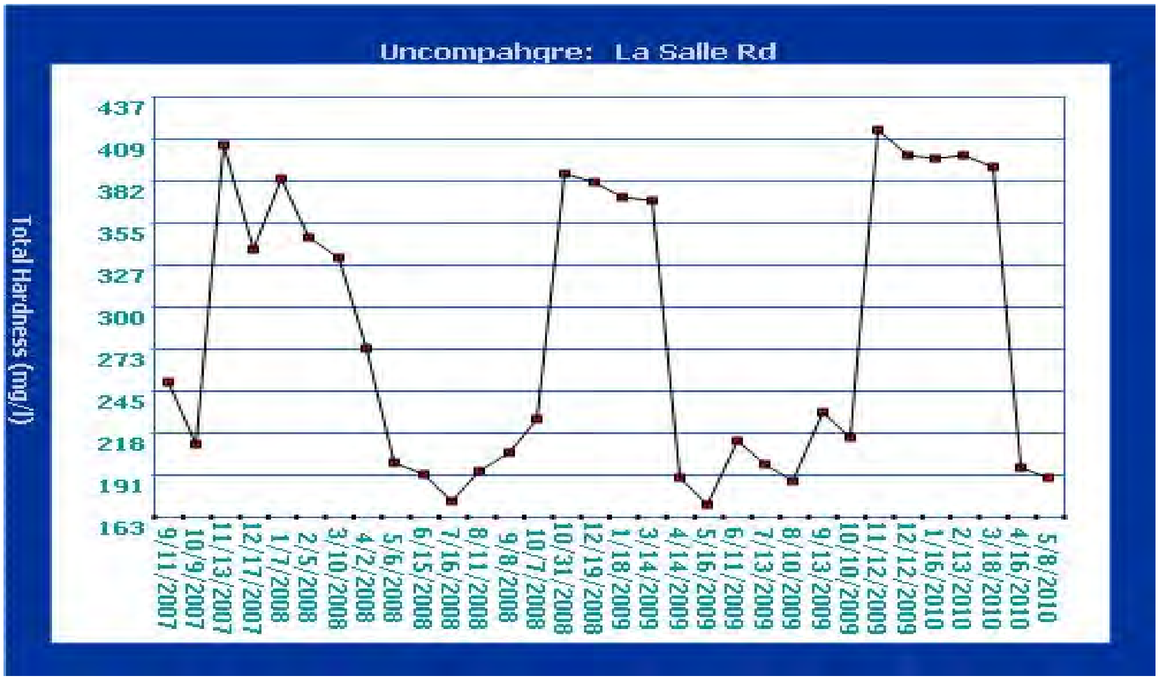


Figure 44. Nitrate (NO_3 as N mg/L) in the Uncompahgre River at LaSalle Road (2007 - 2009)

Figure 45. Total dissolved solids in Uncompahgre River in Delta (Site 55).

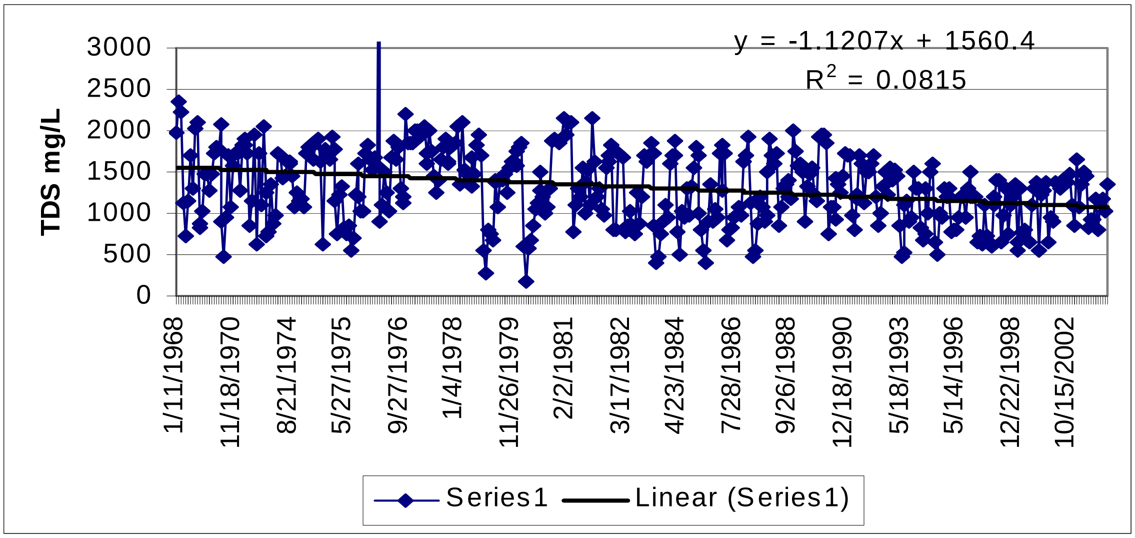


Figure 46. Suspended Solids (mg/L) in Uncompahgre River in Delta (Site 55). (1968-2007)

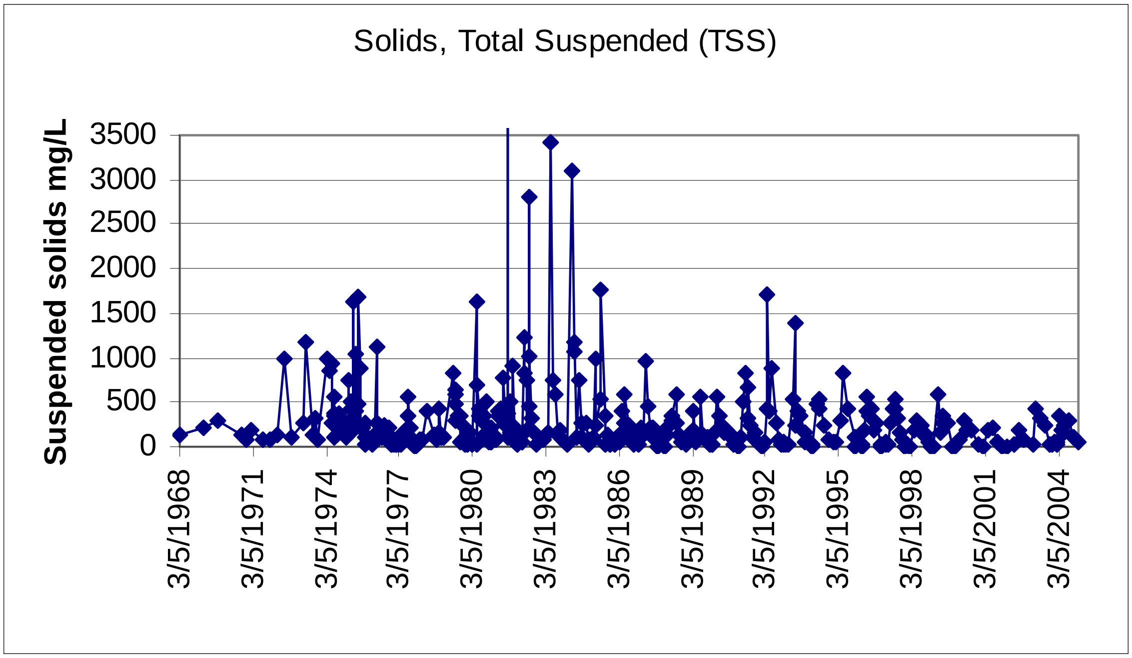
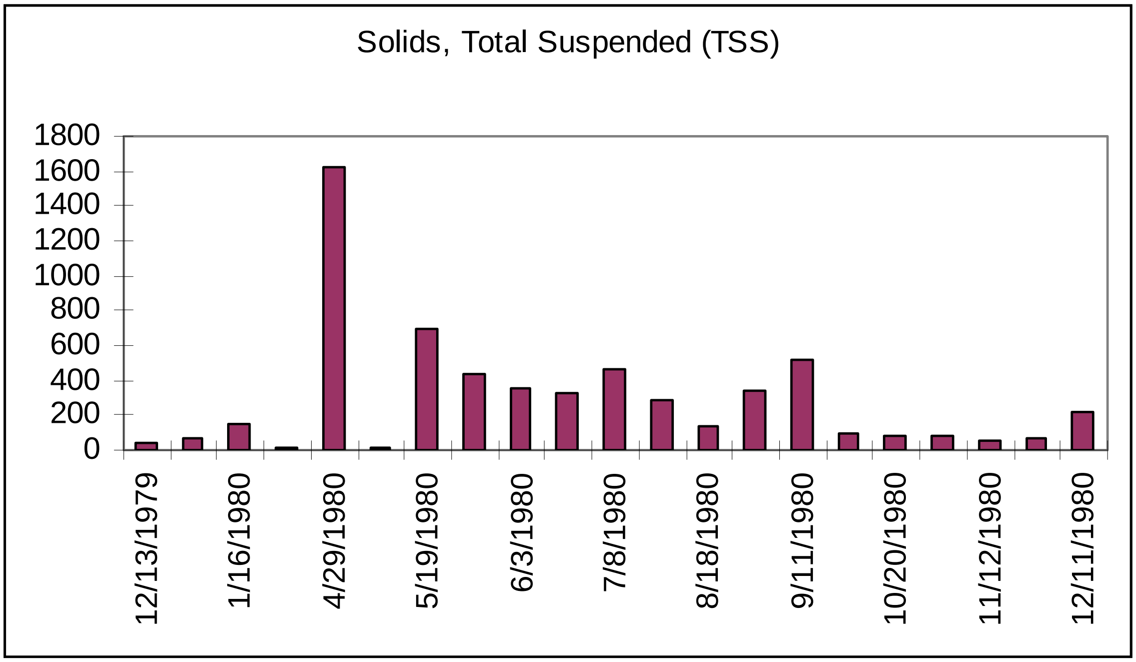


Figure 47. Monthly Suspended Solids in Uncompahgre River at Delta (Site 55) (1979-1980)

Note: The time period of 1979 to 1980 was selected randomly to provide the resolution



needed to demonstrate that suspended solids in the Uncompahgre River routinely exceed 200 mg/L during multiple months each year. This same pattern exists for most years for which data are available.

Figure 47. Total Aluminum ug/L Uncompahgre River at Delta (Site 55) compared to chronic Table Value Standard

Note: All hardness concentrations exceeded 220 mg/L $CaCO_3$, so chronic standard is 1,437 ug/L. Aluminum standards not adopted for the Uncompahgre River Basin.

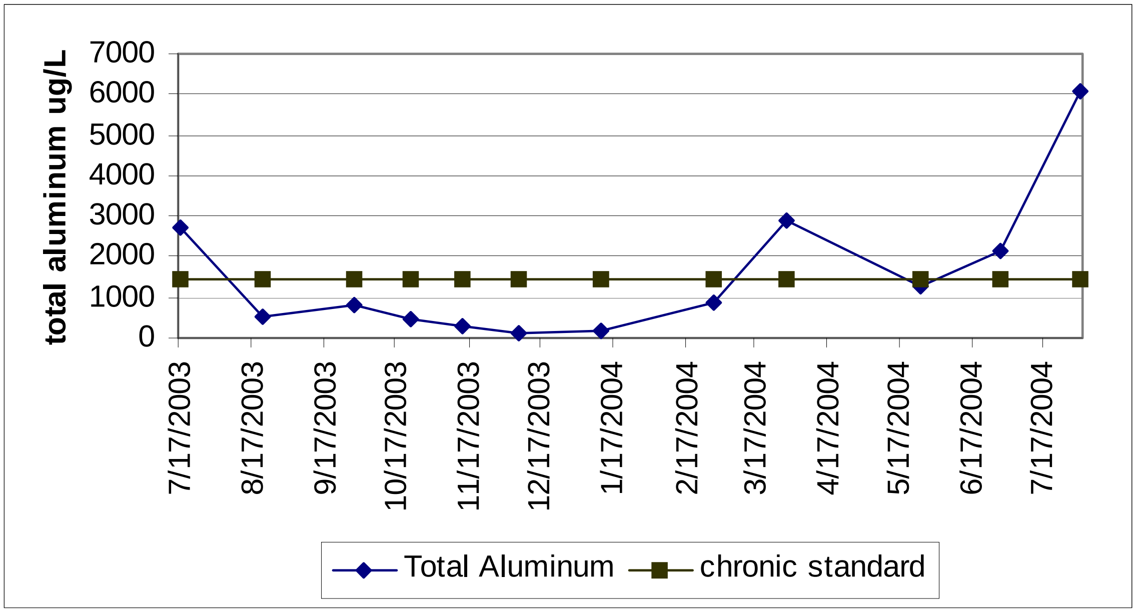
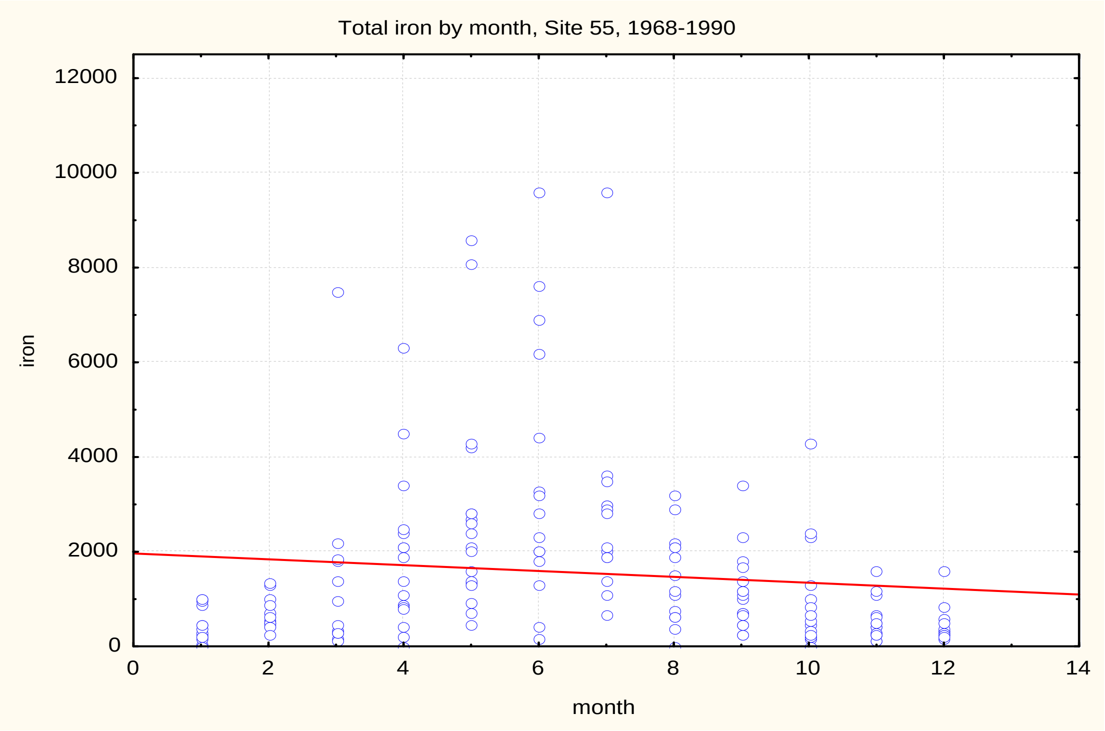


Figure 48. Total iron (ug/L) in Uncompahgre River at Site 55.



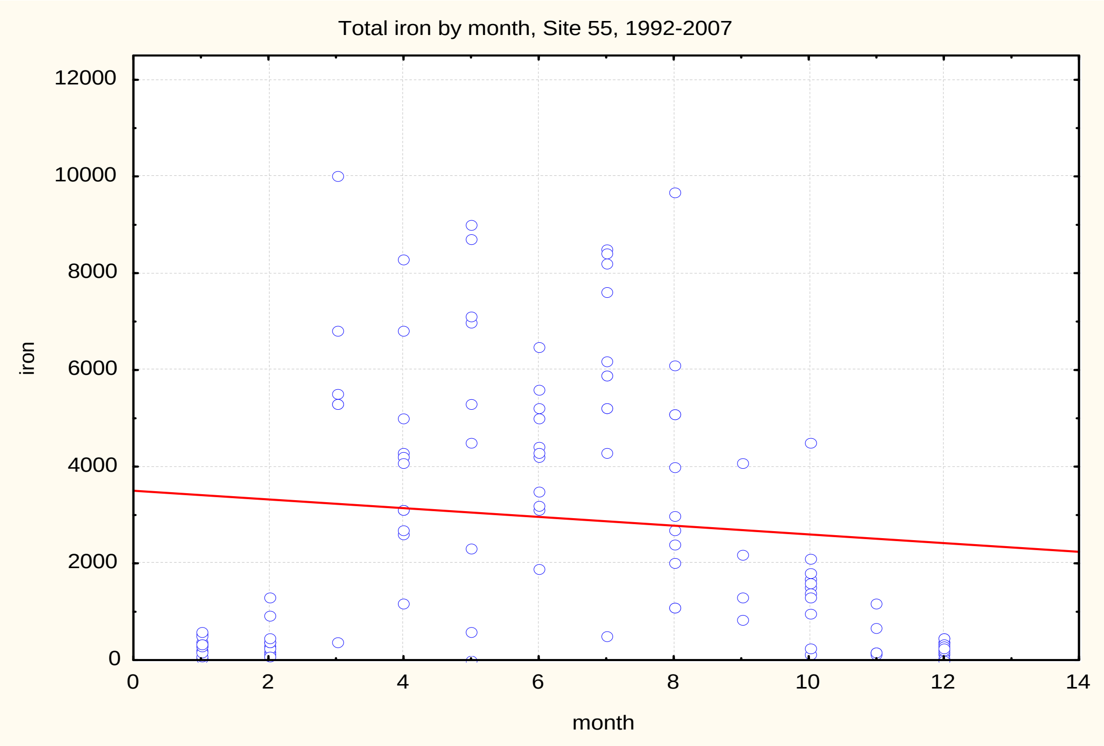


Figure 49. Dissolved selenium (ug/L) in Uncompahgre River in Delta (Site 55).
Note: Values collated by month. Numerals = months, 1 = January, 8 = August, etc.