Black Canyon Creek

Watershed/Aquatic Habitat Enhancement Basis of Design Report

New Mexico Environment Department

Grant County, New Mexico

Natural Channel Design, Inc.

May 2019

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Basis of Design Report

Submitted to:
New Mexico Environment Department- Surface Water Quality Bureau
3082 32nd Street Bypass Road. Suite D
Silver City, NM 88061

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PROFESSIONAL ENGINEER

May 2019

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May 9, 2019

John Moeny
Watershed Protection Section
New Mexico Environment Department
3082 32nd Street Bypass Road, Suite D
Silver City, New Mexico 88061

RE: Black Canyon
Watershed/Aquatic Habitat Enhancement Project
Black Canyon, Grant County, New Mexico

Dear Mr. Moeny

Natural Channel Design, Inc. is pleased to present this final report relative to the Black Canyon Aquatic Habitat Enhancement Project. The project focus is primarily on improving water temperature impairment and habitat for the Gila Trout within a 3.25 mile reach of the Black Canyon Creek from the boundary of the Luna Leopold Wilderness to the confluence with Aspen Canyon.

In general, the assessment and design included herein and in the accompanying plans is based upon our team knowledge and experience with wetlands, riparian habitats, aquatic habitats, hydrology, hydraulics, geomophology and civil engineering practices. Specific conclusions presented herein relative to the possibilities of aquatic habitat enhancement within the creek are also based upon careful field observations at the site; specific channel reach and cross section surveys, and other data gathered throughout the project during multiple site visits in 2018 and 2019.

It is anticipated that the prescriptions for habitat enhancement included within the plans and described within this report will be implemented in a multi-phased approach over several years as funding and logistics allow. Given the dynamic nature of the stream, some channel and floodplain conditions along the project reach may vary from what was observed during the assessment and design process. It is recommended that Natural Channel Design be consulted when implementation is planned, to confirm the conditions and appropriateness of the prescriptions at that time. We would look forward to providing additional assistance to the New Mexico Environment Department and working with its implementation team(s) to ensure that the intent of the design is met.

If you have any questions relative to the content of this report or the accompanying plans, please feel free to call us at your earliest convenience.

Sincerely,

Allen Haden
Aquatic Ecologist, President
Natural Channel Design, Inc.

Michael D. Kearly, PE, CFM
Principal Engineer

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PROJECT DESCRIPTION

Black Canyon Creek supports an important Gila trout (*Oncorhynchus gilae)* habitat and is listed under the Clean Water Act Section 303d due to excessive temperature loading. The watershed that drains into Black Canyon Creek has been subject to several wildfires since the late 1990s and overgrazing that extended for decades before that. These events have caused the creek morphology to change, particularly causing the creek to become wider and plugged with sediment. Due to these changes, the EPA approved a Watershed-Based Plan (WBP) in 2017 that identified numerous "low value" aquatic habitat areas that contribute to the excessive temperature loading in the creek. The low value habitat areas are characterized by wide and shallow geometries with open canopy that lead to warming water temperatures that exceed the water quality standard of 20 degrees Celsius. Temperatures above this limit are seen as detrimental for the Gila trout. This objective of this current effort is to build on the approved watershed-based plan and develop an implementable design to address water quality impairments. The project consisted of assessing the current stream morphology, geomorphology, and habitat conditions in order to understand the complexity of the creek through the study reach. The assessment was then used to design a riparian enhancement plan with the primary focus of reducing water temperature and increasing viable fish habitat.

PROJECT PURPOSE

The New Mexico Environmental Department (NMED) wishes to enhance the stream morphology and fish habitat in Black Canyon Creek and to reverse the rising water temperatures. A Watershed-Based Plan (WBP) was completed by NMED to determine the causes and sources of increased temperatures in Black Canyon Creek and outlined possible measures to decrease water temperatures and improve water quality. The purpose of this project is to provide a design for the enhancement of Black Canyon Creek in order to decrease temperature and improve conditions for the Gila trout. The enhancements presented in the design are intended to improve the stream and riparian habitat conditions for the Gila trout by increasing riparian cover and improving the geomorphic stability of the steam. The design has been informed by a geomorphic assessment of Black Canyon Creek to describe habitat conditions and trends and by temperature modeling to determine current and improved temperature loading.

PROJECT LOCATION

Black Canyon Creek is an east-to-west running steam that drains to the west side of the Black Range Mountains and joins the East Fork of the Gila River, north of Silver City, NM in Grant County. The downstream project reach begins to the east of the Diamond Bar Ranch at the border of the Aldo Leopold Wilderness (33.185375, -108.006212) and ends upstream at the confluence of Aspen Canyon and Black Canyon (33.1632, -107.9616). The project reach is accessed by North Star Road and taking the Black Canyon trail which follows the private land boundary, or by gaining access through Diamond Bar Ranch. The project reach is located within the Aldo Leopold Wilderness and covers 3.25 miles. Figure 1 and Figure 2 show the approximate location of the project site.

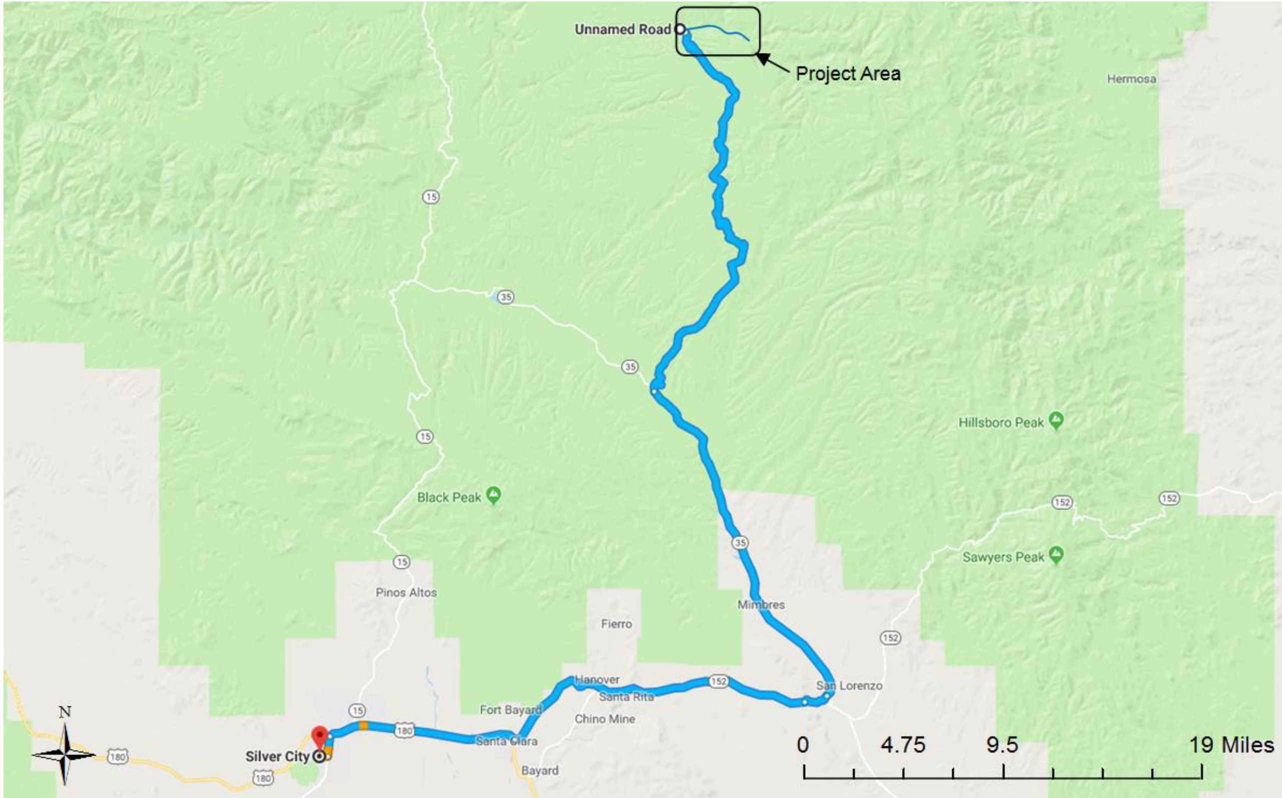

Figure 1: Location of the project reach of Black Canyon Creek in relation to Silver City.

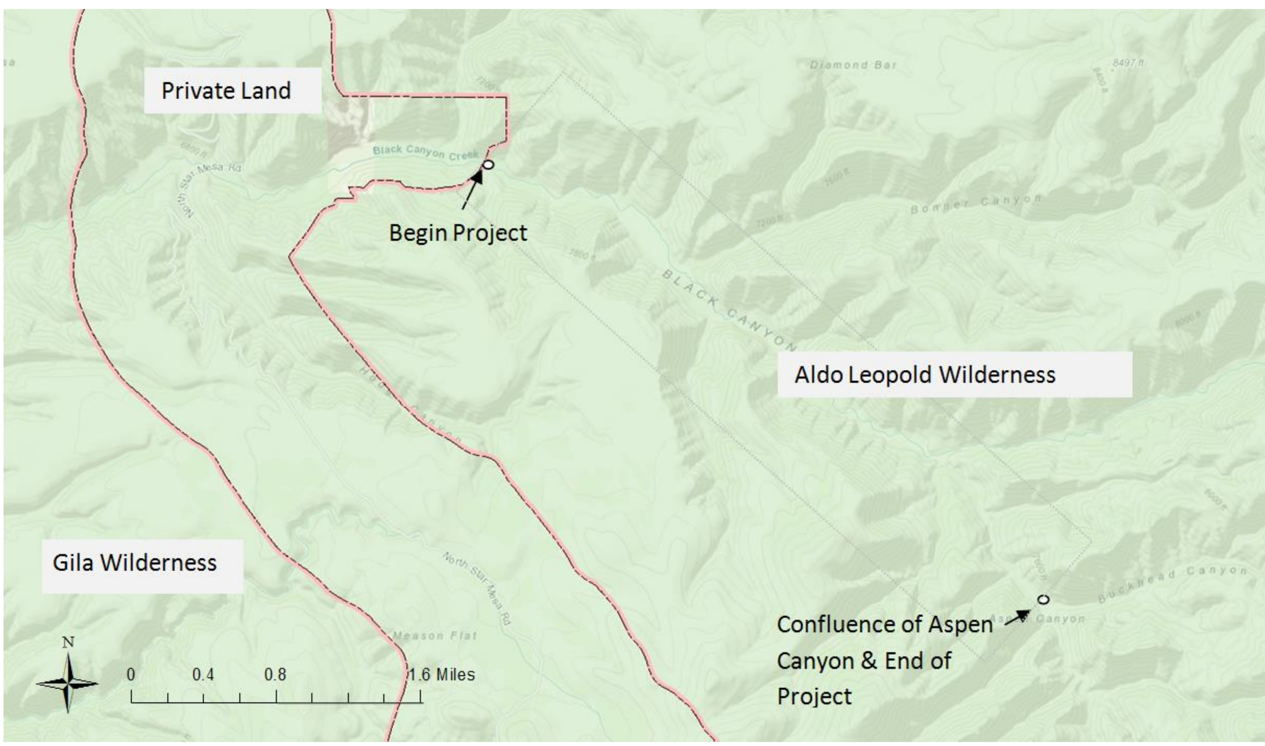

Figure 2: Project Location map of Black Canyon Creek.

SITE DESCRIPTION

The watershed of Black Canyon Creek lies on the western slope of the Black Range along the Continental Divide. The stream flow originates from two springs located on the western face of the Black Range near Reeds Peak. The flows run into Black Canyon Creek and then run west and eventually meet with the confluence of the East Fork of the Gila River. The project area is located along 3.25 miles of Black Canyon Creek that lies within the Aldo Leopold wilderness area. The area elevations range up to 7,199 feet. The elevation of the watershed at its highest point is 10,000 feet. The hill slope vegetation is ponderosa pine, transitioning into spruce fir in the higher reaches of the watershed. The riparian vegetation along the creek includes willow and cottonwood.

The watershed has been impacted by several wildfires as well as livestock grazing which has led to changes in the creek's geomorphology and a loss of riparian vegetation. Much of the watershed was impacted by the historical grazing, with 75% of the Black Canyon watershed located within the boundary of an old grazing permit. In 1996 the permit to graze was not renewed and by 2006 all the cattle had been removed from the area. Wildfires have also significantly altered the area, with 6 significant wildfires affecting the watershed since 1995. The fires and the year burned are: Silver (2013), Diamond Bar (2011), Aspen (2010), Meason (2009), Rocky (1997), and Bonner (1995) (NMED, 2017). The Rocky and Meason fires burned in the lower riparian portion of the watershed destroying cottonwoods and other riparian vegetation, but not the pine forest. The Bonner and Silver fires burned with higher severity in the upper area of the watershed, burning the pine forest and greatly disturbing the watershed. The impact to the watershed was evident after the Silver fire when post fire flows transported sediment into the Black Canyon creek within the Aldo Leopold wilderness area. The sediment was deposited throughout the reach, filling pools and creating mid-channel bars in riffles, altering the stream morphology and topography.

SURVEY PROTOCOL

Due to the diverse characteristics and length of the creek within the project area, an on-the-ground assessment was the most efficient way to analyze the individual reaches. During multiple the site walks, data was collected in order to evaluate stream hydrology, geomorphology, vegetation, and aquatic conditions. The entire length of the stream in the project area was walked on three separate occasions and visually inspected; areas with good habitat and areas with high potential for enhancement were marked with a GPS unit. During the assessment walks, photos were also taken to document certain stream information. Photographs recorded:

- Functioning habitat,
- Natural structures that may be mimicked in enhancement work,
- Areas that need enhancement,
- Permanent landmarks, such as waterfalls or bedrock structures
- Reference areas and habitat types.

Numerous representative cross sections and profiles were measured along the creek within the project area in field determined reaches. Cross-sections reveal morphological characteristics of the stream including floodplain height and width, bankfull stage, and thalweg depth. Stream profiles provide information about the slope of the reach, including the number and spacing of channel bedforms. This survey data was used to understand the channel and to establish reference conditions for assessing current conditions.

The quality of fish habitat was visually assessed during the survey. The abundance of pool habitat, fish cover types, substrate types and activity of fish spotted in stream were documented. Access to the stream for working crews, as well as proximity of suitable materials for stream improvements, were also noted.

Site visits were conducted during late May, mid-July and early August of 2018. In May, a visual survey of the entire stream was conducted from the Aspen Creek confluence through the canyon to the downstream Wilderness Boundary. During the May visit, five temperature data loggers were placed in the stream. The temperature loggers were subsequently removed in mid-July to download data prior to monsoon season. In August, cross section and longitudinal profile data were collected in cooperation with New Mexico Environment Department personnel and the temperature loggers were put back in place. Additionally, specific points for potential enhancement were identified and located by GPS and prescriptions for stream enhancements were made. Locations of cut banks, pools, functioning habitat, and general vegetation condition were also made during the site visits and recorded using GPS.

EXISTING CONDITIONS

The following sections describe the current vegetation, hydrology, geomorphology, and temperature loading of the Black Canyon creek. The information in this section will be the basis for creek enhancements and improvements.

VEGETATION

The upper watersheds of Black Canyon, Aspen Canyon, and Bonner Canyon are generally Ponderosa Pine forest. The vegetation in the upper portions of the Aspen Creek watershed and the Black Canyon watershed was heavily burned by the Silver fire in 2013. These areas are still recovering and are now largely covered with grasses and other pioneer vegetation. Other fires, including the Bonner fire, burned the riparian area of the creek in the mid to late 1990s. Two initiatives to increase vegetative cover in 2007 and 2011 planted approximately 2,500 cottonwood and willow along the creek to reduce temperature. Both initiatives were deemed successful but much of the riparian vegetation was destroyed in floods following the Silver Fire (NMED, 2017).

The current vegetation along the stream is sporadic, with some areas that are well vegetated and shaded with willows and other riparian vegetation and other areas that are open and slightly shaded by ponderosa pine canopy. In order to categorize the amount of cover provided vegetation within the project reach, densiometer readings were taken at each cross section. Table 1 below displays the percent vegetation cover over each cross section and Figure 3 displays the locations of each reading.

Table 1: Densiometer Vegetation Density Readings
The values are color coordinated according to the percent of occupation with red 0-25%, orange 25-50%, yellow 50-75%, and green 75-100%.

XS	X	Y	% Occupied	XS	X	Y	% Occupied
XS1	-107.96079	33.16357	57.4	**XS12**	-107.97976	33.17393	77.9
XS2	-107.96101	33.16353	45.4	**XS13**	-107.98301	33.17586	53.2
XS3	-107.96210	33.16325	44.4	**XS14**	-107.98613	33.17791	36.0
XS4	-107.96299	33.1638	26.4	**XS15a**	-107.98611	33.178	17.1
XS5	-107.96318	33.16412	34.0	**XS15**	-107.98818	33.18171	24.3
XS6	-107.96749	33.16534	37.3	**XS16**	-107.99009	33.18203	8.0
XS7	-107.97099	33.16746	16.5	**XS17**	-107.99055	33.18193	55.8
XS8	-107.97099	33.16756	38.6	**XS18**	-107.99565	33.18294	55.0
XS9	-107.97384	33.16993	49.0	**XS19**	-108.00145	33.18514	97.4
XS10	-107.97760	33.17322	23.6	**XS20**	-108.00562	33.18548	32.7
XS11	-107.97965	33.17390	53.5	**XS21**	-108.00592	33.18546	80.2

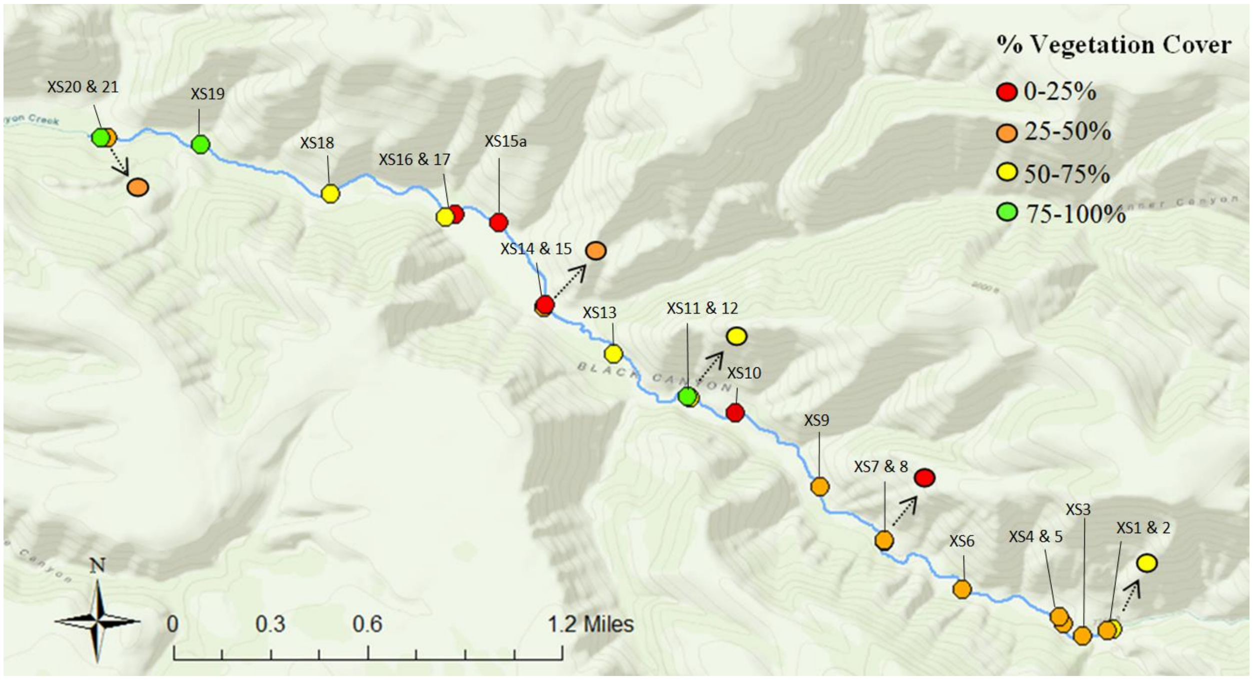

Figure 3: Vegetation densiometer readings by cross section. (Arrows indicate a hidden reading). *Photo examples of percent cover are provided below.*

A typical red (0-25%) and orange (25-50%) section appear like Figures 4 and 5 below, respectively. The red areas with 0-25% vegetative cover are typically open and grassy, with few surrounding ponderosa pines. The orange areas with 25-50% vegetative cover are similar, but have more ponderosa pines closer to the banks of the creek. Some of the orange areas also have willows and oaks, but those are not mature enough to produce significant shade for the creek.

Figure 4: XS 16 with 8% vegetation cover. *Grass on banks with few ponderosa pines.*

Figure 5: XS 5 with 34% vegetation cover. *Grasses and other riparian shrubbery with ponderosa pines near the channel banks*

There are areas in Black Canyon Creek that are well vegetated and provide ample shade and fish habitat. Many of these areas are vegetated with cyote willows (*salix exigua*), oaks (*quercus*), water cress (*nasturtium officianale*) and other riparian vegitation on the banks of the creek and in the creek. The yellow (50-75%) areas of the creek are either vegetated with spotted willows or a thick ponderosa pine canopy, or a combination of the two. Figure 4 shows a yellow area shaded with willows and Figure 5 with ponderosa pine. Green (75-100%) areas are typically shaded with both dense willows and/or ponderosa pine, and examples are shown in Figures 6 and 7.

Figure 6: XS 11 with 54% vegetative cover.
Large willow population with breaks.

Figure 7: XS 1 with 58% vegetative cover.
Many ponderosa pines on bank and in floodplain providing good canopy cover.

Figure 8: XS 19 with 97% vegetative cover.
Dense willow and oak population with little to no breaks

HYDROLOGY

Black Canyon Creek is ungaged and therefore requires flows to be modeled. Base flows of the creek originate from two upstream springs, but are intensified through snowmelt and rain events. The creek is intermittent however, and can cease flowing in certain stretches during warmer months. During our field survey in August 2018, there were several gaining and loosing water reaches with areas where the base flow became completely subterranean with the longest subterranean reach measuring 0.45 miles. Ground cover in the watershed is still recovering from grazing and fire events, with the majority of the watershed now covered with grass, at a minimum.

To gain an understanding of the flows in Black Canyon Creek, base flow, bankfull flow and storm flows were calculated. Base flows were determined by the Natural Resource Conservation Service (NRCS) Cross Sections Analyzer using water surface elevations obtained during the August 2018 survey. The bankfull flow was derived by comparing cross section, profile, and watershed information with data from the eastern Arizona/New Mexico sites regional discharge curve developed by Moody et al (2003) - see Figure 10.

Two stream flow models were utilized for the storm flow analysis for comparison purposes. The National Streamflow Statistics Program (NSS, Ries, K.G., III, 2006) estimates stream flow using regional regression equation estimates while Wildcat5 (Hawkins, R, 2006) uses watershed area, elevation, vegetation parameters and precipitation frequency data. Wildcat5 was specifically developed for use in forested watershed and burned watersheds. The watershed that was used for analysis can be seen below in Figure 9. The sub watersheds were delineated by determining areas where significant flows entered Black Canyon Creek. These sub watersheds were determined to be the upper Black Canyon watershed, the Aspen Canyon watershed and the Bonner Canyon watershed.

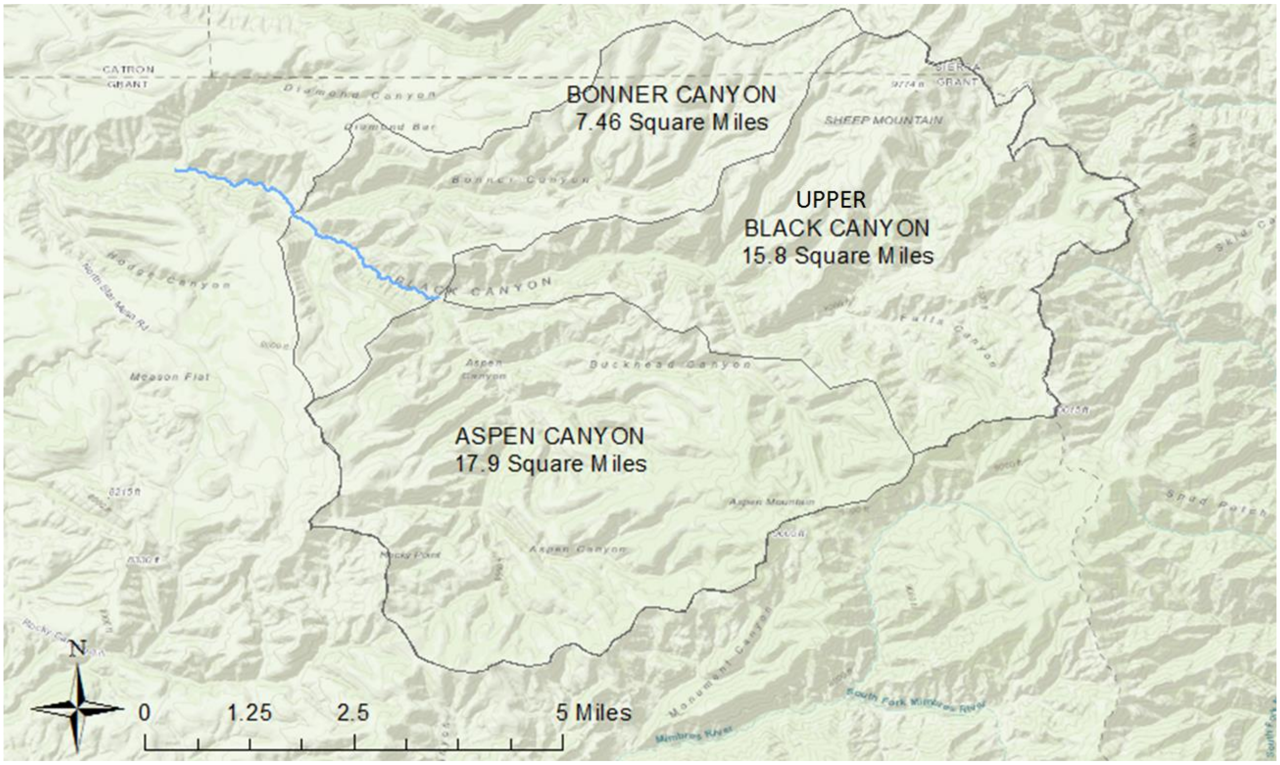

Figure 9: Sub watersheds flowing into Black Canyon Creek

Results from both storm models are based upon the combined area of the sub watersheds as they contribute to the creek. Both models were run using the NOAA ATLAS 14 precipitation data for 2-, 5-, and 10-year 24-hour precipitation reoccurrence intervals for the area. The NSS model typically produces results that are of higher magnitude, as it produces an average based on all streams within the area. The Wildcat5 model is specific to the Black Canyon Creek project area, as it includes data about the area's vegetation and watersheds. The results indicate that the watershed has the potential to produce significant flood volumes during infrequent flood events. The estimated bankfull discharge was based on regional geomorphology of the stream and is normally a $Q_{1.5}$ to Q_2 event (Moody, et al 2003). The results provide a range of flows likely to be produced by the watershed. All results are displayed in Tables 2-4.

Bankfull discharge is an important element to evaluate for channel design. From a design perspective, bankfull discharge gives the foundation for the approximate shape and size of the channel that is to be restored. It is the flow stage associated with channel maintenance through sediment transport, deposition and scour. We utilized a regional curve to estimate bankfull discharges and calibrated these estimates against the bankfull channel dimensional data and estimates of roughness that were gathered in the field.

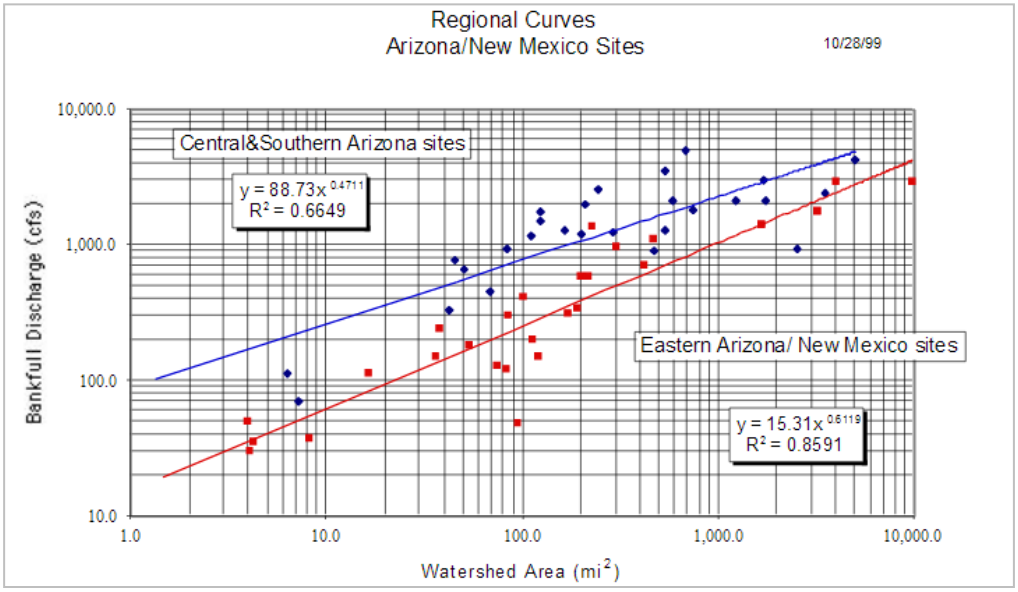

Figure 10: Bankfull Discharge Regional Curves for Arizona and New Mexico Sites (Moody 2003)

Table 2: Estimated Discharges for the Black Canyon Watershed using the Regional Curve, Wildcat5 and NSS

Black Canyon WS: 15.759 Mi²					
Recurrence Interval (yr)	**Storm Precip.(in.)**	**Wildcat5 Runoff (cfs)**	**NSS Runoff (cfs)**	**Regional Curve (cfs)**	**NRCS Cross Section (cfs)**
August 2018 Base Flow	-	-	-	-	0.66 (XS 2)
BKF (1.5 – 2)	-	-	-	82.75	-
2	2.01	52.4	81.6	-	-
5	2.53	115.3	187	-	-
10	2.94	179.9	290	-	-

Table 3: Estimated Discharges for the Black Canyon and Aspen Canyon Watershed using the Regional Curve, Wildcat5 and NSS

Black + Aspen Canyon WS: 33.65 Mi²					
Reoccurrence Interval (yr)	**Storm Precip. (in.)**	**Wildcat5 Runoff (cfs)**	**NSS Runoff (cfs)**	**Regional Curve (cfs)**	**NRCS Cross Section (cfs)**
August 2018 Base Flow	-	-	-	-	1.30 (XS 7)
BKF (1.5 – 2)	-	-	-	131.62	
2	2.01	88.2	150	-	
5	2.53	212.5	325	-	
10	2.94	343.5	489	-	

Table 4: Estimated Discharges for the Black Canyon, Aspen Canyon, and Bonner Canyon Watershed using the Regional Curve, Wildcat5 and NSS

Black + Aspen +Bonner Canyon WS : 41.11 Mi^2					
Reoccurrence Interval (yr)	**Storm Precip.(in.)**	**Wildcat5 Runoff (cfs)**	**NSS Runoff (cfs)**	**Regional Curve (cfs)**	**NRCS Cross Section (cfs)**
August 2018 Base Flow	-	-	-	-	1.43 (XS 20)
BKF (1.5 -2)	-	-	-	153.98	
2	2.01	92.9	176	-	
5	2.53	231.9	376	-	
10	2.94	382.7	562	-	

GEOMORPHOLOGY

Black Canyon Creek is in a moderately confined alluvial valley with steep side slopes containing finer soils on the valley floor. The valley slope is gentle at 0.015 ft/ft. To assess the geomorphology of the channel slopes, bedforms, cross-section shape and dimension were characterized by longitudinal profiles and cross-section surveys for representative reaches of the stream. Each surveyed reach was classified using the Natural Channel Classification System (Rosgen 1996). For this assessment, twenty-two cross sections and fourteen profiles were analyzed. Of the twenty-two cross sections, four were monumented with re-bar to allow for comparison surveys in the future. The locations of the monumented cross sections are in Table 5. Four of the twenty two cross sections were also taken at the locations of the temperature data logs.

Table 5: Monumented Cross Sections.
Locations of left pin as you look downstream. The right pin is located across the stream perpendicular to flow.

Monumented Cross Section	Latitude	Longitude
	Left Pin	
3	33.163443	-107.961091
7	33.167459	-107.970992
10	33.173222	-107.977597
20	33.185477	-108.005616

Black Canyon Creek is a single thread channel with occasional split flow conditions or flood channels. Pool bed forms were limited in depth and frequency, primarily occurring at bends near bedrock outcroppings and under cross-channel logs and other channel restrictions. These pools seem to hold the majority of trout along the study reach (see the “Fish Habitat” sections for more detailed information). Data from the profiles and cross sections indicate that the average slope of Black Canyon Creek is approximately 1.2 % (0.012 ft/ft) above the confluence with Aspen Canyon and increases to around 2% (0.02 ft/ft) after the confluence. The slope changes again at the nexus with Bonner Canyon, decreasing to about 1.3% (0.013 ft/ft). The stream has low to moderate sinuosity at ~1.2, with bankfull channel widths ranging from 13 to 28 feet. The stream is generally wide with moderate to high width/depth ratios and is moderately to slightly entrenched. The valley floor is wide, and the stream generally has good access to its floodplains. The stream bed is composed of gravel and sand with occasional cobbles. Results of the geomorphic survey are given in Table 6 and locations of the reaches and cross sections are in Figure 11. Cross sections can be seen in Appendix A.

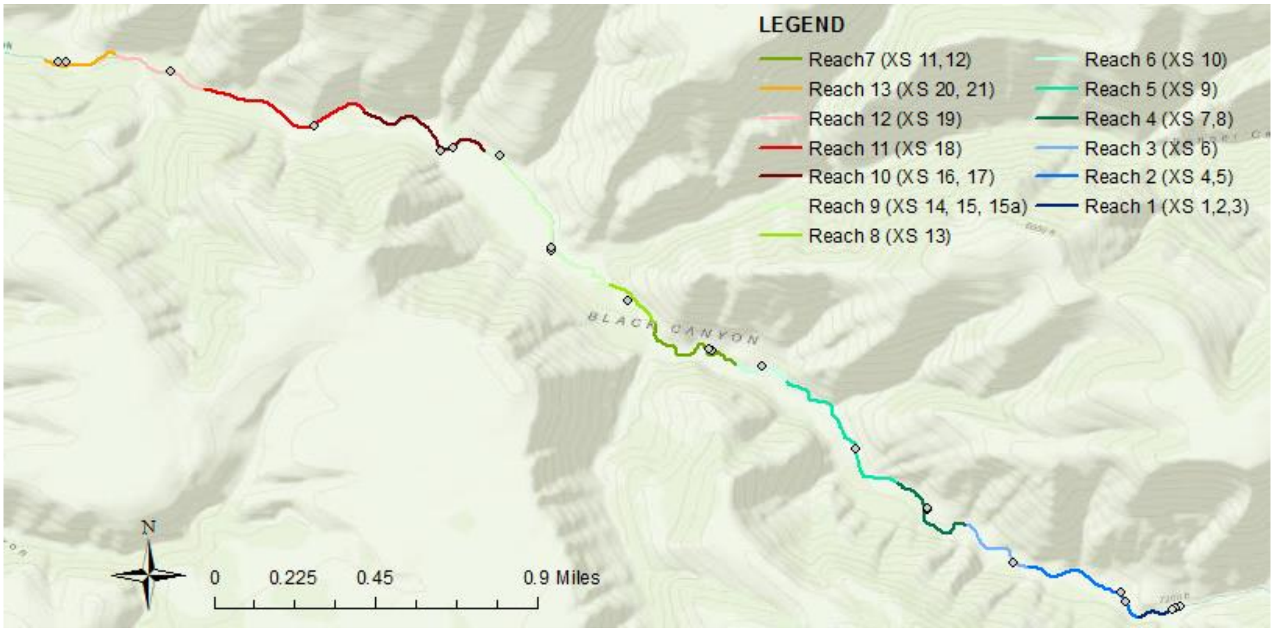

Figure 11: Reach locations with cross section locations

Table 6: Channel Dimensions for Survey Sites in Black Canyon Creek.
Locations of samples sites are given in Figure 9. Reference reaches are highlighted in green.

Watershed	Reach	XS	Pool/ Riffle	Slope (Riffle-Riffle)	Class	Bankfull Width (ft)	Bankfull Area (sq ft)	Entrenchment Ratio[1]	Width/ Depth Ratio[2]	Mean Depth (ft)	Max Depth (ft)
Black Canyon	Reach 1	XS1	Pool	0.0116	-	15.6	16.61	1.61	13.97	1.09	2.23
		XS2	Riffle		B4c	16.9	12.54	1.55	22.89	0.74	1.4
		XS3	Riffle		C4	12.7	12.54	2.49	13.05	0.98	1.63
Black + Aspen Canyon	Reach 2	XS 4	Riffle	0.0163	C4	24.3	22.38	5.49	26.46	0.92	1.8
		XS 5	Pool		-	27.5	22.11	1.84	35.21	0.78	1.42
	Reach 3	XS 6	Riffle	0.0330	E4b	15.5	23.03	2.88	10.38	1.49	2.27
	Reach 4	XS 7	Riffle	0.0196	B4c	21	23.07	1.58	22.69	1.01	1.79
		XS8	Pool		B4c	17.4	20.88	2.02	14.49	1.2	1.8
	Reach 5	XS9 (dry)	Riffle	0.0148	B4c	22.1	22.69	1.42	21.46	1.03	1.76
	Reach 6	XS10	Pool	0.0177	-	25.2	20.84	1.57	30.36	0.83	2.18
	Reach 7	XS11	Pool	0.0190	-	23.5	24.29	2.77	22.85	1.03	2.65
		XS12	Riffle		B4c	21.2	24.5	2.22	17.21	1.19	2.81
Black + Aspen + Bonner Canyon	Reach 8	XS13	Riffle	0.0157	C4	22.6	29.36	1.02	17.38	1.3	2.38
	Reach 9	XS14	Pool	0.0064	-	21.7	29.64	2.12	15.85	1.37	3.1
		XS15	Riffle		B4c	20	27.46	2.2	14.59	1.37	2.14
		XS 15a	Riffle	0.0133	B4c	8.29	27.26	1.41	35.84	0.87	1.81
	Reach 10	XS16	Riffle	0.0158	C4	21	27.51	4.1	16.07	1.31	2.23
		XS17	Pool		-	14.9	12.77	2.99	17.52	0.85	2.27
	Reach 11	XS18	Riffle	0.0084	B4c	27.6	27.7	1.52	27.63	1	1.91
	Reach 12	XS19	Pool	0.0112	-	24.2	29.54	1.85	19.89	1.22	2.56
	Reach 13	XS20	Riffle	0.0142	B4c	23.3	29.59	1.72	18.31	1.27	2.49
		XS21	Pool		B4c	21.5	34.72	1.52	13.25	1.62	3.01

[1] Entrenchment Ratio is defined as floodprone width divided by bankfull channel width and describes the floodplain area available for spreading moderate flow events.
[2] Width-Depth Ratio is defined as bankfull channel width divided by mean bankfull depth and describes the bankfull channel shape.

The stream shear stress at bankfull stage was calculated, and was used to estimate the largest particle that could be moved at the bankfull flow stage. The sediment competence, bank shear stress, and the mobile substrate material are provided in Table 7. Comparison to the available substrate indicates that bankfull flows are competent to move all but the largest particles in the stream. This suggests that the stream competence is sufficient to initiate incision and bed stability is likely dependent on a high sediment supply or on the presence of a larger substrate layer below the finer accumulated sediment.

Table 7: Pebble Count Results and Sediment Competence in Black Canyon Creek.

Watershed	XS	D50 (mm)	D84 (mm)	D95(mm)	D100(mm)	Sediment Competence (mm)	Bankfull Shear Stress (lbs/ft^2)	Mobile Substrate Size
Black Canyon	XS2	10.54	42.56	84.27	143	98.47	0.5541	D95+
	XS3	8.28	45.98	88.53	256	120.16	0.7263	D95+
Black + Aspen Canyon	XS 4	21.32	100.36	199	281	144.77	0.9358	D84+
	XS 6	21.66	71.74	127.22	290	212.88	1.5806	D95+
	XS 7	32	81.4	146.16	300	182.73	1.2842	D95+
	XS9 (dry)	5.36	62.72	120.89	380	146.53	0.9512	D95+
	XS11	16.83	72.62	151.01	205	176.09	1.2212	D95+
	XS12	-	72.62	151.01	255.99	197.02	1.4227	D95+
Black + Aspen + Bonner Canyon	XS13	12.47	63.35	174.83	292	183.06	1.2874	D95+
	XS15	16.41	49.75	141	217	97.56	0.5471	D84+
	XS 15a	19.82	64.61	168.34	470	119.64	0.722	D84+
	XS16	7.77	82.94	169.32	275	183.5	1.2916	D84+
	XS18	21.19	72.67	126.42	264	94.53	0.5242	D84+
	XS20	33.73	86.41	158.34	260	165.81	1.1253	D95+

A number of small split flow/abandoned channels and disconnected pools suggest that the Black Canyon Creek has migrated slightly over the valley floor within recent history. The creek also shows many segments of over widening throughout; with several width to depth (W/D) ratios exceeding the reference W/D ratios. Over wide cross sections overlaid with their respective reference cross sections are shown in Figures 12 and 13 below. The widening likely occurred as post-fire, high flow events impacted the creeks watershed, producing high sediment loads. The sediment was then deposited in the creek allowing the redistribution of shear stress to induce bank erosion and create a wider channel. In the three areas where vegetation density is high (75-100% cover) the width to depth ratios are less than 20. The vegetation in these areas likely increased the creek's stream bank stability and kept it from widening.

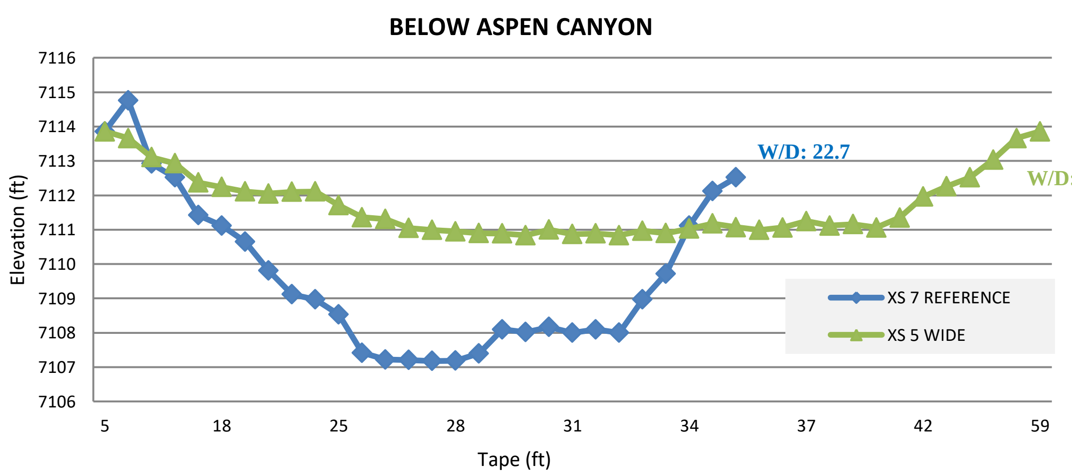

Figure 12: Cross sections below Aspen Canyon.
XS5 elevations were altered to overlay.

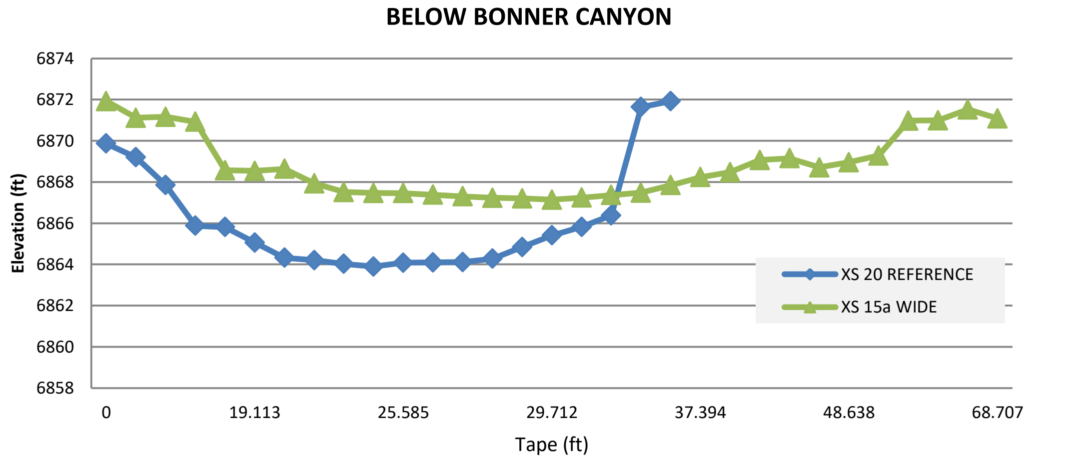

Figure 13: Cross sections below Aspen Canyon.
XS15a elevations were altered to overlay.

Bank Erosion:

While active bank erosion was not evident throughout most of the survey, the post fire high flows have eroded many of the channels banks, leaving steep cut banks and wide, shallows areas of the channel. In most cases, the banks are naturally re-vegetating with willows, grass, or other emerging plants. These banks have a low or moderate bank erosion potential. However, there is active bank erosion in several reaches. Locations of eroding banks can be seen in Figure 14. To further understand the erosion potential of the stream, bank erosion hazard index (BEHI) ratings for the actively eroding areas were determined and are in Table 8. The BEHI quantifies the potential risk for a stream banks to erode and is based on the study banks dimensions, root composition, and surface protection.

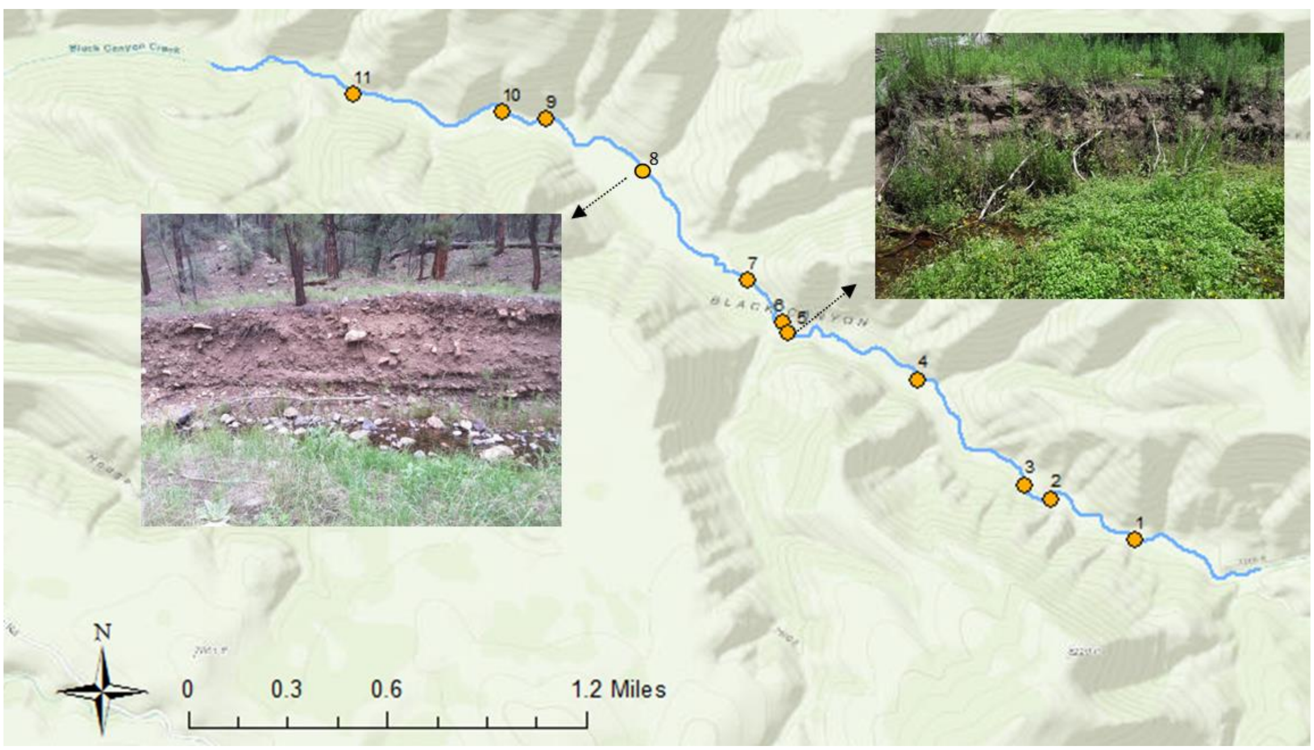

Figure 14: Locations of eroding banks in Black Canyon Creek.
The images show the typical state of eroding banks at the locations indicated

Table 8: Calculated BEHI ratings for selected banks with eroding faces.
The ratings correspond to the eroding banks shown in Figure 14.

Bank	BEHI Rating	Rating
1	High	31.2
2	High	37.5
3	High	35.1
4	High	30.9
5	High	36.5
6	Moderate	25.8
7	Moderate	28.5
8	Very High	41.9
9	Moderate	28.2
10	High	32.4
11	High	34.3

The BEHI ratings show that the banks are likely to erode further, especially those with high and very high ratings. The shorter and/or more vegetated/protected a bank is, the lower the BEHI rating. Bank 8 is the tallest and least vegetated of the banks, which is why it has a very high BEHI rating.

Fish Habitat:

Previous habitat restoration efforts installed in 2007 included stream barbs and rock weirs along the in an effort to reduce water temperatures. A few of the structures that were put in place remain intact and have successfully created fish habitat and narrowed the channel. However, the creek itself does not possess an appropriate amount of pools for fish habitat. The pools that do exist in a typical riffle, run, pool sequence are shallow and therefore prone to larger temperature changes in summer months, especially in areas where vegetation cover is minimal. The exceptions were where exposed bedrock at stream bends or fallen trees have created deep pools that presented the best fish habit in the creek. However, not all of the deep pools are cool enough to sustain large number of Gila trout. Locations of these pools (18 in total) are shown in Figure 15.

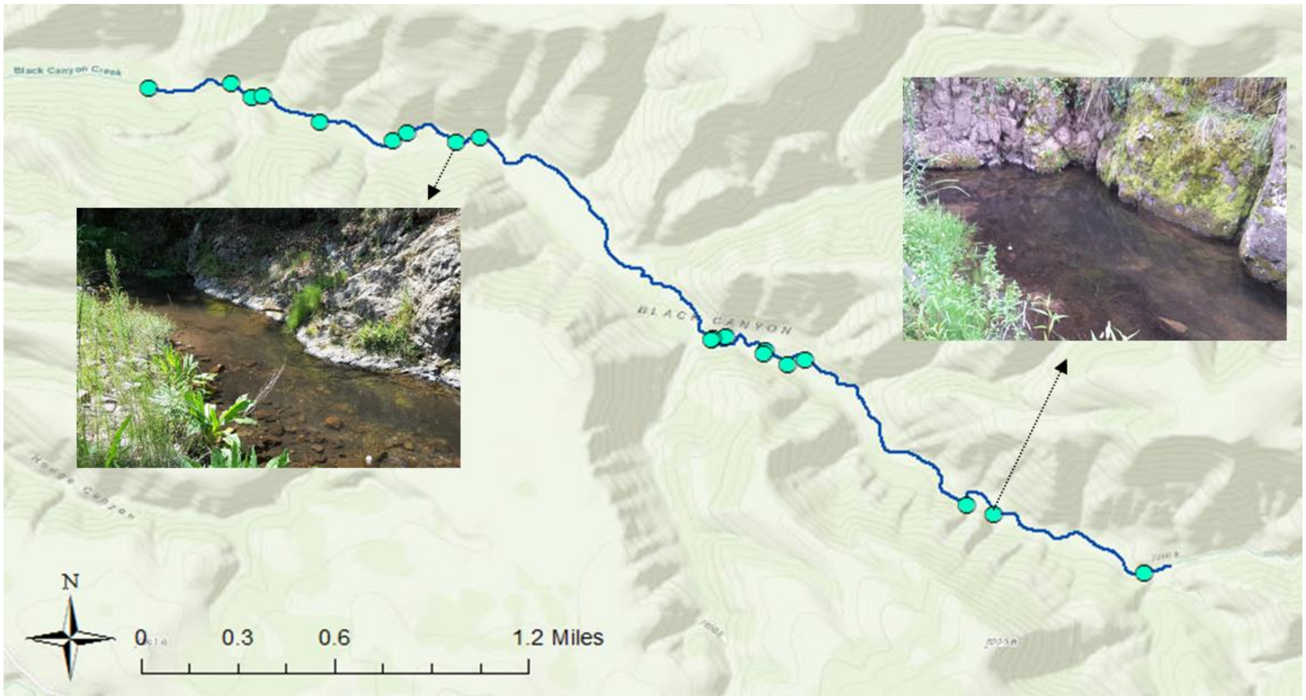

Figure 15: Locations of deep pools along the creek.
Many of the deepest pools were against exposed bedrock at stream bends.

TEMPERATURE DATA LOGGING

Temperature loggers were placed in the field to gain an understanding of the existing temperature variability in the stream. Stream temperatures were measured and analyzed using ONSET HOBOware™ temperature loggers and analysis software. Five loggers were placed in pools with varying features and vegetative cover throughout the study area and one logger was placed in a tree near the stream to record ambient air temperature. The location of each temperature logger can be seen in Figure 16. At each temperature logger a cross section was surveyed and a densiometer reading was taken to further understand the pool and the associated vegetative cover.

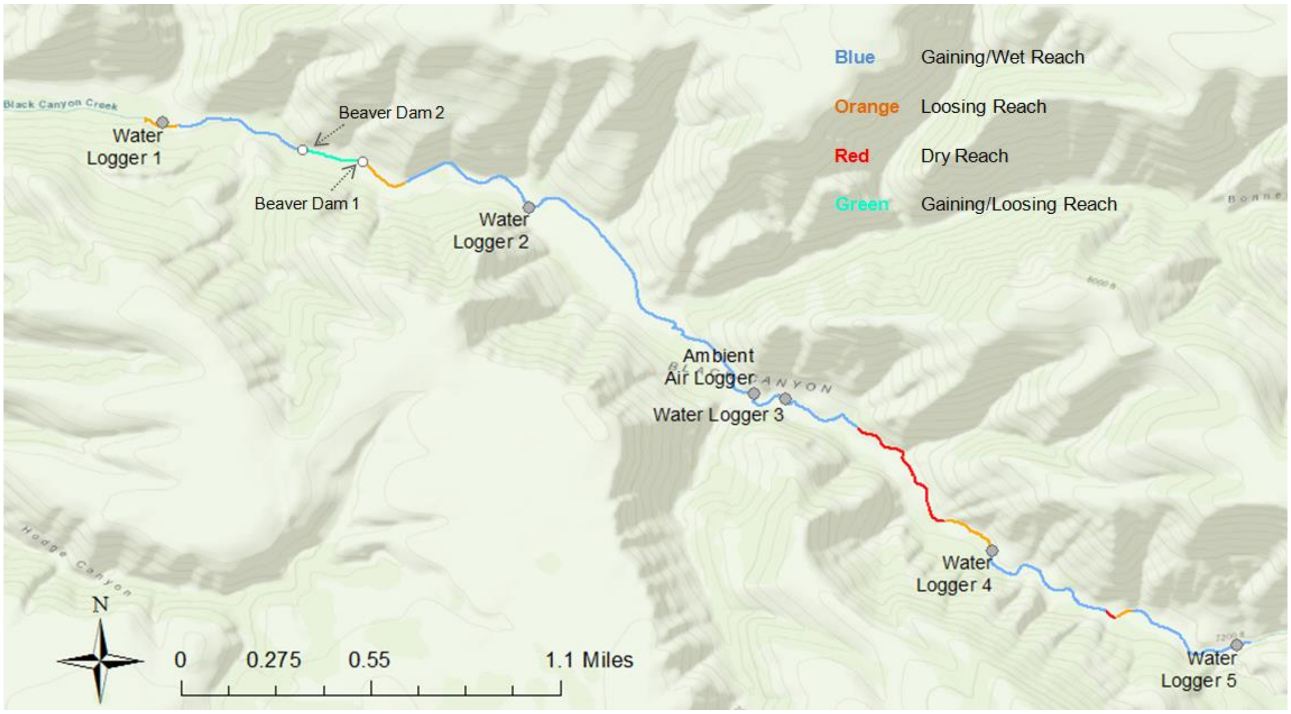

Figure 16: Temperature Logger Locations

Each data logger recorded temperatures for approximately 50 days taking a reading every 15 minutes, for a total of 4768 samples. Sampling started on May 31st and ended on July 19th, which is generally within the hottest time of the year. The vegetative cover at each logger determined by the densiometer is provided in Table 9. The maximum, minimum and average temperatures recorded and the time spent at high temperatures for each logger is provided in Table 10. A graph of each temperature log is provided in Figures 18–21 with the ambient air temperature overlaid. The solid red line in each graph represents the NM Environment Department target temperature for cool water streams (20C max for < 4 hrs on 3 consecutive days). The NM Environment Department maximum temperature (23C max) and a maximum temperature threshold for Gila trout (27C for < 2 hours) are shown as dotted red lines.

Table 9: Vegetative cover at each data logger

	Corresponding XS	% Vegetative Cover
Data Logger 5	1	57.36
Data Logger 4	8	38.64
Data Logger 3	12	77.9
Data Logger 2	17	55.8
Data Logger 1	21	80.24

Table 10: Temperature data from each data logger

	Maximum Temp °C	Minimum Temp °C	Average Temp °C	Standard Deviation	Time Spent at Given Temperature (%)			Times that Temp >20°C for 4 hr in 24 hr for 3 days (4T3)
					>28°C	>23 °C	> 20 °C	
Data Logger 5	27.4	8.0	17.1	4.2	0	11.9	25.6	4
Data Logger 4	32.3	7.0	16.7	5.2	2.9	14.0	25.1	6
Data Logger 3	24.7	11.0	15.9	2.6	0	0.2	10.0	2
Data Logger 2	29.3	6.0	16.4	4.8	0.1	10.6	26.7	5
Data Logger 1	32.1	7.8	17.5	5.5	5.9	17.8	28.8	6
Ambient Air	37.6	4.3	18.9	7.2	13.0	31.8	14.1	-

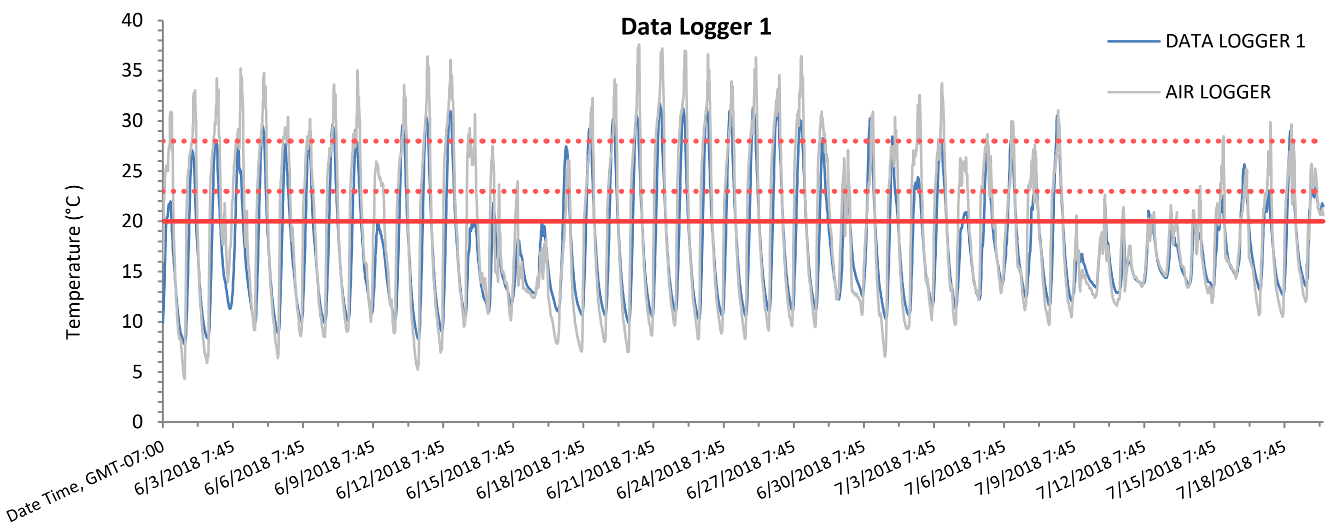

Figure 17: Data Logger 1 and Air Logger Temperatures

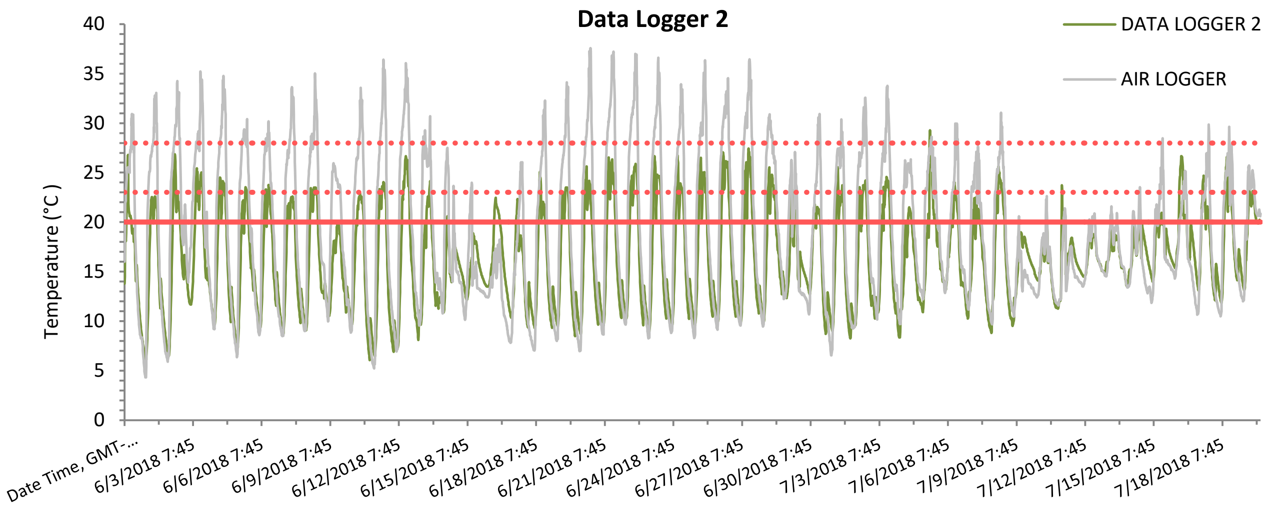

Figure 18: Data Logger 2 and Air Logger Temperatures

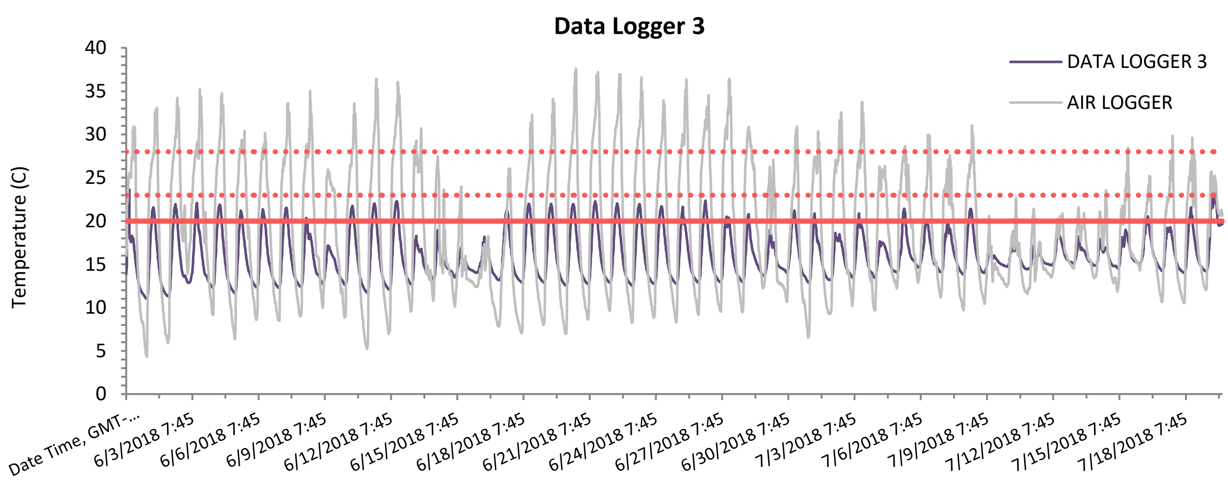

Figure 19: Data Logger 3 and Air Logger Temperatures

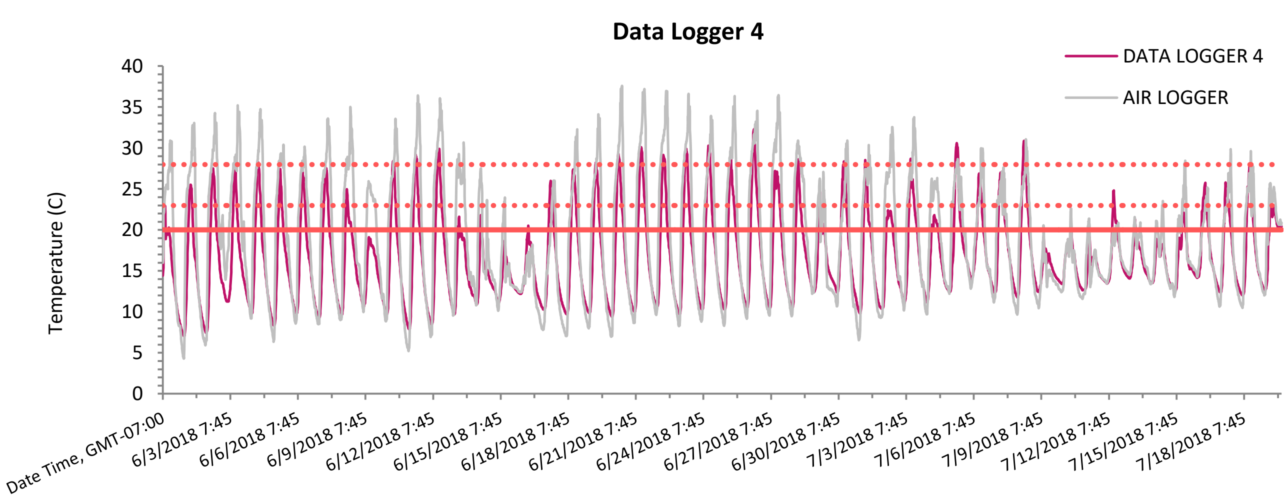

Figure 20: Data Logger 4 and Air Logger Temperatures

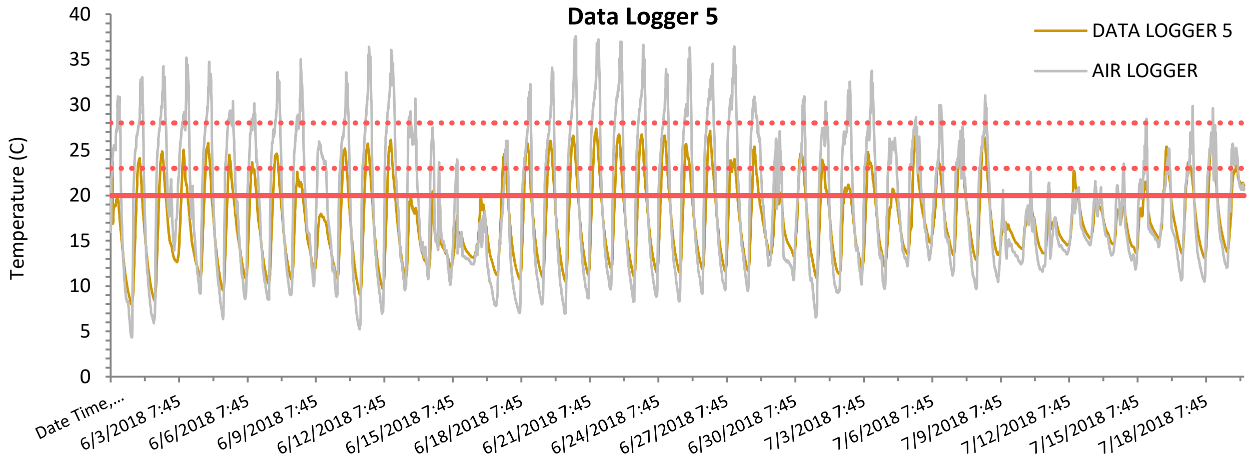

Figure 21: Data Logger 5 and Air Logger Temperatures

Temperature data logger data for the summer of 2018 suggest that none of the reaches in Black Canyon obtained the water quality targets for temperature reaching lethal temperatures and the farthest downstream reach may be reaching lethal temperatures for Gila trout. The coolest temperatures were logged by Data Logger 3, with the maximum temperature reaching 24.7°C. The likely reason for the cool temperatures is that water emerges after being subterranean 0.24 miles upstream from that logger. When surveyed, the water emerged at 12.7°C. The minimum temperature in this area was 11°C and the standard deviation 2.6, showing that the temperatures at this location are relatively stable. The data indicate that this reach comes closest to maintaining temperature standards and has the highest quality water for trout habitat.

Data Loggers 1 and 4 have the highest temperature readings. These data loggers are in losing reaches, meaning that an unknown amount of water is going subterranean, resulting in rapid heating of the diminished surface water. In the 50 days that the creek was surveyed, Data Logger 1 recorded temperatures at or higher than 30°C for approximately 26 hours, with Data Logger 4 recording 8 hours. Additionally, both loggers show the lowest minimum temperatures and highest standard deviations, indicating that ambient air temperature has a relatively large effect on water temperature at these locations.

Temperatures were also taken in the field above and below two beaver dams that are approximately 0.17 miles apart, downstream from data logger 2. The location of the beaver dams can be seen in Figure 14. The close proximity of these beaver dams has allowed a marsh to develop leading the water level to be in flux; infiltrating into the ground and gradually seeping back into the creek simultaneously. In this 0.17 miles area, the water is a consistent 20°C likely due to the influences of this subterranean flow.

These results show that there is likely a correlation between gaining and losing reaches and significant changes to temperature. To further establish how temperature changes throughout the creek, particularly with vegetation cover, temperature modeling was used. The model helps to understand and predict how the width, depth, vegetative cover, and infiltrating ground water effects water temperature in the creek.

TEMPERATURE MODELING

A stream temperature model was utilized to examine how stream channel enhancement might affect temperature. The model helps to understand and predict how the width, depth, vegetative cover, and infiltrating ground water effects water temperature in the creek. A temperature model was used to determine the magnitude by which the total maximum daily temperature load could be lowered by altering width, depth and vegetation along the banks of the creek. The Stream Segment Temperature Model (SSTEMP), as available from the USGS, was used for the analysis. In order to calibrate the model, water and air temperature data was taken in various locations in the field and checked using SSTEMP. When input data correlated with the known temperatures, parameters were modified and the resulting temperature changes analyzed. Reaches 1 & 2, 4, 7 & 8, and 13 & 14 were analyzed in this manner.

Early in the process, it was determined that SSTEMP has the greatest response to changes in shading parameters. Due to this, four areas of the creek were analyzed using collected vegetation data and target vegetation parameters in June and August. No changes to the width and depth of the reaches were analyzed due to the minute changes in temperature. Current flow data for the model was determined using the Natural Resource Conservation Services (NRCS) cross section hydraulic analyzer. Flows were calculated using the known water surface elevation for each cross section. Meteorology data from days spent in the field was used for the August analysis and known area averages were used for the June analysis. Each reach analyzed had correlating cross section and profile data that was used for the models hydrology inputs. Densiometer readings were taken at every cross section. If more than one densiometer reading was taken within a reach, the results were averaged. Other shade variables were determined by analyzing photos.

Reach 1 & 2: These reaches cover the creek before and after the nexus with Aspen Canyon creek (Figure 20). The hydrology and geometry inputs were determined by averaging data obtained from cross sections two through five. The shade variables used in the modeling is presented in Table 11. This reach has an average vegetation density of 34.6% and is primarily shaded by the ponderosa pine canopy with few areas that have established riparian vegetation.

Table 11: Shade variable inputs for Reach 1 & 2

SHADE VARIABLES – Current Conditions			SHADE VARIABLES – Ideal Conditions		
Avg.	**West**	**East**	**Avg.**	**West**	**East**
Veg. height (ft)	70	70	Veg. height (ft)	70	70
Veg. crown (ft)	10	10	Veg. crown (ft)	10	10
Veg. offset (ft)	14	14	Veg. offset (ft)	2	2
Veg. Density	**31.15**	**38.02**	**Veg. Density**	**80**	**80**
Topographic Altitude (d)	25	25	Topographic Altitude (d)	25	25
Segment Azimuth	-17	-			

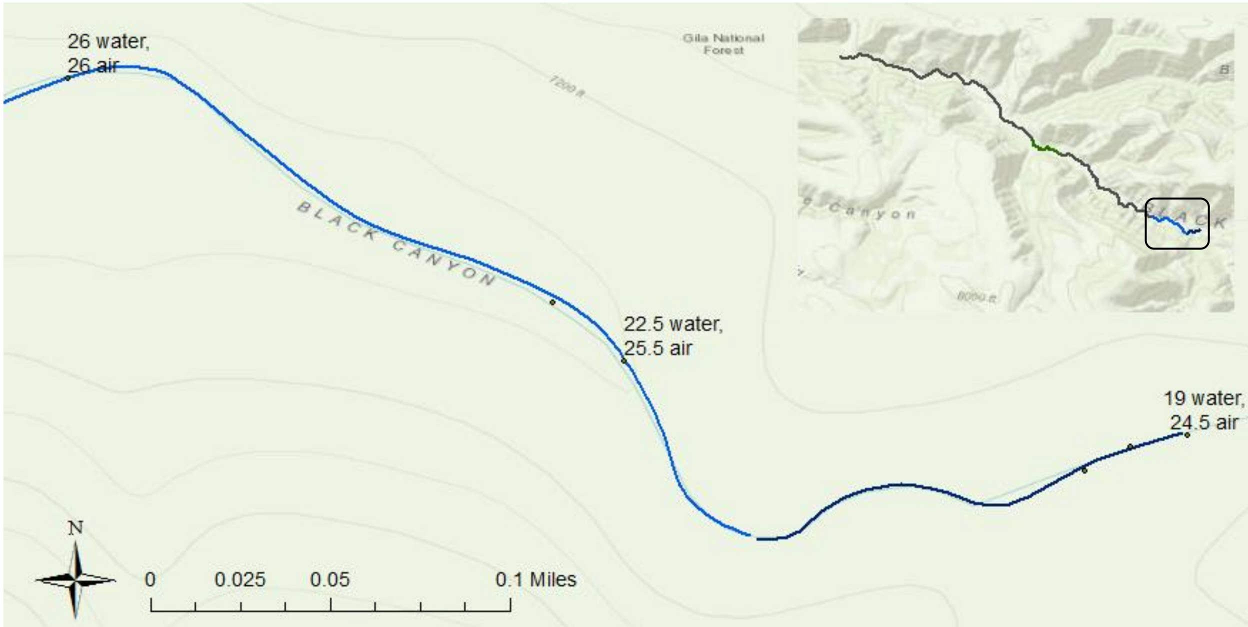

Figure 22: Location of Reach 1&2 and the August temperature readings

The solar load under current conditions was determined to be 198.3 (j/m^2/s) in August and 213.15 (j/m^2/s) in June. The corresponding maximum temperatures are 27.2 ° C and 32.1 ° C respectively. By increasing the vegetation density to 80% on both banks of the creek and decreasing the vegetation offset to 2 ft. the solar load conditions were lowered by 55.9 %. Specific solar loads were determined to be 87.29 (j/m^2/s) in August and 93.93 (j/m^2/s) in June, with resulting temperatures of 23.3° C and 27.7° C. While the reduction would not meet the 20° C water quality standard, there is a significant decrease in water temperature. The average segment azimuth is -17° offset from the West, which is a potential leading cause in the higher temperatures of the segment.

Reach 4: This reach covers a small segment of creek roughly a half mile downstream of the aspen canyon confluence before the flow goes subterranean. The hydrology and geometry inputs were determined by averaging data obtained from cross sections seven and eight. The shade variables used in the modeling can be seen in Table 12. The flow increases throughout the reach, and therefore the accretion temperature was set to 13° C. Reach 4 has the least vegetative cover of all the reaches analyzed, with the only shade coming from the ponderosa pine canopy, with a vegetation density average of 12.6%.

Table 12: Shade variable inputs for Reach 4

SHADE VARIABLES – Current Condition			SHADE VARIABLES – Ideal Conditions		
Avg.	**West**	**East**	**Avg.**	**West**	**East**
Veg. height (ft)	40	40	Veg. height (ft)	40	40
Veg. crown (ft)	5	5	Veg. crown (ft)	5	5
Veg. offset (ft)	10	10	Veg. offset (ft)	2	2
Veg. Density	**15.24**	**10.04**	**Veg. Density**	**80**	**80**
Topographic Altitude (d)	40	60	Topographic Altitude (d)	40	60
Segment Azimuth	-5	-			

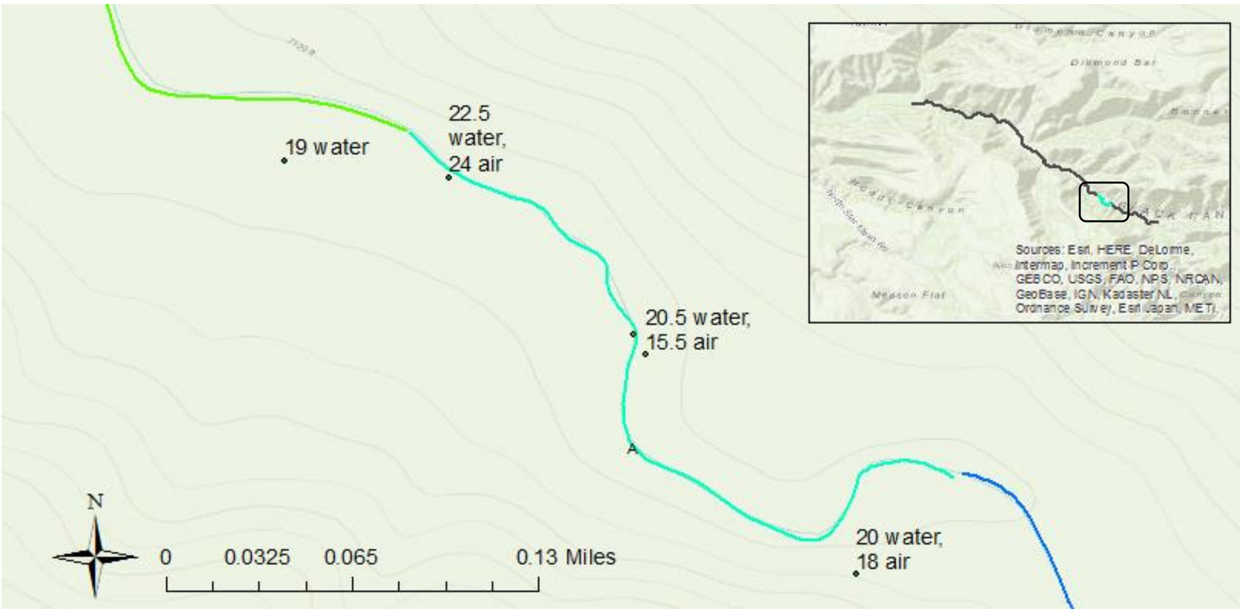

Figure 23: Location of the analyzed reach and the August temperature readings

The solar load under current conditions was determined to be 163.39 (j/m^2/s) in August and 199.24 (j/m^2/s) in June. The corresponding maximum temperatures are 22.5° C and 27.3 ° C respectively. By increasing the vegetation density to 80% on both banks of the creek and decreasing the vegetation offset to 2 ft. the solar load conditions were lowered by 48%. Specific solar loads were determined to be 84.52 (j/m^2/s) in August and 103.86 (j/m^2/s) in June, with resulting temperatures of 19.2° C and 23.2° C. The temperature reduction would meet the 20° C water quality standard in August but not in June.

The average segment azimuth is -5° offset from the West, which is a potential leading cause in the higher temperatures of the segment. Higher temperatures would be expected for this reach based on the segment azimuth and the low vegetative cover, but are stunted due to the addition of groundwater to the flow of the reach. Planting vegetation in this reach should be prioritized as temperature reduction is below water quality standards.

Reach 7: This reach covers the segment just before the confluence with Bonner Canyon. The reach begins just as water begins to emerge from being subterranean. The hydrology and geometry inputs were determined by averaging data obtained from cross sections ten through twelve. The shade variables used in the modeling can be seen in Table 13. This segment is primarily shaded by the ponderosa pine canopy with few areas that have established riparian vegetation and has average vegetation density of 36.2%

Table 13: Shade variable inputs for Reach 7

SHADE VARIABLES – Current Condition			SHADE VARIABLES – Ideal Conditions		
Avg.	**West**	**East**	**Avg.**	**West**	**East**
Veg. height (ft)	24	24	Veg. height (ft)	26.67	26.67
Veg. crown (ft)	5	5	Veg. crown (ft)	5	5
Veg. offset (ft)	4	4	Veg. offset (ft)	2	2
Veg. Density	**29.63**	**42.80**	**Veg. Density**	**80**	**80**
Topographic Altitude (d)	31.67	31.67	Topographic Altitude (d)	31.67	31.67
Segment Azimuth	-31.667	-			

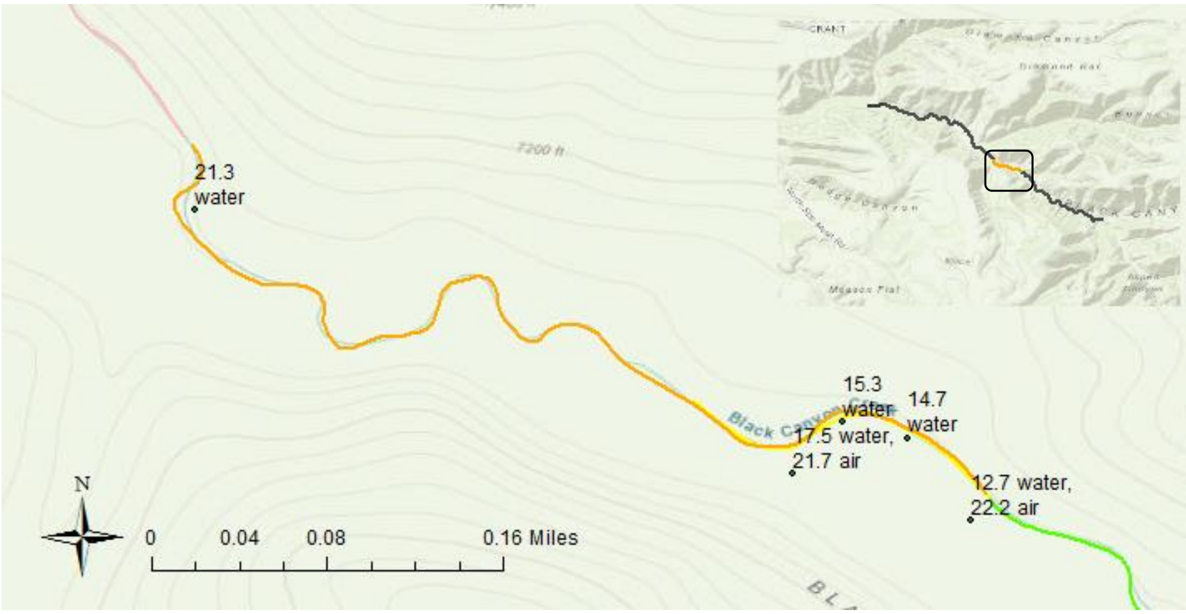

Figure 24: Location of Reach 7 and the August temperature readings

The solar load under current conditions was determined to be 187.55 (j/m^2/s) in August and 226.68 (j/m^2/s) in June. The corresponding maximum temperatures are 20.6° C and 24° C respectively. By increasing the vegetation density to 80% on both banks of the creek and decreasing the vegetation offset to 2 ft. the solar load conditions were lowered by 54.2%. Specific solar loads were determined to be 84.95 (j/m^2/s) in August and 104.96 (j/m^2/s) in June, with resulting temperatures of 16.8° C and 19.4° C. The temperature reduction would meet the 20° C water quality standard in both August and June.

The average segment azimuth is -32° offset from the West, which is a potential leading cause in the lower temperatures of the segment. The water also enters the segment at a cool temperature of 12.7° C, as it had been subterranean for roughly .45 miles. Planting vegetation in this reach should be prioritized.

Reach 13 & 14: This reach covers the last segment of creek in the project reach. There is a beaver dam at the beginning of the analyzed section, which is noted in Figure 25. The temperature at the end of the reach was not determined in the field, therefore there is not a check temperature in this segment. The hydrology and geometry inputs were determined by averaging data obtained from cross sections nineteen to twenty-one. The shade variables used in the modeling can be seen in Table 14. This segment is well vegetated with established riparian vegetation and ponderosa pine leading to an average vegetation density of 63.6%

Table 14: Shade variable inputs for Reach 13 & 14

SHADE VARIABLES – Current Condition			SHADE VARIABLES – Ideal Conditions		
Avg.	**West**	**East**	**Avg.**	**West**	**East**
Veg. height (ft)	41.67	41.67	Veg. height (ft)	50	50
Veg. crown (ft)	8.33	8.33	Veg. crown (ft)	10	10
Veg. offset (ft)	10.67	10.67	Veg. offset (ft)	2	2
Veg. Density	**65.68**	**61.52**	**Veg. Density**	**80**	**80**
Topographic Altitude (d)	18.33	18.33	Topographic Altitude (d)	18.33	18.33
Segment Azimuth	45	-	Segment Azimuth	45	-

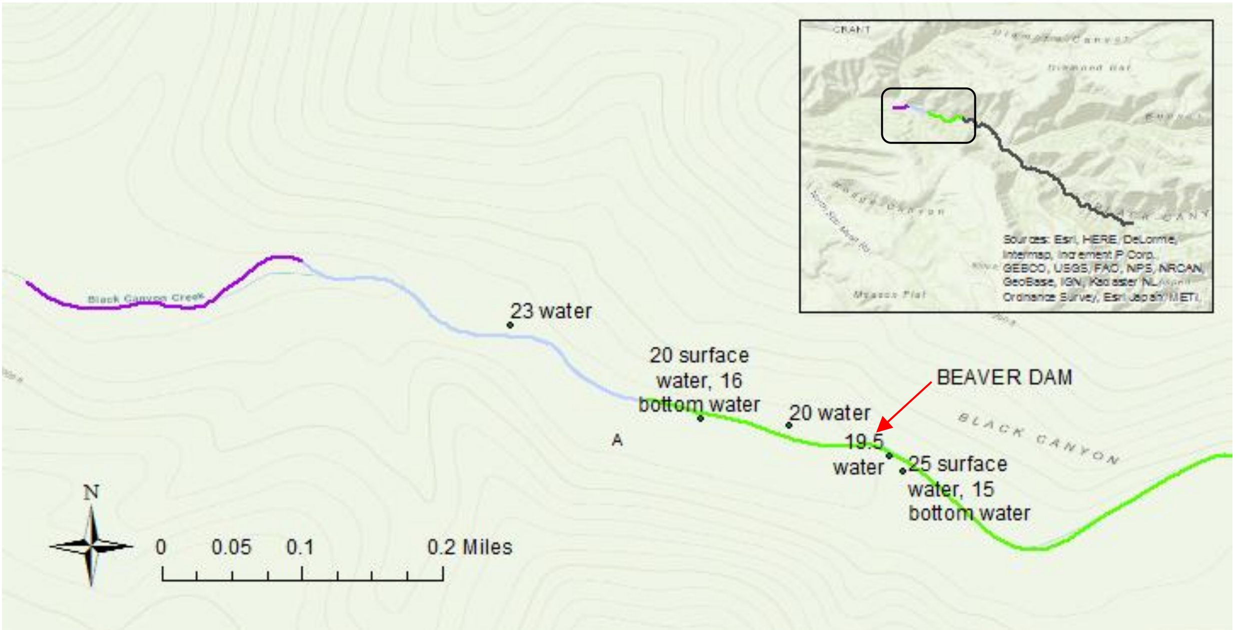

Figure 25: Location of Reach 13 & 14 and the August temperature readings

The solar load under current conditions was determined to be 156.62 (j/m^2/s) in August and 194.95 (j/m^2/s) in June. The corresponding maximum temperatures are 24.2° C and 28.3 ° C respectively. By increasing the vegetation density to 80% on both banks of the creek and decreasing the vegetation offset to 2 ft. the solar load conditions were lowered by 55.3%. Specific solar loads were determined to be 70.68 (j/m^2/s) in August and 86.44 (j/m^2/s) in June, with resulting temperatures of 21.6° C and 24.8° C. The temperature reduction would not meet the 20° C water quality standard, but would represent a significant decrease in water temperature.

The valley widens in this area, decreasing the average topographic altitude in this reach to around 18°. The slope is also gradual in this area, leading to pockets of still water which leads to higher temperatures.

SUMMARY AND RECOMMENDATIONS

Fire that burned through the riparian zone, and post-fire flooding which incised several stream reaches are the key disturbances which degraded habitat in Black Canyon Creek. Recovery of the riparian vegetation was slowed, by a history of heavy grazing in the watershed which prevented normally rapid regeneration of riparian vegetation. Grazing pressure has been removed and there have been no recent fires in the watershed. Black Canyon is slowly recovering from the effects of post-fire flooding and sediment inflow. The general condition of the stream appears to be that the flood prone width has evolved through channel widening to be within the range of a stable channel. However, many portions of the active or bankfull channel are wider and shallower than well-functioning reaches. These high width to depth ratio reaches are especially troublesome for fish habitat because they lack depth at low flows to support fish and provide a high surface area to volume ratio that warms efficiently when exposed to insolation and high air temperatures. The high width to depth ratio reaches are also problematic because riparian vegetation is unable to establish in the active channel, leaving a relatively wide portion of the channel cross section unshaded.

Habitat has poorly recovered from past flooding events and the relatively high sediment loads associated with channel widening after incision. These pools will likely rebuild as the channel naturally narrows and sediment transport is enhanced. This process could likely take years to decades to reach the state where

habitat quality is high. The combination of high summer stream temperatures and limited availability of deeper habitat is likely limiting trout population recovery.
The analysis of the logger data and the temperature modeling revealed that the gaining reaches of the creek maintain the coolest temperatures. The source of the gaining reaches are not well known, but it seems reasonable to assume that lost surface flow from upstream reaches travels through the hyphorheic zone in loose gravels before it resurfaces due to the influence of bedrock or some other less permeable structure. The emerging flow is cooler and helps to reset stream temperatures to a lower temperature which then warms again as it flows on the surface. The warming trend is moderated by reaches with higher density vegetation cover over the stream and narrower active channel widths. These two conditions often coincide. The existing beaver dam showed a similar pattern of temperature moderation, where flow emerging from sediments at the base of the dam was somewhat cooler than the upstream flow.

It appears that the stream habitat quality is slowly improving after a period of degradation. However, conditions for Gila trout are of immediate concern due to low base flow and high summer temperatures. Enhancement aimed at improving temperature and habitat conditions is highly recommended to speed fish recovery in the very near future.

Installation of practices that will speed the recovery of a relatively stable stream channel that can support lower water temperatures and a dense riparian zone will necessarily be driven by the location of the project within a wilderness area. Use of mechanized tools will be limited and work will need to be accomplished by hand crews utilizing minimal tools. This will limit the types of practices that can be utilized and will likely influence the timeline for accomplishment. Smaller practices which can be installed by hand crews should focus on utilizing the forces of the stream to move materials, either forming pools, floodplains or appropriate channel dimensions while minimizing the amount of materials moved by hand. Accordingly, practices should focus on utilizing local materials and not rely on import. The limited volume of work that can be accomplished by a hand crew may dictate that the project be completed in phases. It is recommended that reaches where target temperatures can be attained, be prioritized for work. For this reason, planting in Reach 4 and in Reach 7 should be prioritized. Once these gaining reaches are able to sustain cooler temperatures, the respective downstream reaches would also be able to sustain cooler temperatures, creating a “piggy back” effect in progressively improving habitat downstream.

We explored the utilization of beaver dam analogue structures for use in Black Canyon. These structures fit the criteria of being constructible by hand crews and would help to insure surface flows were directed into the soil profile to improve temperature, onsite water retention and stability of base flows. Improvement of these functions would very much improve the habitat quality of Black Canyon Creek. However, we found very little evidence that Black Canyon would or could support an extensive anastomizied channel/wetland system that would be the end result of these efforts. Additionally, beaver dam analogues require extensive and frequent maintenance unless they are colonized by beavers to do the work. The remote nature of Black Canyon would make it difficult to monitor and repair the structures as needed. Without vigilant monitoring and repair it is likely that the structures would fail, creating additional erosion and channel instability. Currently there are limited beaver dams in Black Canyon. There is one active dam in the lower portion of the reach and another blown-out dam higher in the system. These beaver should be encouraged to expand their distribution in the canyon and it is likely that their activities will positively impact portions of the reach for limited time periods until the dams are destroyed by higher flows.

As an alternative, we have proposed practices that are focused on maintaining a relatively stable, well shaded, single thread channel through the project reach. The practices are meant to narrow the active channel, promote a much narrower and deeper base flow condition, stabilize banks in some areas and improve the distribution and density of riparian vegetation for shade. Target vegetation canopy densities for the project area are >70% over the stream. Planting with rapid growing willows and cottonwoods in all the open areas is a key to success. Manipulation of the stream geomorphology should be in support of vegetation recruitment and establishment. We have also included some practices that will improve depth and cover for Gila Trout. There are numerous practices throughout the project area and it is likely that even concerted efforts by handcrews could not accomplish installation of all of them in a short time frame. It is suggested that installation efforts be driven by budget availability and time with specific reaches prioritized. Such an approach should help attain temperature goals for specific reaches of the stream in a reasonable budget and timeframe.

PROPOSED PRACTICES

Willow Pole Plantings

Willow pole plantings use cuttings from willow (Salix spp) shrubs that are used to revegetate shallow, eroding streambanks, providing protection against erosion and ultimately shading the stream. Hand tools are used to collect willow poles (½ inch diameter or larger) from the project site. Holes are dug along the toe of the bank using hand tools such as a digging bar, and are deep enough to encounter permanent water. One to three willow poles are placed into the holes, ensuring the butt ends are in water. Holes are then back filled with a mud slurry to eliminate air pockets. The tops of the poles are cut off approximately one foot above soil level. Poles are typically planted in a staggered pattern on banks on two to four foot spacing. Planters must ensure that the base of the poles are below the annual low elevation of ground saturation and the upper part of the stem is in good contact with soil that is relatively well drained for much of the year.

Figure 26: Willow pole plantings at stream bank as part of stream/habitat restoration

Vertical Willow Bundle

Vertical willow bundles are used to plant and establish willow vegetation that will stabilize eroding banks and provide shade to streams. This practice allows for planting and establishing willows on taller banks than with pole plantings. Willow bundles use 3-5 willow cuttings (minimum ½ inch diameter by 6 ft long) harvested by hand from native willows growing at the site which are tied together with coir twine. Hand tools are used to dig a shallow, 3-4 inch deep vertical trench on a bank down to water permanent water level. The bases of the stems are placed into water, while the rest of the stems are buried along their length, leaving approximately one foot exposed at the top. Wooden stakes are used to secure the bundle to the bank. The willow poles will take root along the buried portion, establishing a dense matrix of roots which will spread over the bank. The stems will sprout along their length, resulting in willow cover up the bank, providing protection against erosion and ultimately shading the stream channel. Trenches are placed approximately every 4-8 feet along an eroding bank.

Figure 27: Willow bundles being installed on a river bank

Log and Willow Barbs

Log and willow barbs are structures installed along eroding banks, on the outside of meanders or in locations where additional fish habitat is desired. Their function is to direct channel flows away from the bank and back towards the center of the channel. The structures provide bank protection and also create fish habitat features, as scour pools usually form on the downstream side with the structure providing overhead cover.

Logs barbs are constructed out of straight, sound logs (either green or dead), 12 to 24 inches in diameter and 15 to 20 feet in length. Willow barbs are assembled from dead and live willow stems that are formed by overlapping and compressing the stems into 8-10 inch diameter bundles, 15 to 20 feet in length. Bundles are tied together with ¼ inch jute or coir rope, or other natural material every four feet. To create a "log", three to four bundles are then tied together with natural material rope or with 1/8 inch wire rope.

The wood or willow logs are buried into the bank at bankfull height and are ballasted with large boulders or earth anchors. They are positioned into the channel pointing upstream, and sloped down, towards the rivers bed. The in stream end of the barb is placed approximately 1/3 channel width away from the bank and is buried into the channel down to bed level. The end is held in place with earth anchors or rock bolsters. After installation, the upstream side of the barb can be backfilled with large cobbles or boulders to prevent water from flowing under the structure.

Figure 29: Willow Barb

Figure 28: Willow Barb

Figure 30: Log Barb

Rock Barb

Rock barbs serve the same function as the log barbs but are built out of larger boulders or graded rock. The structure is placed at bankfull elevation where it ties to the bank. It angles upstream, away from the bank at 20-30 degrees, and down to bed elevation. The rocks should fit tightly together so water is forced over the top of the structure. A scour pool can be excavated on the downstream side to enhance habitat. Willow poles are planted around the end of the structure along the bank to provide additional shading and bank stabilization.

Figure 31: Rock Barb extending from left side into the base flow channel

Mini Weir

The mini weir is a rock structure that creates small pockets of streambed scour and provides vertical cover in midstream areas. These structures are created with larger boulders (small enough to move by hand) and extend no higher than bankfull elevation above the bed. Rocks are placed into a chevron configuration with the point facing upstream. The bed is dug out enough to place footer rocks which anchor the top rocks in place, and a scour hole is left on the downstream side. Mini weirs are used to establish ‘pocket habitat’ in riffles. They will slow high flow velocities by creating additional roughness but should not be considered as grade control.

Figure: Mini weir in mid-channel

Figure 32: Mini weir mid-channel

Willow Fascine

A willow fascine is a bioengineering technique that protects the toe of a bank from scour and is also used to secure erosion control fabric along the base of a bank. Fascines comprised of live and dead willow stems that are bundled and compressed together in an overlapping fashion to create an 8 to 10 inch diameter “log” of the desired length. The fascines are tied with jute or coir rope and are installed along the toe of a bank and partially buried. Tapered wood stakes are used to secure the fascine to the bed.

The advantage of using live willow stems is that they can take root and sprout, adding additional woody bank vegetation that protects against erosion and provides shade over the stream channel. Willows are harvested from the project site and hand tools are used for installation. If sprouting and establishment of willows at the site is desired, soil should be covering the stems with good soil to stem contact or roots will not establish.

Figure 33: Willow Fascine

Rock or Log Deflectors

The purpose of a rock or log deflector is to constrict flows and form a low flow channel in an overwide section of stream which can improve fish habitat and reduce thermal gain. These low structures are installed on the bed of the channel, forming a triangle extending out at approximate 45 degree angle from the bank to the center of the channel. The height of the “point” of the triangle is the elevation of the base flow water surface. If the channel has an appropriate width/depth ratio, the structure can remain flat as it progresses towards the bank. If modifications to the bankfull width/depth ratio are needed, the structures can rise as you move towards the bank up to bankfull elevation. Wetland vegetation can be planted in the fill portion.

The structure can be constructed out of appropriately sized rock if available, or a frame can be constructed out of 12 inch or larger logs which are buried in the bank, and infilled with smaller materials (rock, gravel, brush). Structures are placed in straight channel reaches, typically on alternating banks to create a sinuous low flow channel, or can be placed across from each other to create a narrow channel in the center.

Figure 34: Low deflector built at Canyon Creek, Az.

Figure 35: Log deflectors from both banks
Image from afterwildfirenm.org

Log Overhang

Log overhangs are installed on the outside of meander bends and provide overhanging cover and shade for fish. These structures are constructed against the bank, with a log set on footers and anchored with earth anchors or rock bolsters. The bottom the log is set at an elevation that provides a swimming depth for fish at base flow. The top of the log should not extend above the bankfull elevation. Voids between the bank and log are filled with ballast rock and can be covered with soil and planted with wetland vegetation or willows. Stream currents at the meander help to keep the opening under the log free of sediment. Boulder clusters at the exterior of the structure can be placed to ensure that some stream current it directed towards the structure.

Figure 36: Log Overhang

Figure 37: Log Overhang

Boulder Cluster

Boulder clusters are composed of three to four larger sized boulders (18-20 inch) placed into a stable section of stream channel, in riffles, glides, or pools, wherever cover for fish is desired. The rocks provide side and overhead cover; create scour pockets around the boulders and builds quiet water resting areas in riffles. Boulders are placed in a triangular or diamond shaped pattern with spaces between boulders ranging from 6 inches to a foot. The tops of boulders should be below bankfull elevation.

Figure 38: Boulder Cluster

Figure 39: Boulder Clusters

Log Weir

A log weir is a structure used for grade control and bank protection, while creating a scour pool and overhead cover for fish. The structure is a chevron shape, made out of three logs and with the point facing upstream and the arms rising downstream to bankfull elevation. The logs used to create the structure are 12 to 24 inch logs. The throat log is approximately 1/3 bankfull channel width long, with the arm logs 14 to 24 feet in length. Logs are pinned together with rebar pins and are held in place by earth anchors, bolster rock or trees adjacent to the channel. The throat of the structure is buried into the channel bed substrate with the arms rising at a 2 to 7% slope to bankfull elevation. The arms are buried into the bank with rock bolsters holding the ends in place. Care should be taken to ensure that the stream does not undercut the logs or the structure will fail. Utilize available stream cobble, soil and larger rocks to block flow from the underside of the structure. In some situations it may be necessary to bury a second log below the main structure.

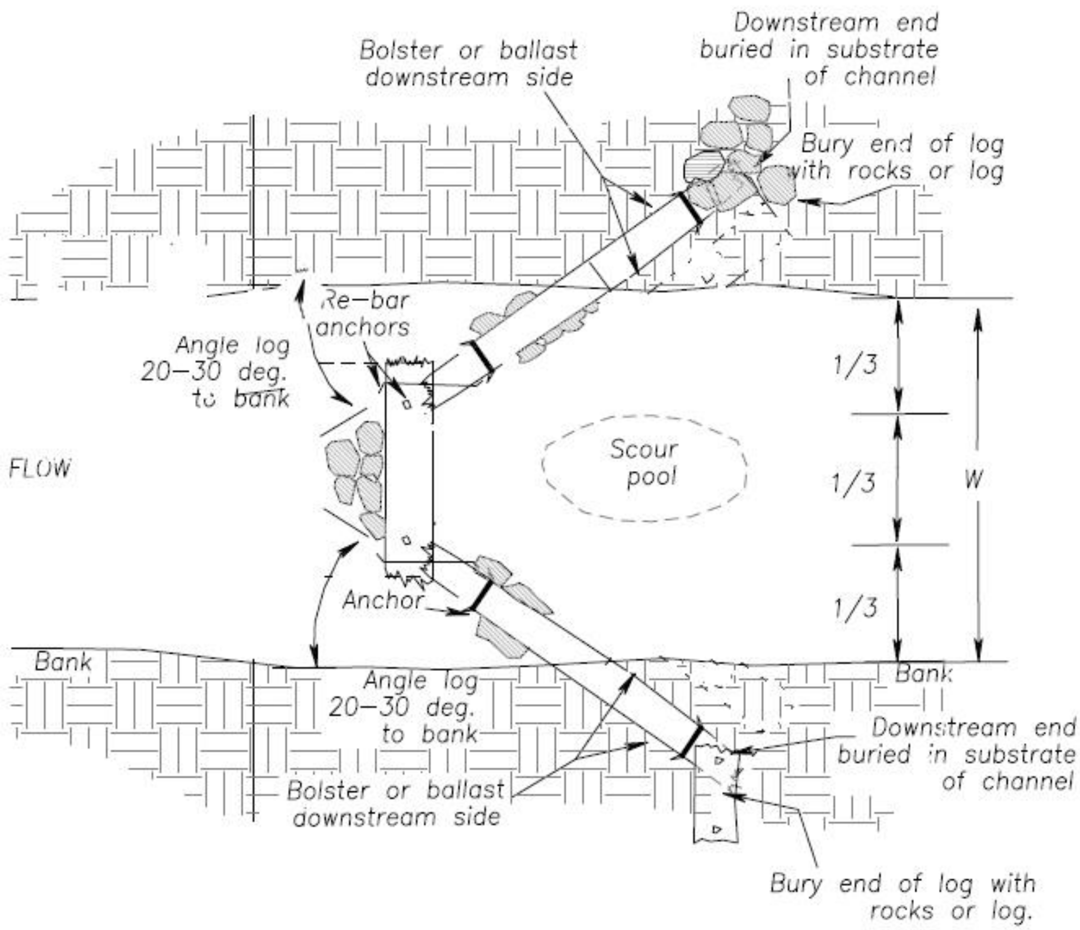

Figure 40: Log Weir

Brush Revetment

This practice provides temporary, physical protection to the toe of a bank while acting as a sediment catch to build out the toe of the bank. The revetment is made of live, branchy trees or brush (2-6 inch diameter, juniper or fir with needles on work well) which are placed along the toe of an eroding bank. The top of the revetment should be placed near the bankfull elevation. Trees are shingled along the bank starting at the downstream end, with each subsequent tree overlapping by 1/3 of its length. Trees are wired together with 12-gauge galvanized wire. The revetment needs to withstand the force of the flowing water. Revetments need to be staked to the bank with earth anchors, rock bolsters or t-posts (if t-posts are utilized, they should be removed in 2-3 years). Anchor points include each end of the revetment and at each overlap section at a minimum. Willows should be planted behind the revetment to provide permanent cover and a dense root mat. Flood flows will be slowed by the dense woody barrier and sediment will accumulate. Wetland plants will colonize the fresh sediment bench. The long-term effect will be to reduce stress on the outside of meanders and reduce stream width.

Figure 41: Brush Revetment

Crossover Logs

Cross over logs provide overhead cover and shade and help the stream create a relatively deep scour pool beneath to provide fish habitat. The 12 to 24 inch diameter log is felled perpendicular to the stream flow and spans the entire width of the bankfull channel. The log is placed so the bottom of the log is just above bankfull elevation. Bolster or ballast rock is placed on either end of smaller logs to provide anchorage. However, anchorage should be minimal since permanently anchored logs or logs placed too low relative to bankfull will likely cause the stream to erode around the end of the log. Willow poles can be planted around either end of the log to provide additional shade. Flows in excess of bankfull will be deflected vertically and scour the pool. If the log is placed in a meander or at proper pool to pool spacing the pool will persist even after the log has been dislodged and moved. This practice can be expected to cause some bank erosion and should not be placed where a loose log or debris could cause an issue for downstream infrastructure.

Figure 42: Crossover Log

The practices described herein are proposed to improve habitat along the subject reach of Black Canyon Creek. Specific proposed locations for these practices have been identified within the plans as developed by NCD for this project. Some variability of the exact location for each practice should be anticipated due to the natural variability of the stream and with an expectation that judgment of the existing conditions at the time of construction will need to be part of the implementation effort.

It should also be understood that some of the practices will be temporary in nature, intended to accelerate the development of habitat and spur more permanent changes in the stream morphology by way fostering key points of scour and/or deposition and establishment of vegetation. Revegetation and bio-engineering practices will become more resistant to wash-out during flood events as the willows and other vegetation becomes established. Feature rocks and logs used within the practices may be subject to migration downstream, depending upon the severity of future flood flows, but should serve to provide immediate improvements to habit while in their placed positions and then will likely recreate habitat where they are relocate to after an inevitable future flood event occurs.

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