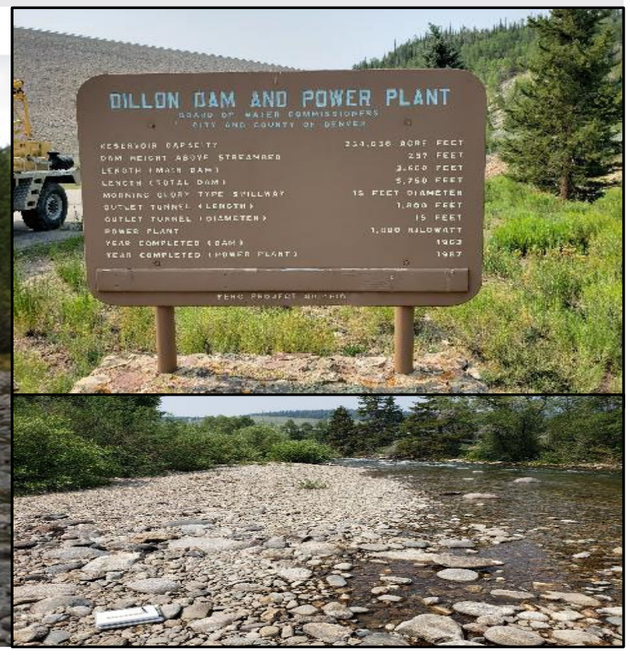
BRWG
BLUE RIVER WATERSHED GROUP

Blue River Integrated Water Management Plan

Blue River Conceptual Restoration Master Plan

Dillon to USFS Campground



July 2023

TETRA TECH

TROUT UNLIMITED

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Acronyms and Abbreviations

cfs	Cubic feet per second
CR	County Road
CWBC	Colorado Water Conservation Board
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
NEPA	National Environmental Policy Act
FACStream	Stream Visual Assessment Protocol
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
U.S.	United States

1 OVERVIEW

1.1 Background

The Blue River watershed is in Summit County Colorado, located at the top of the Continental Divide on the west slope of the Rocky Mountains. The river extends 62 miles flowing from south to north to its confluence with the Colorado River near the Town of Kremmling. The watershed is a small drainage basin, covering 699 square miles, following the County boundary, and encompassing the Gore, Tenmile, and Front Ranges. The river flows near or through the Towns of Blue River and Breckenridge, then into Dillon Reservoir near the Towns of Dillon, Frisco, and Silverthorne. From Dillon Reservoir the river flows north-northwest along the base of the Gore Range, through Green Mountain Reservoir, past the Town of Heeney, and into the Colorado River near Kremmling (**Figure 1**).

Historical and current impacts within the watershed have been significant, including dredge boat mining, hard rock mining, and two major water impoundments. Transbasin diversions move 20 to 30% of the total water yield generated within the watershed to the front range. Snow and rain are the only sources of this water, and no water is imported into the Blue River watershed from other sources or locations.

In 1983 Colorado Parks and Wildlife (CPW) designated the Blue River below Dillon Reservoir to Green Mountain Reservoir as a Gold Medal Fishery. The biological criteria for a Gold Medal fishery is defined as a *fishery consistently producing a trout standing stock of at least 60 pounds per acre and an average of at least 12 "quality trout" (14+ inches) per acre (CPW, 2019)*. In 2016 the designation was removed between the Town of Silverthorne and the Blue River Campground, located north of Silverthorne because the river was unable to meet CPW's biological criteria (CPW, 2019). This policy decision was driven primarily by a fishery management report prepared in 2018 (Ewert. 2018) where CPW biologists indicated low productivity may be caused by a combination of suboptimal physical habitat under low flow releases from Dillon Reservoir (noted as being less than 100 cubic feet per second (cfs) (Nehring 1988) and a lack of food and/or limited biological productivity. The upstream portion of the reach retained its Gold Medal designation largely because of (1) the Town of Silverthorne's early-2000s in-channel river restoration efforts (Reuter, 2002), and (2) stocking by CPW with catchable rainbow trout. The Blue River Integrated Water Management Plan (BRIWMP) (Tetra Tech, 2020), completed in 2020 and subsequent monitoring and analyses support CPW's conclusions. The monitoring and analyses prepared in conjunction with the BRIWMP included benthic macroinvertebrate sampling, periphyton sampling, and habitat assessments (Assessment of Current Aquatic Habitat, Hydrology, and Hydraulics in the Blue River downstream of Dillon Reservoir Dam (Tt & MEC, 2022), and Assessment of Current Aquatic Habitat in the Blue River Below Dillon Reservoir, Subreach 2.2 (Tetra Tech et al, 2023)). Major factors from these studies include the following:

- Pool habitat, is sparse and average depths shallower than the recommended 1.5 feet at low flows to provide adequate cover, resting, and refuge habitat. Pools in the upper reaches specifically within the Town of Silverthorne were extremely limited.
- Cover such as rocks, logs, bank vegetation, pool depth and debris all serving as a refuge for fishes to rest and hide from predators is poor to nonexistent in many locations.

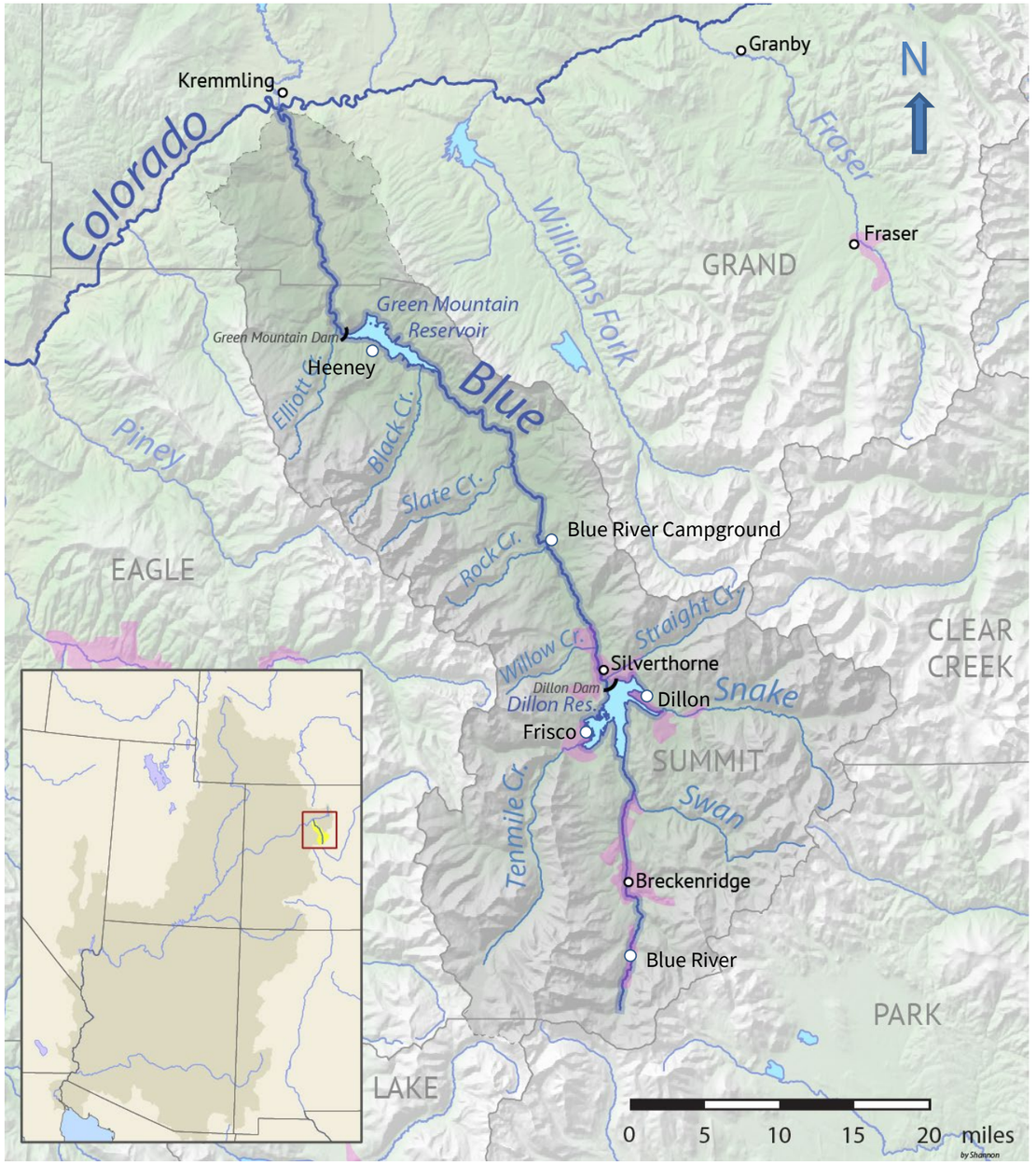

Figure 1. Blue River Watershed, Summit County CO

- Benthic macroinvertebrate communities were “impaired” immediately downstream from Dillon Reservoir in the spring and fall, while further downstream benthic macroinvertebrate communities were “impaired” during the summer.
- Improvements in benthic macroinvertebrates were consistently observed moving from upstream (near Dillon Reservoir) to downstream (near Green Mountain Reservoir) of the study area. Alterations from the natural flow and temperature regime imposed by reservoir operations were responsible for a decline in the richness and abundance of sensitive and specialized taxa.
- Lack of periphyton, or benthic algae, may be limiting invertebrate populations and, subsequently, the fishery. Longitudinal declines in periphyton abundance were seen for the first 1 ½ miles below Dillon Reservoir. Further downstream periphyton abundance sampling indicates some recovery moving further downstream but remains variable.
- Existing boulder drop structures in the Town of Silverthorne are located in a very wide channel section with shallow depths and a lack of diversity. The drops are limiting upstream fish passage.
- Water is released from the bottom of the reservoir which results in cold water releases, frequently below optimal temperature ranges for brown trout (Raleigh, et al. 1986), and likely have a negative impact on all life stages of the fishery. Release temperatures are less than 10°C. The low temperature affects the aquatic biota in several ways. Benthic macroinvertebrates that require natural seasonal temperature fluctuations to complete their life cycles are absent or in low numbers. Growth rates for fish are slowed because of lower metabolic rates.
- Trout spawning success can be decreased by the low water temperatures, especially for spring spawning species such as rainbow trout and cutthroat trout (Miller, 1988). These species normally experience rising water temperatures during egg incubation.
- Low water temperatures (less than 10°C) can delay embryo development and hatching in rainbow trout (Timoshina, 1972). This delay offsets the timing of the hatch with the types and availability of food sources, specifically invertebrates, putting the fry at a disadvantage when competing for food.
  Monitoring in 2020 shows a reservoir spill between late June and early July that created an increase in temperature of 6.6° C (4.8 to 11.4 ° C) in 48 hours, which is considerable when compared to the conditions on the Blue River upstream of Dillon where water temperatures changed 1.2° C (7.7 to 8.9° C) over the same 48-hour period. Likewise, when the spill ended, temperatures dropped back to the pre-spill temperatures. The fishery, being cold-blooded animals is physically stressed by sudden changes in temperatures.
- A comparison of water temperatures downstream of Dillon Reservoir shows a warming trend moving downstream of Dillon Reservoir. Temperature monitoring shows incremental increases until downstream of the Boulder Creek confluence, 11 miles downstream of Dillon Reservoir, where recorded water temperatures were similar to the temperature readings above Dillon Reservoir recorded at the Blue River inlet to the reservoir.
- November temperatures show a reverse temperature trend with a cooling trend moving downstream of Dillon Reservoir. The abnormally warm water temperature influences many biological processes of aquatic organisms and may also contribute to the formation of anchor and frazzle ice, having negative impacts on habitat.

This Master Plan is the first step of several stages of improvement and is focused on creating and restoring the physical habitat for the Blue River fishery. Recognizing there are limitations on flow modifications, the focus here is to modify the habitat to better fit with the prevailing flow conditions. These improvements in combination with future additional improvements such as restoration of tributaries, access for spawning in tributaries, and addressing temperature and flow ramping will be required to maximize the potential for the fishery and aquatic life upon which the fishery depends.

1.2 About This Report

The Project Reach extends from the outlet of Dillon Reservoir to the USFS Blue River Campground, approximately 10 miles. The BRIWMP designates the Project Reach as Subreaches 2.1 and 2.2, located within Reach 2 which extends from Dillon Reservoir to Green Mountain Reservoir, an additional 10 miles beyond the Blue River Campground. For purposes of developing this master plan, the Project Reach has been further divided into nine secondary Subreaches (2.1.1-2.1.3, and 2.2.1-2.2.6) as shown in **Figure 2**. Each Subreach is comprised of sections of the river with similar planform and physical conditions to aid in the assessments and site descriptions. This Restoration Master Plan Report is presented as follows:

Section 2: Objectives and Methods: This section describes the methods used to develop a level or standard for acceptable physical habitat within a river system such as the Blue River, and to assess and compare these standards to the current conditions.

Section 3: Key Findings: This section presents results from the habitat, stream health, and morphology assessments conducted for the Blue River from Dillon Reservoir outlet to the Blue River Campground. Habitat assessments were conducted in two phases: one in 2021 for the first three miles downstream of the Dillon Reservoir outlet, and the second in 2022 from the Blue River Trail bridge crossing to the USFS Blue River Campground for an additional seven miles. The habitat assessments are documented under separate cover and results are summarized in this master plan report. The stream health assessment and morphology overview were conducted specifically to support this master plan and are presented in section 3 of this report. Results are combined with the habitat assessment results and used to inform on restoration opportunities and priorities.

Section 4: Restoration Recommendations: This section presents an array of techniques to improve the physical habitat for the fishery. This section includes descriptions and details for typical restoration elements.

Section 5: Site Descriptions and Restoration Recommendations: This section includes mapping of the Project Reach, divided into 16 subsections at 200 scale, each presented with a summary of assessments and restoration recommendations, and a conceptual level restoration plan depicting these recommendations.

Section 6: Overview of Implementation: This section includes an overview of the ‘Next Steps’ for project implementation.

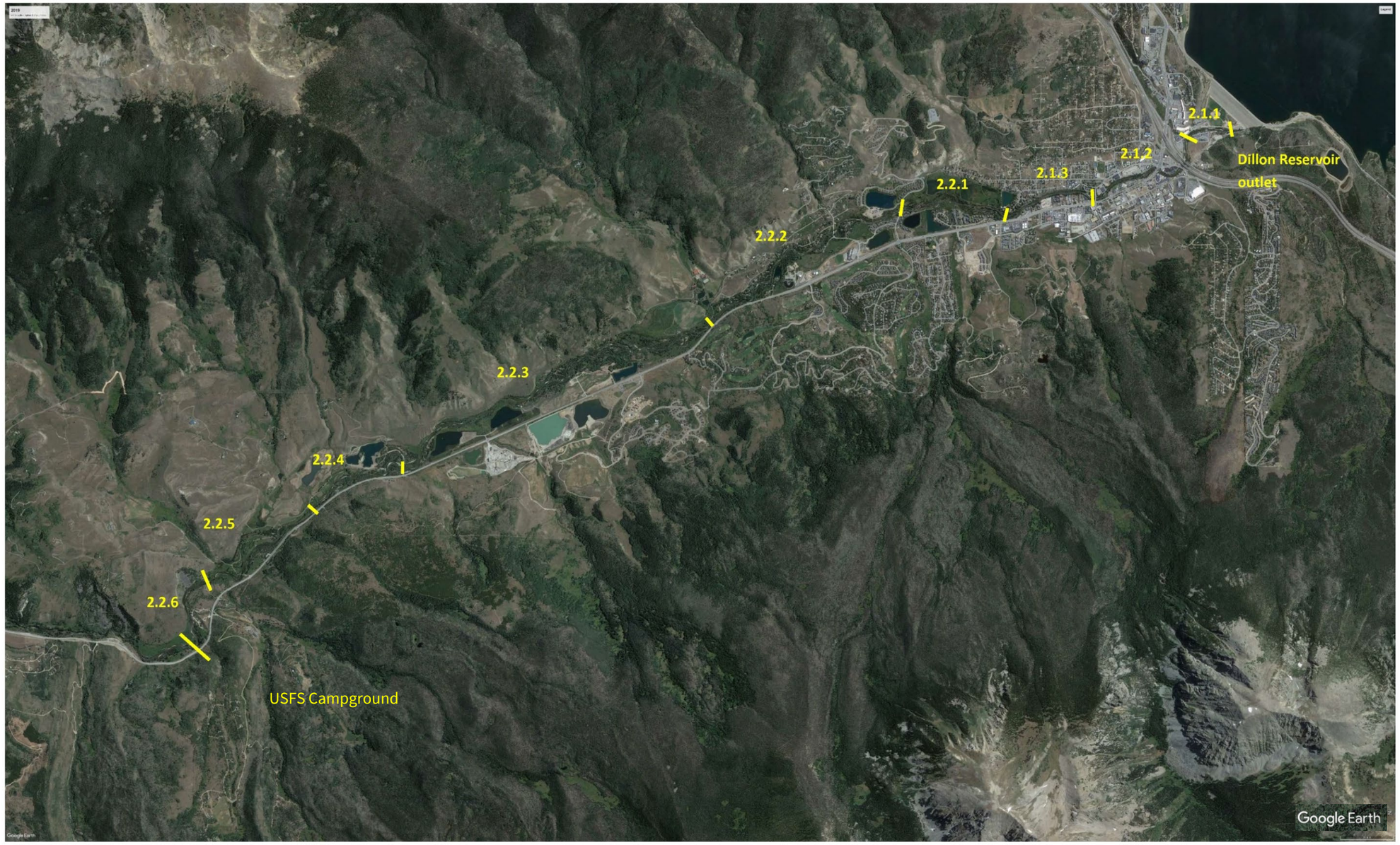

Figure 2. Blue River Project Reach Subreaches 2.1 and 2.2

2 OBJECTIVES AND METHODS

The primary objective of this master plan is to develop recommendations to improve the physical conditions in support of the aquatic habitat. The assessments and recommendations focus on shallow channel depths and overly wide channel sections and reaches lacking in habitat diversity such as pools, riffles, glides, and areas lacking in cover. In reaches with anthropogenic impacts, recommendations may include bank stabilization and revegetation, and improvements for connectivity and fish passage. Conceptual level restoration measures are described in Section 4 of this report and where appropriate, shown in sketches for use in preparing site-specific plans for implementation. Key parameters used to inform on restoration are outlined as follows.

2.1 Hydrology and Hydraulics

Hydrologic analyses were completed to identify a range of flows representative of current conditions with which to assess aquatic habitat and develop restoration recommendations. Data sources included the USGS's stream gaging records (Tt & MEC, 2022), FEMA's Flood Insurance Study for Summit County, CO (FEMA, 2018), and CWCB's instream flows (CWCB, 2018). The USGS data were used to compile representative hydrographs and flow duration curves. A one-dimensional (1D) numerical model (HEC-RAS) was prepared to simulate hydraulic conditions in the Project Reach. Parameters of interest for use in the habitat assessment included (1) wetted perimeter of the channel, (2) channel hydraulic depth, and (3) channel maximum depth (Tt & MEC, 2022).

2.2 Habitat Assessments

Habitat inventories were completed at eight sites located within the Project Reach to measure and assess habitat conditions supportive of a cold-water fishery and compare these results to 'known standards' or available guidance that describes productive and healthy habitat. The habitat inventory included two assessments. The first used a quantitative protocol developed by the USFS to measure the area of each habitat type (pools, riffles, and glides) and to visually estimate cover and stream substrate (Tt & MEC, 2022). The second assessment was conducted of the physical instream habitat for aquatic biota such as bankfull width and depth of flow following the principles and guidance for instream flow and hydraulic-habitat evaluations in several foundational instream flow documents (Stalnaker et al., 1995; Bovee et al., 1998; Annear et al., 2004). Channel cross sections were surveyed, and 1D hydraulic modeling conducted to quantify the relationships between flow and hydraulic indicators of aquatic habitat quality. These relationships are key to better understanding how channel hydraulics and habitat change as a function of flow. Hydraulic indicators targeted in this assessment included channel wetted perimeter, average (hydraulic) depth of the channel, and channel maximum depth in the major habitat types of pools, riffles, and runs as discussed below.

Pool Habitat

Pool habitat provides resting and refuge habitat for fish, especially at low flows. Winters and Gallagher (1997) state that pool depths of at least 1.5 feet are the minimum needed to provide resting and refuge habitat for trout. This guidance was not developed for any specific trout species, but as a repeatable method that could be utilized to inform on current habitat conditions and provide a monitoring tool. This guidance also does not consider the long-term impacts of sustained minimum pool depths. Generally, a 50:50 ratio of pool to riffle is considered optimal (Cristi Cave, B.S., Fisheries, 1998) although, for mountain rivers, pools are less frequent and therefore often a lower percentage. Based on the morphology of the Blue River pools naturally would form on the outside bends adjacent to the banks.

Riffle habitat

Riffle habitat is important for benthic invertebrate production, which serves as a food source for higher trophic levels. The riffled water surface in this habitat type also provides oxygenation to the river and aids in supporting aquatic biota. Both width and depth are considered in assessing the quality of a riffle. Width is the bank-to-bank measurement at elevations above sedges, willows, and other plants that may survive submerged, under high flows (Colorado State University, 2019). The minimum riffle wetted perimeter for a flow of interest in the Blue River sites is 50 percent of the bank-to-bank width (Tt & MEC, 2022).

Adequate depth in riffles is also needed for benthic invertebrate production. Minimum depth criteria in riffles, needed for longitudinal habitat connectivity for fish species and for providing stable habitat for benthic species, ranges from 0.6 to 1.0 feet (Nehring, 1979). While wider wetted width and wetted perimeter provide more habitat area for benthic production, which is beneficial to higher trophic levels, the flow-limited conditions seen in this reach of the Blue River will result in shallower depths, negating the benefits of the wider wetted permitters.

Run/Glide Habitat

Glide habitat (synonymous with "Run" in some classification systems) is the transition between low-velocity pool habitat and the fast-velocity riffle habitat. Glide habitat is uniform in depth with very little water-surface disturbance from fast velocity and shallow depth. Adequate depth in run and glide habitat is required to provide feeding locations for fish. Depths no less than the minimum riffle depths recommended by Nehring (1979)(0.6 to 1.0 feet) provide appropriate function as foraging locations. Depths greater than the minimum may provide enhanced function. Run wetted perimeter as a function of discharge parallels the interpretation of pool and riffle wetted perimeter. The terms run and glide in this report are used interchangeably.

Cover

Cover includes features such as rocks, logs, bank vegetation, turbidity, and debris that serve as a refuge for fishes to rest and hide from predators. A growing body of evidence highlights the importance of cover and the role of cover for salmonids, particularly for populations living at high latitudes and altitudes (i.e., in low productivity environments) where the warm growing season is short and then the inactivity period is long (Allouche, S. 2001).

2.3 Additional Assessments

Two additional assessments were conducted and combined with the habitat assessment to identify restoration needs. The first assessment was a morphological overview, which includes a review of the geology, soils, planform, and pre-dam conditions of the Blue River using a 1954 aerial photo.

The second assessment was a stream health assessment conducted for the purpose of rating functional ecological conditions in the Project Reach. This assessment utilized the framework outlined in the Functional Assessment of Colorado Streams (FACStream) version 1.0 (Beardsley et al. 2015). FACStream rates the functional conditions of a

stream using the level of departure from a reference reach. A reference reach is defined as a river segment that represents a stable channel within a particular valley morphology, in an unimpacted condition, which should be thought of as "the river in its state of natural dynamic equilibrium or 'optimal' functioning river system, likely present prior to settlement in or around the 1800s." For purposes of conducting this stream assessment, the use of the term "reference reach" will be limited to a general understanding of what undisturbed conditions might have been for the Blue River. Based on guidance outlined in FACStream, and a general understanding and familiarity of the watershed, an overall reference standard would be described as a single thread channel with areas of bar/island braiding. The typically included a wide floodplain, unconfined or partially confined valleys, pool-riffle bed formation consisting primarily of cobble and gravels, and a moderately dense riparian vegetated corridor. This reference reaches would have no local water use, transbasin diversions, or water impoundments.

FACStream uses ten ecological variables (**Figure 3**) and can be employed as a reconnaissance assessment utilizing observable factors (Level 1), routine assessment using observable factors and review of existing information (Level 2), or intensive assessment using observable factors, review of existing information, and the use of predictive models to further document the degree of impairment and loss of function (Level 3) effort.

Scale	Variable		Metrics
Watershed	V_{hyd}	Flow Regime	Peak flow, base flow, rate of change
	V_{sed}	Sediment Regime	Land and channel erosion; transport through the reach
	V_{chem}	Water Quality	Temperature, nutrients, metals, others
Riparian	V_{con}	Floodplain Connectivity	Extent of lateral flooding and duration
	V_{veg}	Riparian Vegetation	Vegetation banks and overbanks, diversity, connectivity
	V_{deb}	Debris	Large wood, soil and duff, organic matter
Stream	V_{morph}	Stream Morphology	channel planform/dimensions, profile
	V_{stab}	Stability	channel stability and ability to recover
	V_{str}	Physical Structure	Bank and bed structures (rock and wood) supporting aquatic life
	V_{bio}	Biotic Structure	Macroinvertebrates, fishery

Figure 3. FACStream Ecological Variables.

These ten variables are assessed and rated in a report card, grading scale relative to the degree of functional impairment or deviation from the reference standard. Details on the scoring guidelines can be found in the FACStream 1.0 (Beardsley et al., 2015). The primary purpose of using FACStream for this master plan is to rate the reaches relative to each other to inform on priorities for restoration, and to highlight some of the more impactful factors to the river health.

3 KEY FINDINGS

3.1 Hydrology

In 1988 the Colorado Division of Wildlife (CDW) (now Colorado Parks and Wildlife (CPW)), prepared a report titled Stream Fisheries Investigations (Nehring, 1988) which identified limiting life stages for both rainbow and brown trout and provided recommendations of optimum and critical flows for the Blue River within the Project Reach. The report notes that flows should not be allowed to fall "if at all possible" below the 'spawning' level at any time during the spawning, incubation and hatching periods for rainbow and brown trout. Should flows fall below those present during spawning, the eggs deposited in the gravel have the potential to 'dry up' causing mortality of the eggs. These critical time periods and flows on the Blue River occur from October 15 through June 1, with recommended minimum flows of 50 cfs and optimum flows of 100 cfs. Nehring's report also notes that these recommendations should not be construed as being safe on a long-term basis, defined as being a year or more, but rather as short-term recommendations that will adequately protect the trout population through the various critical life stages. The report also notes that these flows do not necessarily protect the total aquatic stream ecosystem, citing the need for flushing flows to maintain riffles.

In 1973, the General Assembly authorized the CWCB to appropriate water rights for instream flows and natural lake levels to preserve the natural environment to a reasonable degree. Since 1973, CWCB has appropriated instream flow water rights on nearly 1,700 stream segments covering more than 9,700 miles of stream, and natural lake level water rights on 480 natural lakes. Utilizing CDW studies and recommendations for instream flows to support the Blue River fishery, instream flows for the Blue River in Reach 2 were established as follows:

- 50 cfs Dillon Reservoir to Straight Creek (year-round)
- 50 to 55 cfs Straight Creek to Willow Creek (varies year-round)
- 75 cfs Willow Creek to Rock Creek (year-round)
- 90 to 115 cfs Rock Creek to Boulder Creek (varies year-round)
- No flushing flow recommendations on any segments

A detailed hydrologic analysis was prepared for flows at the 'Blue River at Dillon' gage immediately downstream of the Dillon Reservoir dam outlet (Tt & MEC, 2022). The analysis included a review of flood flows, average daily flows, daily average flows with a 10%, 50%, and 90% exceedance probability and flow duration curves. The annual flow duration curve shows that approximately 10 percent of each year (5 weeks a year) daily average flows exceed 500 cfs, and 50 percent of each year (26 weeks a year) daily average flows are between about 80 and 120 cfs. The months with the lowest daily average flows are December, January, and February, with flows between 80 and 100 cfs (**Figure 4**). The lowest daily average flows occur in January.

An exceedance analysis was also developed to assess annual peak flows from 1988 to 2021 at the outlet of Dillon Reservoir. While the dam has been in operation since 1963, a hydropower plant was added in 1987 which changed the operational criteria. Average daily flows recorded at the USGS's gaging station downstream of the Dillon Reservoir Dam (Gage No. 09050700) were reviewed to evaluate the influence of power plant operations. The flow records were compiled starting after the construction of the dam (1963) and after the completion of the power plant (1987). Daily average flows indicated the power plant operations increased releases from January through April and

decrease releases from mid-June through September (Figure 4). These differences constrained analyses of hydrology to water year 1988 and later based on the assumption that future releases will be best represented by historical releases reflecting current operation of the power plant. This analysis shows the 50% exceedance flow, which would typically represent bankfull flows in a natural channel, is between 700 and 800 cfs for this portion of the Blue River. Note that a HECRAS 1D analysis prepared for the Habitat Assessment (Tt & MEC 2022) indicates most of the surveyed cross sections have a bankfull capacity in excess of the current 50 percent exceedance discharge, on the order of 1,000 to 2,000 cfs. Denver Water operates Dillon Reservoir by striving to keep releases during spring runoff below 1,800 cfs to moderate flood impacts in the Town of Silverthorne.

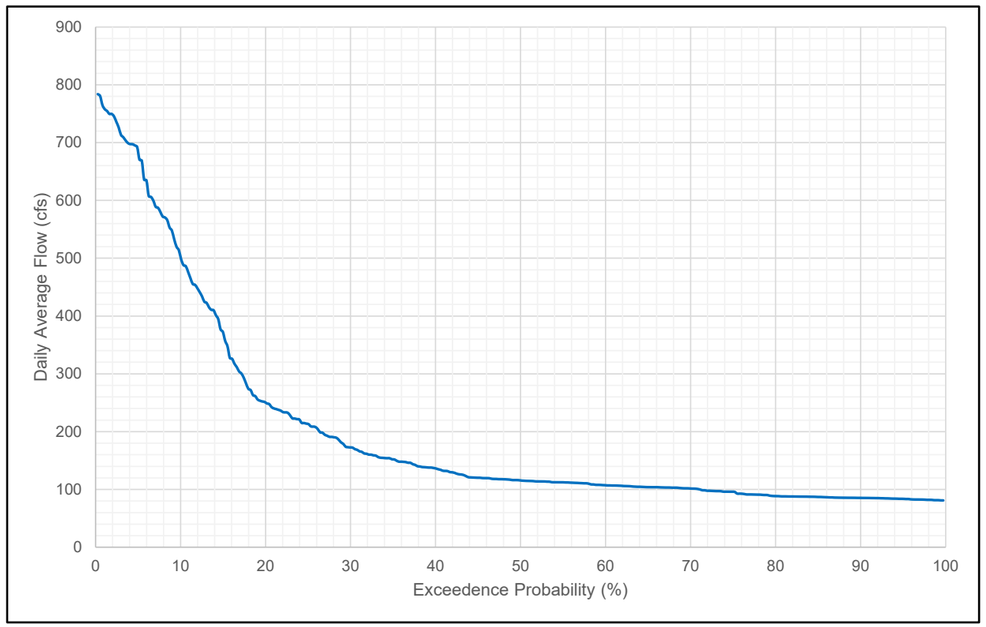

Figure 4. Blue River (USGS 09050700) annual flow duration for water years 1988 through 2021

A hydrologic analysis was also completed to compare flows in the Blue River released from the Dillon Reservoir dam outlet to flows entering Green Mountain Reservoir. This analysis used the USGS recorded flows released from the Dillon Reservoir dam outlet at gaging station 09050700 and the U.S. Bureau of Reclamation back-calculated inflows to Green Mountain Reservoir using reservoir stage changes. The preliminary analysis used data collected in 2021 which shows that the inflow to Green Mountain Reservoir is twice the release from the Dillon Reservoir dam outlet indicating that the tributaries between Green Mountain and Dillon Reservoirs contribute, on the average, flows equal to those released from Dillon.

In September 2022 flows were measured in Sites 4 through 8 and upstream of Green Mountain Reservoir at the Highway 9 bridge near the turnoff to Heeney. The releases out of Dillon Reservoir dam outlet were 56 cfs, as measured at the USGS gaging station 09050700 located downstream of the outlet, with Sites 4 through 8 measured at approximately 59 to 88 cfs. Measurements of flows upstream of Green Mountain Reservoir were 120 cfs, confirming the initial conclusion that low flows at Green Mountain Reservoir were typically double the releases from Dillon Reservoir due to contributions from the tributaries.

This habitat assessment also required an estimate of flows at Sites 4 through 8 for a range of flows relative to the flows being released out of the Dillon Reservoir dam outlet. This was accomplished by averaging the discharges per square mile below Dillon Reservoir for both the surveyed flows and 2-year flows calculated using StreamStats (USGS 2022) to develop a blended rate of flow increase below Dillon Reservoir. The 'rate of increase' was multiplied by the drainage area below Dillon Reservoir for each site and then added to the flows being released out of the reservoir to estimate the total flow at each site for the specified flow event.

This was done for each site assuming Dillon Reservoir dam outlet releases of 100 cfs to 1,000 cfs. 'Surveyed flows' at Sites 1-3 are all based on flows recorded at USGS gaging station 0905077 **(Table 1)**. Minimum appropriated instream flows are also provided in Table 1.

Table 1. Flows selected for habitat assessment, cfs

Dillon Releases (cfs)	Flows at sites (cfs)	Site 1-3	Site 4	Site 5	Site 6	Site 7	Site 8
Instream flows versus surveyed flows							
56*	Surveyed flow (Sept 26-30, 2022)	56	59**	73	74	76	88
50	Minimum appropriated Instream flow downstream of Dillon Reservoir in September	50	75	75	75	75	90
50	Flows utilized to calculate hydraulic parameters for habitat assessments	50	59	73	74	76	88
100	Average daily average flow during winter months (Nov. – Mar., inclusive)	100	107	107	109	111	113
200	Anecdotally fills channel in widest reaches upstream of Willow Creek confluence	200	213	215	218	221	227
400	Anecdotal maximum wadable flow and minimum float boating flow	400	426	429	436	442	453
500	10 percent exceedance based on average of daily average flows WY88-WY21	500	533	537	545	553	566
1,000	Optimum flow for kayaking (Sanderson, 2012)	1000	1066	1073	1089	1106	1133

* USGS recorded flow, gaging station 09050700 located downstream of Dillon Reservoir outlet.
**Surveyed flows at Site 4 lower than expected, likely due to unlined ponds immediately adjacent to the river.

3.2 Habitat Assessment

Habitat assessments were conducted at the eight sites along Subreaches 2.1 and 2.2. The first habitat assessment was initiated in 2021 and extended downstream from Dillon Reservoir for approximately 2.4 miles, covering Subreach 2.1.1, 2.1.2, and 2.1.3 as identified in the BRIWMP and shown **in** Figure 2. These Subreaches are above, or upstream of the existing tributaries to the Blue River except for Straight Creek, representing the most hydrologically stressed sections of the river between Dillon and Green Mountain Reservoirs, and the most stressed sections of the river from anthropogenic impacts including urban encroachments and surface water runoff pollutants (Tt & MEC, 2022).

The second habitat assessment was initiated in 2022 and extended downstream of Subreach 2.1 for approximately 7.6 miles, covering Subreach 2.2.1 to 2.2.6. Together, Subreaches 2.1 and 2.2 comprise just under 10 miles of the Blue River from the Dillon Reservoir dam outlet to the USFS Blue River Campground. Six flows were selected between 50 and 1,000 cubic feet per second (cfs) as shown in Table 1 to calculate hydraulic parameters. Each site was surveyed to calculate the habitat composition. Detailed results of the habitat assessments can be found in the two assessment reports appended under separate cover (TT & MEC 2022, TT et al. 2023) and summarized as follows:

- All eight sites were dominated by riffle and run/glide habitat types and channel substrate was comprised of cobble and boulders.
- Pool habitat was sparse. Sites 1 – 3 and Site 8 had 0% to 8.4% pool habitat, well below optimum of 50% riffle to pool ratio, and Sites 5 - 7 ranged from 30.2 % to 44 %, slightly less than optimal value.
- Of the possible cover types, 'no cover' made up at least 98% of Sites 1 through 3 and 79% to 98% at Sites 5 through 8.
- Average depths in riffle habitat at all eight sites were at or greater than the standards (0.6 feet to 1 feet minimum) for the fishery and should be suitable to support benthic invertebrate production as a food source for higher trophic levels.
- Average depths in glide or run habitats at all eight sites were at or greater than the standards applied in minimum flow studies (0.6 feet to 1 feet minimum) and should be suitable to provide foraging locations for fish.
- Pool habitat at seven of the eight sites were shallower than the standards applied with average depths less than or equal to the recommended 1.5-feet to provide adequate cover, resting, and refuge habitat when flows are 50 to 100 cfs.
- Hydrologic calculations indicate shallow pool habitat depths are present for extended time periods, estimated to be at least 50% of the year.

The lack of pool habitat is the most notable concern. Pools in Site 1, while located on the outside bend of the low flow meander channel, were shallow. Pools in Site 2 were located in the center of the river, downstream of constructed boulder weir drop structures, and pools in Site 3 were extremely limited and located mid-channel. Pools in Sites 4 through 8 were generally associated properly with outside bends in the low flow channel or associated with mid-channel structures such as boulders but limited in the overall makeup of the habitat. The limited number of pools and the shallow depths may be a key contributing factor to the impairment of the trout fishery through the assessed reach of the Blue River. The habitat assessments also noted that there are multiple drop structures in the first several miles of the Blue River below Dillon Reservoir likely impeding fish passage. In addition, there is a lack of spawning gravels due to the interception of sediments from Dillon Reservoir. There is a contribution of spawning gravels from the tributaries moving downstream of the reservoir, however, the presence of spawning gravels contributions was not observed until Site 6, midway between Dillon Reservoir and the Blue River Campground.

3.3 Additional Assessments

Morphological Overview: Geology

The USGS describes the geology of the Blue River watershed north of Dillon Reservoir as follows:

> *North from Dillon Reservoir, geology of the lower Blue River watershed along the Blue River consists of Quaternary-age glacial drift, landslides, gravels, and alluvium overlying Cretaceous-age sedimentary rocks of the Pierre Shale, the Colorado Group (Niobrara Formation and Benton Shale), and the Dakota Sandstone. Precambrian-age granite and gneiss are present along Straight Creek with the Quaternary deposits and small outcroppings of the Cretaceous sedimentary rocks. The Precambrian granite and gneiss form the Gore Range and the Williams Fork Mountains along the western and eastern boundaries of the watershed. North from Green Mountain Reservoir, there is a change from the igneous and metamorphic Precambrian rocks to Cretaceous-age sedimentary rocks (Bauch, N.J., Miller, L.D., and Yacob, Sharon, 2014).*
>
> *The valley once was filled by sediments and volcanic rocks that are now largely eroded. During the last few hundred-thousand years, at least two periods of glaciation sculpted the mountains bordering the valley and glaciers extended down the Blue River valley as far south as present Dillon Reservoir (Kellogg, K.S., Bryant, Bruce, and Shroba, R.R., 2016).*

According to the soil surveys (U.S. Department of Agriculture [USDA] 1980), soils today within the Blue River valley downstream of Dillon Reservoir consist of Handran gravely loam, on relatively flat slopes ranging from 0 to 3 percent. This is a deep, well-drained soil on level terraces. This material formed in alluvial deposit formations from a variety of rocks. Permeability is rapid and surface runoff is slow. Beyond the river valley corridor soils include the Frisco Peeler complex, which is well-drained, moderately slope soils on fans, mountain sides and ridges, formed from glacial drift. The floodplain consists of small, isolated areas Quander soil and Cumulic Cryaquolls soils which are poor draining materials underlain by sand and gravels and rock outcrops.

Morphological Overview: Channel planform

The Blue River is located in a wide and unconfined valley. Average channel gradients are 0.7 percent through Subreaches 2.1.1, 2.1.2, and 2.1.3, and 0.6 percent through Subreaches 2.2.1 through 2.2.6. Entrenchment ratio and width-to-depth ratios are moderate, and the dominant bed form is riffle-pool-run, although habitat assessments conducted in 2021 and 2022 indicate very little pool habitat is present, likely due to the prevailing low and shallow flow conditions. Channel substrate is primarily cobbles and boulders. Further review of the pre-dam 1954 aerial photography (**Figure 5**) compared to Google Earth images indicate the following:

> In 1954 Subreaches 2.1.1, 2.1.2, and most of 2.1.3 were single thread channels with well-defined banks and a low sinuosity. A narrow band of vegetation was present along the channel banks. Today the alignment of

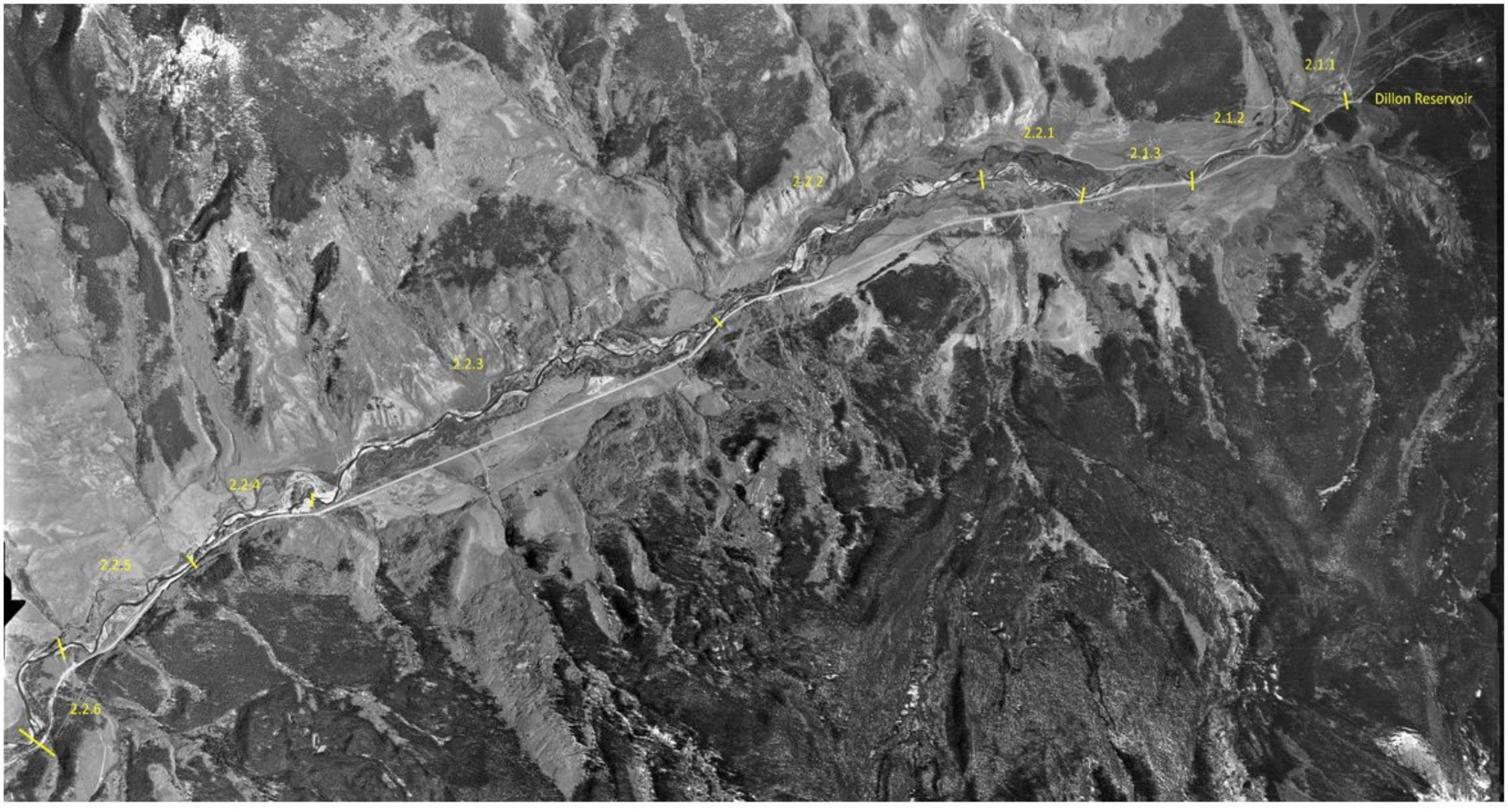

Figure 5. Blue River, Summit County Colorado, Dillon to Blue River Campground, 1954.

these Subreaches is almost identical to that seen on the 1954 aerial and vegetation density appears to be confined to the channel banks similar to the vegetation seen on the 1954 aerial.

Subreaches 2.2.1, 2.2.2, 2.2.3, and 2.2.4 are currently a single thread channel with some areas of bar/island braiding . Prior to the construction of Dillon Reservoir, the channel appears to have had more extensive areas of bar/island braiding. Low flow conditions, vegetation encroachment, and floodplain development have resulted in these reaches becoming predominantly a single thread channel.

Subreach 2.2.5 and 2.26 are single thread channels. The valley at these subreaches is narrowed compared to the subreaches 2.2.1-2.2.4 due to rock outcrops to the west and topography to the east. In addition, there is

evidence of a debris flow or possibly an avalanche from the west at both these sites. Deposits are evident and both sites today have a debris fan southwest of the river. The debris fans are primarily cobbles with few fines and organic matter and little to no ground cover. Vegetation encroachment has not been a significant factor along the mainstem in Subreaches 2.2.5 and 2.2.6.

Overall, the Blue River today is a single thread channel with areas of bar/island braiding. The overall slope is less than 1% and sinuosity is low. The general channel planform and alignment have changed little since the construction of the Dillon Reservoir dam, although vegetation and floodplain encroachment are clearly visible when comparing pre-dam conditions to today's imagery. Vegetation and floodplain encroachment have both likely contributed to the reduction of the bar/island braiding.

Bankfull discharge is defined as the dominant channel forming flow with a typical recurrence interval ranging from 1 to 2 years. Bankfull discharge is also correlated to the maximum discharge the channel can convey without overtopping onto the floodplain. It is considered to be the most effective flow for moving sediment, forming, or removing bars, forming, or changing bends and meanders, and generally "doing work that results in the average morphological characteristics of channels" (Dunne and Leopold, 1978). Based on the hydrologic analysis for the Blue River the 2-year flow (50 percent annual exceedance) is between 700 and 800 cfs for water years 1988 to 2021 (34 years), assessed at the USGS gaging station 09050700 located downstream of Dillon Reservoir outlet.

The HECRAS 1D analysis indicate most of the surveyed cross sections have a bankfull capacity in excess of the current 50 percent exceedance discharge, on the order of 1,000 to 2,000 cfs. Denver Water operates Dillon Reservoir by striving to keep releases during spring runoff below 1,800 cfs to moderate flood impacts in the Town of Silverthorne. This indicates that the channel has not experienced overtopping to the same extent as prior to the construction of Dillon Reservoir, which is evident when comparing vegetation encroachment visible in today's aerial imagery.

Floodplain development has impacted channel plan form including gravel pit mining and urban encroachment. Urban encroachment has occurred primarily in the Town of Silverthorne. Most development lines the channel banks that were present in 1954 with impacts to the overbank vegetation but little alteration to the channel alignment. Gravel pit mining occurred sometime between 1954 and present day. Several of the gravel pit ponds are within Subreaches 2.2.1 and 2.2.2 in the Town of Silverthorne and appear to be hydraulically connected to the river, either by overland flooding or via groundwater and as a result support riparian and wetland vegetation between the two features. The development of these gravel pits also appears to have included the diversion of the mainstem into a side meander channel. These side channels are typically narrower than the historical mainstem and can be seen in the downstream portion of Subreach 2.1.3, all of Subreaches 2.2.1, 2.2.2 and 2.2.3 and the upstream portion of Subreach 2.2.4 (Figure 2). It is possible these diversions into the narrow side channels have benefited the aquatic habitat as the narrow channels are more suitable to today's flow regime. Site 4 in Subreach 2.2.2 in particular has some of the best habitat surveyed in the assessments. Detailed aerial mapping of these Subreaches is provided in Appendix A.

FACStream

A stream health assessment was conducted for the purpose of rating functional ecological conditions in the project reach using the level of departure from a reference reach. For purposes of this restoration master plan, FACStream is used to combine the morphological overview, the habitat assessment, hydrologic and hydraulic analyses, and field observations in a comparable format to inform on the prioritization of restorations by reach. The Blue River project reach was originally assessed using a Level "1 to 2" protocol utilizing observable factors and to the extent practical, existing available reports and data. Following the habitat assessment and field reconnaissance conducted in 2022, the assessment was updated, incorporating the data, surveys, and additional observable factors gathered during the field reconnaissance (Tt, 2022 and Tt, 2023).

Ten stream health Variables were assessesed generally following the guidance outlined in FACStream (Beardsley et al. 2015)**.** These ten variables are rated using a report card grading scale relative to the degree of functional impairment or deviation from the reference standard. The scores for these variables are combined as a weighted average to give an overall reach condition score referred to as the functional capacity index (FCI). The results by variable are described below and detailed ratings are provided in **Appendix B**. The FACStream ratings, combined with key factors from the habitat assessment are depicted in **Figure 7** to inform on conditions in each subreach.

Flow Regime

The Blue River is a snowmelt-driven system, with peak flows typically occurring in late spring and early summer and often lasting for multiple days or weeks. Alterations to natural patterns of flow variability, including the magnitude of peak flows, fluctuations, and rates of change, are particularly important to fish, insects, and other biota that have life history strategies tied to predictable flow rates at specific times of the season (Beardsley et al. 2015). The flow regime in the Blue River downstream of Dillon Reservoir is impacted by reservoir operations and transbasin diversions affecting both peak flows, base flows, and timing of releases. Current estimates indicate annual flow depletions from all transbasin diversions in the watershed above the Project Reach total approximately 30% of the average annual water yield (Tt, 2021). While flow alterations are not a component in this restoration master plan, it is being considered as part of the FACStream analysis as it informs on prioritizing those reaches with the most overall habitat impairment.

Sediment

Dillon Reservoir alters the natural sediment regime, blocking the transport of fine material, small gravels, and cobbles into the Project Reach. There are contributions of sediment from the tributaries moving downstream of the reservoir, however, visible evidence of sediments and gravels were not observed until Site 6, midway between Dillon Reservoir and the Blue River Campground.

Water Quality

Water temperature is perhaps the single most important environmental parameter for fish (Magnussen et al. 1979 as cited by KA 2021). Ambient water temperature drives fish survival, (Brinkman et al. 2013 as cited by KA 2021), behavior (Cook and Bergersen 1988, Rogers 1998 as cited by KA 2021), and growth (Selong et al. 2001, Bear et al. 2007, Brinkman et al. 2013 as cited by KA 2021) and also is known to define the range a fish can occupy (Dunham et al. 2003, de la Hoz Franco and Budy 2005 as cited by KA 2021).

The Colorado Department of Public Health and Environment (CDPHE) lists Blue River as Aquatic Life Cold 1 – Cold Water Aquatic Life with maximum temperature limits set to protect the aquatic community from the harmful effects of high-water temperatures. However, minimum temperature standards or metrics are not set by the CDPHE. For purposes of this assessment and as noted in the BRIWMP (Tt, 2021), low water temperature standards defer to narrative standards developed by the USFWS for different life stages of brown trout (Raleigh et al. 1986, Elliot and Hurley 1999, Elliot, and Elliot 2010).

Water temperature monitoring conducted in 2020 and 2021 indicate temperatures downstream of Dillon Reservoir are frequently below these optimal ranges. Only the portion of Blue River below Boulder Creek, 11 miles downstream of Dillon Reservoir, recorded water temperatures during the summer in the optimal temperature ranges for adult brown trout growth. The water temperatures recorded below Boulder Creek were similar to those recorded above Dillon Reservoir, indicating these cold temperatures are moderated by tributaries and natural warming over an 11-mile distance. Winter temperatures show a reverse temperature trend with warmer temperatures being released from Dillon Reservoir compared to the downstream reaches (Tt, 2021). While temperature remediation is not a component in this restoration master plan, it is being considered as part of the FACStream analysis and informs on prioritizing those reaches with the most overall habitat impairment.

The water quality analysis prepared for the BRIWMP (Tt, 2021) indicates that within the Project Reach standards for arsenic, dissolved oxygen, and silver have been exceeded, typically in the fall and winter seasons. Straight Creek, tributary to the Project Reach, is provisionally listed for Macroinvertebrates. Winter road operations (sanding and deicing) have impacted the water quality directly of both the Blue River and Straight Creek.

The Town of Silverthorne Drainage Master Plan (Plan) was updated in 2020 '*to assess the function of the stormwater infrastructure throughout the Town of Silverthorne (Town) and identify potential multi-objective improvement projects and recommendations*. Seventeen (17) site-specific improvement projects were identified to address deficiencies and provide multiple benefits, including those which improve the quality of stormwater at discharge points along the Project Reach to reduce sediment loading and the influx of deicers.

Floodplain Connectivity

Overbank flooding is significantly reduced due to controlled releases out of Dillon Reservoir. While this dam is not a flood control facility, it is sometimes used, when possible, to maintain flows at or below 1,800 cfs (slightly greater than bankfull capacity) to minimize flood impacts through the urban corridor in the Town of Silverthorne. Impacts from the reduction in overbank flooding is evident by the change in riparian vegetation density, which has increased over the past 60 years (**Figure 6**).

Figure 6. 1954 aerial photo (left) and 2020 aerial photo (right) showing increases in vegetation density on channel banks and bars.

Riparian Vegetation

Within Reach 2 and outside of the urbanized areas the riparian vegetation has become heavier along the channel corridor due to the reduction of overbank flows. Overbank flow in the unaltered system, scoured and mobilized the material in the overbanks thereby maintaining a less dense riparian corridor. Today the vegetation encroachment has stabilized the once barren mobile gravel bars and side channels. In other locations, the riparian vegetation has been impacted by urbanization and gravel pit mining.

Debris

Similar to sediment, Dillon Reservoir alters the passage of debris from the upper watershed. Debris consists of the bodies and fragments of dead organisms, plants, and wood all providing a nutrient source. Large wood also provides a structural component to the aquatic habitat. There are contributions of debris from the

tributaries moving downstream of the reservoir, however, visible evidence of large debris was not observed within the Project Reach.

Stream Morphology

Stream morphology rates the degree of departure from the reference condition, which includes planform, channel dimensions, and longitudinal profile. Based on guidance outlined in FACStream, and a broad understanding and familiarity with the watershed, an overall reference standard could be described as a single thread and partially braided channel with wide floodplains, unconfined or partially confined valleys, pool-riffle bed formation consisting primarily of cobble and gravels, and a moderate to dense riparian vegetated corridor. Ratings within Reach 2 range from mild to significant. The reference reach would have no local water use, transbasin diversions or water impoundments, which in of itself influences the rating of the entire Project Reach. This variable also considers anthropogenic impacts which tend to be more significant in the upper reaches closer to Dillon Reservoir. However, overall, the channel alignment and remnant braiding remain relatively intact due to the stable nature of the channel.

Stability

For the Blue River mainstem, all reaches rated as having a ”mild” departure for stability from the reference reach, indicating that despite the changes that have occurred in the recent past, the mainstem has retained its planform. Based on field observations of the Project Reach there are few visible signs of localized erosion, little systemic degradation (headcutting) or aggradation, and the channel, overall, is relatively stable. This supports the mild departure and indicates an increase in stability. While this increase may be considered a benefit, particularly in an urban setting, it can also be a detriment when considering the possible reduction in recruitment in wood, debris, and gravels. In the absence of sediment delivery from the upper basin due to the reservoir, and in the absence of high flows due to the reservoir operations, the hydraulic conditions required for sediment transport, deposition and/or scour or degradation are infrequent or absent.

Physical Structure

Physical Structure rates the degree to which characteristic patterns of structural heterogeneity are altered as depicted by the processes of erosion, scour, and deposition that shape the form of bed, banks, and substrate. Ratings for this parameter closely follow stream morphology and stability.

Biotic Structure

Sampling and analysis conducted in 2021 and 2022 show benthic macroinvertebrate communities were “impaired” immediately downstream from Dillon Reservoir in the spring and fall, while further downstream benthic macroinvertebrate communities were “impaired” during the summer. Improvements in benthic macroinvertebrate were consistently observed moving from upstream (near Dillon Reservoir) to downstream (near Green Mountain Reservoir) of the study area. Alterations from the natural flow and temperature regime imposed by reservoir operations were likely responsible for a decline in the richness and abundance of sensitive and specialized taxa (Timberline, 2021). The lack of periphyton, or benthic algae, may also be limiting invertebrate populations and, subsequently, the fishery. Longitudinal declines in periphyton abundance were seen for the first 1 ½ miles below Dillon Reservoir. Further downstream periphyton abundance sampling indicates some recovery (Tt, 2021).

The results of the FACStream analysis indicate that Subreaches 2.1.1, 2.1.2, and 2.1.3 are significantly impaired due to low ratings for watershed, riparian, and stream variables. Subreach 2.1.2 is the most impaired of all reaches due to the added impacts from the constructed drop structures and urbanization. Subreaches 2.2.1 to 2.2.6 are all in the mild/significant impairment range with improvements primarily in the flow regime categories, due to flow contributions from the tributaries. This increase in flows also can be seen in several of the other categories including the riparian, sediment, and water quality and temperature categories. Subreaches 2.2.5 and 2.2.6 show signs of some impairment as a result of historical debris flow impacts that have altered the channel and/or impacted the quality of the overbanks in the floodplain.

Blue River		Variable	2.2.6 Site 8	2.2.5 Site 7	2.2.4 Site 7	2.2.3 Site 6/5	2.2.2 Site 4	2.2.1 Site 3	2.1.3 Site 3/2	2.1.2 Site 2	2.1.1 Site 1
Watershed	V_{hyd}	Flow	B-	B-	B-	B-	C	C-	D	D	D
	V_{sed}	Sediment	B-	B-	B-	C+	C	C	C	C	C
	V_{chem}	Water Quality	B	B	B-	C+	C	C	C-	C-	C-
Riparian	V_{con}	Floodplain	B-	B	B-	B	B+	B+	B-	C-	C-
	V_{veg}	Riparian Veg	C	C	B	B	B+	B	C+	C	C
	V_{deb}	Debris	B	B	B	B	B	B	B-	C-	C-
Stream	V_{morph}	Stream Morph	C+	B-	B	B	B	B	C+	B	B
	V_{stab}	Stability	B+	B+	B+	B+	B+	B+	B	B	B
	V_{str}	Physical Struc	C+	C+	B	B	B	C-	C-	C-	B
	V_{bio}	Biotic Struc	B+	B	C+	C+	C+	C	D	D	D
Overall FCI			.64	.66	.66	.66	.64	.58	.48	.44	.48
Reach Condition Score			B-	B	B	B	B-	C+	C	C-	C
Degree of Impairment			Mild/ Sign	Mild	Mild	Mild	Mild/ Sign	Mild/ Sign	Significant	Significant	Significant
Hydraulic Parameters											
Surveyed flows, cfs			88	76	74	73	59	50	50	50	50
Width, ft			76	42-58	42-58	42-58 /55-73	32-50	58-64	54-92/58-64	54-92	34-41
% Pool			14%	36%	36%	44%/30%	47%	0%	0%/8%	8%	7%
Aver pool depth, ft			1.5	1.6	1.6	1.4 / 1.6	1.6	1.0	1.0/ 0.8	0.8	1.2
Max pool depth, ft			2.1	2.4	2.4	2.4/2.2	3.1	1.3	1.3/1.8	1.8	2.1

Figure 7. FACStream and Habitat Assessment Summary

Summary 0f Findings

The habitat assessment focused on evaluating hydraulic conditions in each of the three habitat types. In riffles, the assessment showed all three sites provide sufficient wetted perimeter even at 50 cfs, and average riffle depths were at or greater than the standards applied in minimum flow studies. These results indicate riffle habitat should be suitable to support benthic invertebrate production as a food source for higher trophic levels. Run/glide habitats across all three sites provide hydraulic conditions at low flows that are likely sufficient to provide foraging locations for fish. Pool habitat, where present, exhibited shallower average depths than the recommended 1.5-feet to provide adequate cover, resting, and refuge habitat. The limited number of pools and shallow depth present in the pools may be contributing to the impairment of the trout fishery through the assessed reach of the Blue River.

The morphologic assessment provides additional insight to the substandard habitat conditions, particularly related to the lack of pools and shallow pool depths. While riffle and glide depths and widths meet the minimum standards they are consistently at the very low end of the standard spectrum, again supporting the substandard conditions under the prolong low flows. Based on this understanding of the relationships between the Blue River hydrology, the morphology of the Blue River channel, and hydraulic indicators of aquatic habitat quality, recommendations are offered to improve aquatic habitat to better fit the prevailing flow conditions, specifically narrowing the river through all three types of habitats.

The FACStream rating system indicates the reaches with the highest need for restoration occur immediately downstream of Dillon Reservoir outlet to the Blue River Trail bridge crossing at 13th Street. Ratings begin to improve in the downstream reaches primarily due to the influx of flows, sediments, and nutrients from the tributaries, coupled with stream temperatures moderating due to the air temperatures and tributary inflow, warming during the summer in the downstream direction. Further, the middle reaches are typically the narrowest reaches primarily due to historical gravel pit operations which consolidated the historically braided channel into a narrower single side channel which are more suitable to support aquatic habitat with today's lower flow regime. A good example of this is Site 4 which is the narrowest of the reaches and has some of the deepest and highest percentage of pools There are also two small sections in the middle reaches where the river and floodplain are narrow due to a rock outcrop to the west and hilly terrain to the east. Here again the narrower channel is also deeper and more suitable to support aquatic habitat. The middle reaches are also slowly reestablishing its planform to the altered flow regime because of vegetation encroachment which has cutoff off remnant channel splits and created a single thread channel. Other areas, particularly sites 2.1.1, 2.1.2, 2.1.3, 2.2.5 and 2.2.6 however, would benefit from restoration to improve the aquatic habitat, particularly areas impacted by anthropogenic activity and those areas with little ability to morphologically respond to the change in flow regimes.

4 RESTORATION RECOMMENDATIONS

4.1 Conceptual Design Strategies

Water Quality Improvements

The Town of Silverthorne Drainage Master Plan (Plan) plans to implement seventeen (17) site-specific improvement projects to improve the quality of stormwater at discharge points along the Project Reach, particularly in Subreach 2.1. This planning effort undertaken by the Town of Silverthorne provides an opportunity to coordinate and incorporate these improvements with river restoration efforts. Details of the improvements are available in the Town's Drainage Master Plan.

Narrow and Define Low-flow Channel (Point Bars and Pools)

Pool habitat provides resting areas and refuge for fish and is particularly important when flows are low. The habitat assessments note that the average depths in pools at Sites 1 – 3 are less than 1.5 feet until flows reach or exceed 160 to 250 cfs and only slightly deeper for Sites 5-8. A time series analysis for pool depths, represented by the 50-percent-exceedance daily average flow between water years 1988 and 2021 (Tetra Tech, 2022), indicates the average depth for most sites remains at or below 1.5 feet at 50 cfs all year except during spring runoff from early May 1 through mid-July, or approximately 2 ½ months. Narrowing the wetted perimeters and/or overall channel width will provide deeper pools and channel depths, and for a given flow and are associated with improved habitat. Physical modifications within the low flow channel to narrow the wetted area would also improve channel morphology for conveying water and sediment under the current hydrologic regime. Thus, a key strategy of this Master Plan is to narrow and define the low-flow channel.

In addition, pools should be created, and existing pools deepened and enlarged. While the 1.5-foot depths are considered to be a minimum value, the optimum values are not as well established. Antidotal information provided from improvements elsewhere on the Blue River indicates depths of up to four feet have been successful. Pool depths are best maintained by the natural scouring action of the river which can be achieved if constructed in conjunction with point bars and/or include the addition of wood (root wads) to create localized erosion in the pool itself.

The annual flow duration curve (Tt & MEC, 2021) shows that approximately 10 percent of each year (about 5 weeks) daily average flows exceed 500 cfs; 50 percent of each year daily average flows exceed 120 cfs, and daily average flows are between about 80 and 120 cfs for 50 percent of each year. Based on the habitat assessments the low flow channel should optimize conditions for flows between about 80 and 120 cfs for 50 percent of each year, which could typically be achieved with a channel approximately 35 to 50 feet wide as present in Sites 1 and 4, with average depths of approximately 1.5 feet and pool depths of 2 to 4 feet. Further analysis of the low flow, bankfull channels, and flood conditions will be required for preliminary and final designs to provide site-specific design parameters for sizing and stability of the restoration features as well as assessment of the 100-year flood.

Immediately downstream of 6th Street, near station 435+50 adjacent to the Town of Silverthorne library is an existing cobble bar and riffle displaying point bar, pool and riffle features sized appropriately for current flow conditions. A photo of this section is shown on **Figure 8** and is characterized by the details presented in **Figure 9**

and **Figure 10**. Figure 9 shows a typical plan view channel alignment with a point bar, pool and thalweg alignment and Figure 10 shows a typical cross section. The point bar is located on the inside of bends and will act to increase low-flow channel sinuosity, increase low flow depth, and reduce the low-flow channel width. Point bars should be constructed with a gentle cross slope of approximately 10 percent and be made up of native bed material. Typically, point bars will be inundated during flood conditions and exposed during low flows.

Figure 8. Photo of Point Bar, Pool, and Riffle downstream of 6th Street.

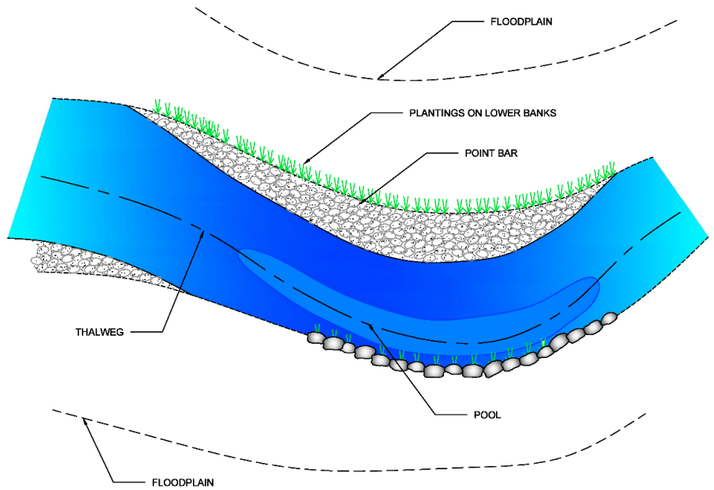

Figure 9. Point Bars and Pools, Plan View

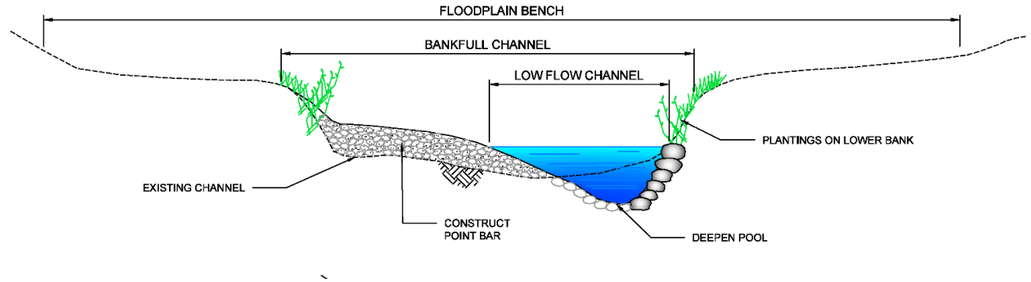

Figure 10. Point Bars and Pools, Section View

Constructed Riffle

Based on field observations of the Project Reach there are no visible signs of systemic degradation or aggradation, indicating the channel, overall, may be relatively stable. In the absence of a sediment source due to the reservoir, and in the absence of high flows due to the reservoir operations, it is possible the hydraulic conditions required for sediment transport, scour or degradation are infrequent or absent. In the case of the Blue River below Dillon Reservoir the existing drop structures are not providing grade control and could be removed, as they are impeding upstream passage of the fishery and located in overly wide sections of the river. Removal of the drop structures will facilitate opportunities to narrow the low flow channel. The use of constructed riffles should be considered as shown on the Master Plan to minimize channel bed regrading from the removal of the drop structures and provide additional riffle habitat. The constructed riffles would be designed to mimic a natural riffle and placed in the proper sequence of a riffle pool configuration. Riffles constructed in similar settings in the Upper Colorado River Basin have proven to have the added benefit of improving habitat for benthic macro invertebrates. See **Figure 11** and **Figure 12**. The cobble gravel substrate should include small boulders and possibly a few scattered boulders.

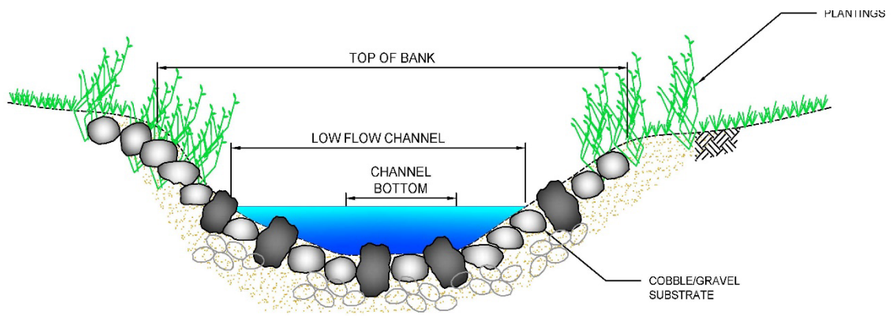

Figure 11. Typical Channel Section Through Riffle

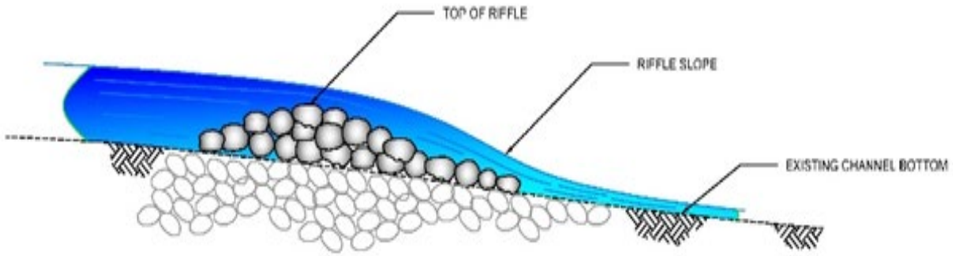

Figure 12. Riffle Profile

Bank Protection and Restoration

Bank protection is recommended in several areas that have been eroded from high flows and/or degraded due to pedestrian use and poor ground cover. Several techniques are provided for bank stabilization and restoration including 'Boulder Bank Protection' for those areas where bank failure would result in loss or damage to buildings, infrastructure, and homes located near the channel banks. Alternatively, a range of bio-engineered techniques could be utilized in areas of lower risk to minimize the loss of vegetation and improve stream side cover.

A riprap bank detail is shown in **Figure 13** and **Figure 14** and includes an option to construct spurs or deflectors to push flow away from the channel banks along the outside of channel bends and/or in areas of higher velocities. Spurs or deflectors could be a single large rock as shown in **Figure 10**, or multiple rocks typically seen in rock vanes or spur dikes and possibly combined with wood.

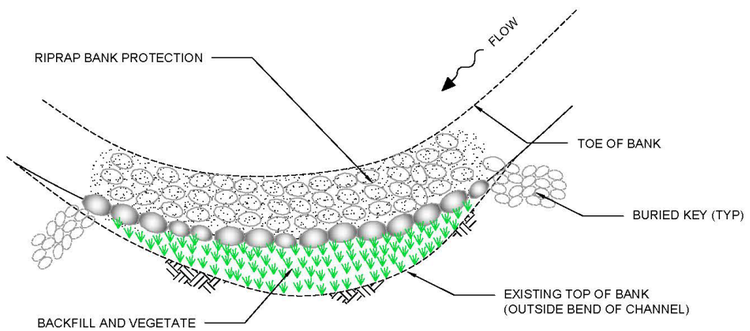

Figure 13. Boulder Bank Protection, Plan View

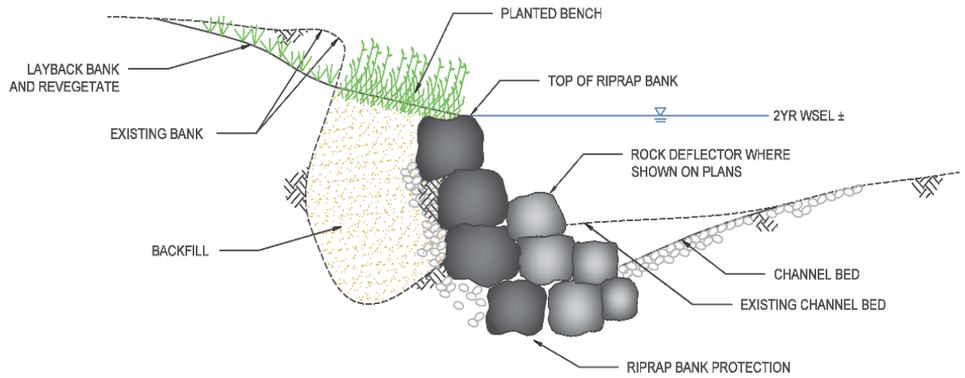

Figure 14. Boulder Bank Protection, Typical Section

Bank Revegetation, Wood, and In-channel Habitat

Figures 15-18 show examples of bio-engineering techniques. **Figure 15** is encapsulated soil lifts with live willow plugs and scour toe protection. The coir fabric is a biodegradable material that requires about 3 to 5 years to degrade. The purpose of coir fabric lifts is to stabilize the newly constructed channel banks for a sufficient period of time to allow for the establishment of the vegetation, primarily willows, which will in turn provide stabilization with their roots and take over the role of bank stabilization. As the coir fabric degrades, the banks will lose some of the soil immediately under the willow layers, which in turn simulates an undercut bank (hence the term deformable). The deformable bank could possibly be integrated with rootwads. **Figure 16** shows a before and after photo of a constructed deformable bank.

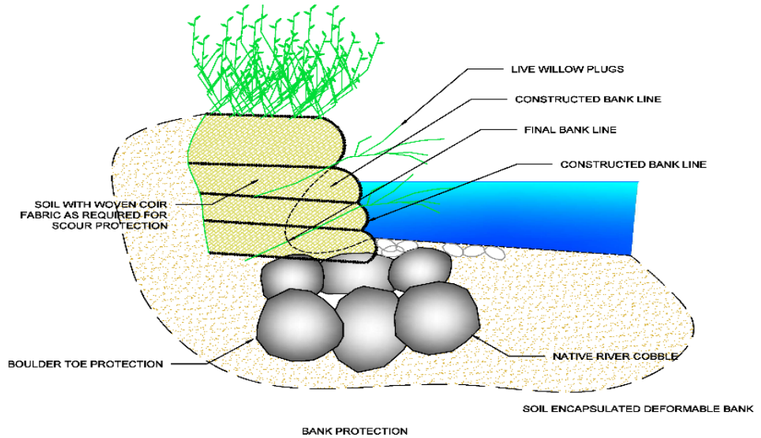

Figure 15. Deformable Bank Protection, Typical Section

Figure 16. Before (aerial on left) and after picture (on right) of deformable bank construction along the Blue River upstream of Dillon Reservoir in Summit County Colorado

Bank Revegetation, Wood, and In-channel Habitat, cont.

Figure 17 shows a typical Boulder cluster layout to help diversify in-channel habitat. Boulder clusters are rocks placed in the stream individually or in groups to add structure and habitat diversity while providing cover for aquatic habitat and protection to eroding banks if strategically placed. Large wood debris such as a rootwad bank (**Figure 18)** is another technique for adding channel diversity and providing bank protection. The roots act as a deflector while creating localized scour around the branches adding to cover habitat and maintaining pool depths. All three techniques could be utilized as a stand-alone restoration measure or grouped together.

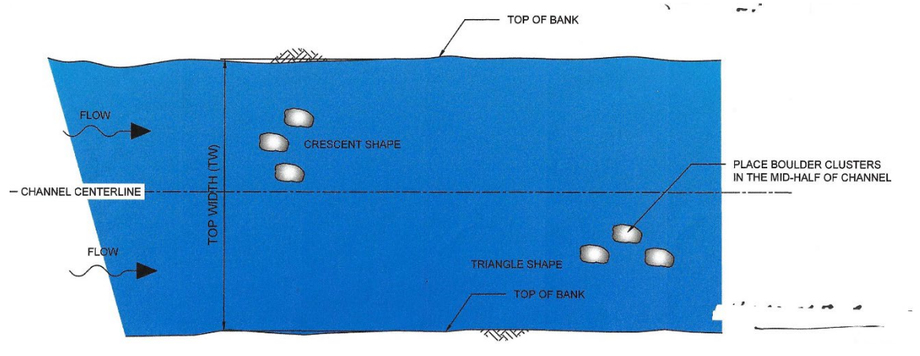

Figure 17. Boulder Clusters

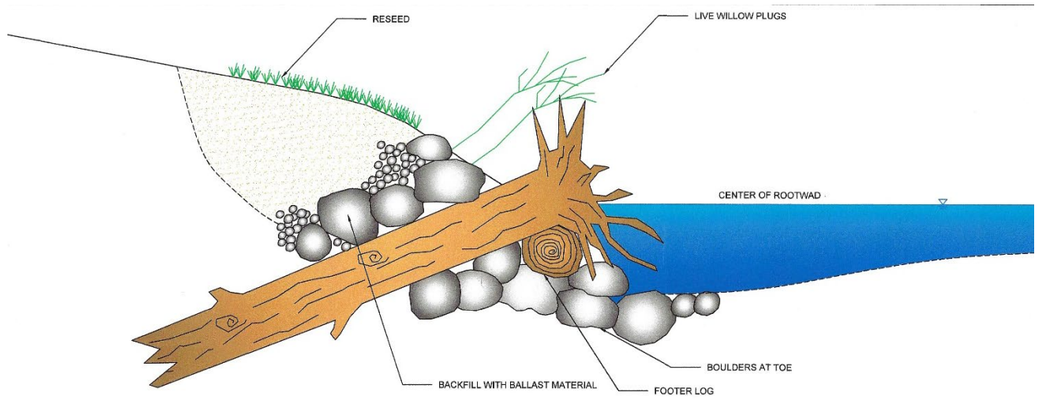

Figure 18. Large Wood Debris .

Trail Construction with Designated Access

Several sections of the Blue River have experienced high use and sustained foot traffic which has resulted in damage to the existing vegetation along the channel banks. The loss in vegetation has resulted in erosion. In these locations constructed trails are recommended. The Town of Silverthorne has already constructed several trails to consolidate foot traffic and stabilize the banks with rock steps as shown in **Figure 19**. A constructed trail could also consist of wood and gravel steps and a simple gravel path, delineated by vegetation on the sides, wood edging and/or markers to define the trail access locations and encourage the use of the trail (**Figure 20**).

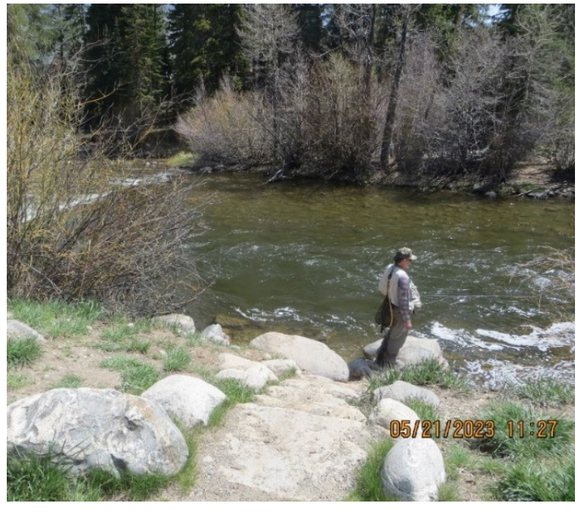

Figure 2. Rock Lined Trail for river Access

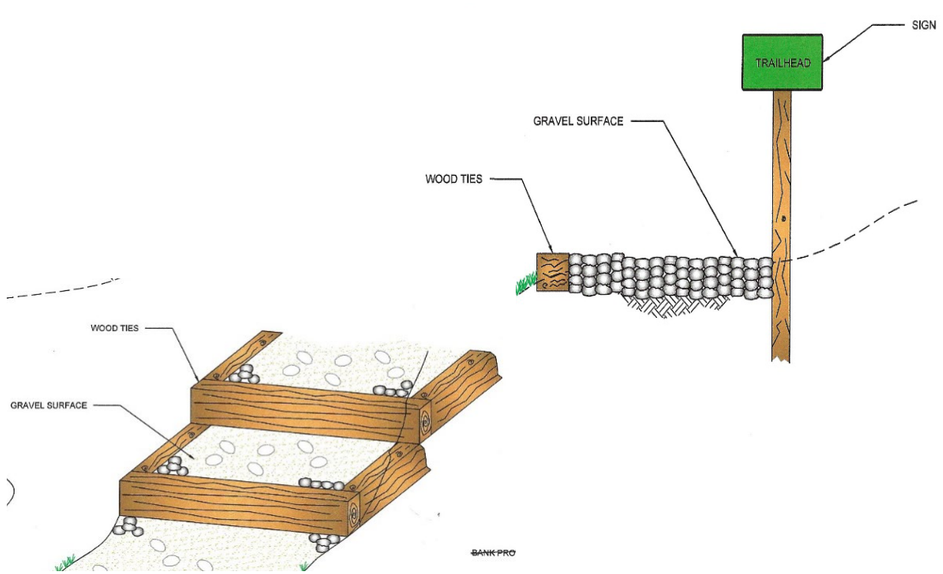

Figure 20. Trail Stabilization and Access Details

Spawning Gravel Replacement

The stream substrate in Reach 2.1 and 2.2 is comprised primarily of cobbles ranging in size from 2.5 to 10 inches. Clean, fine-sediment-free-gravel ranging in size from 0.5 to 1.0 inch is needed for successful trout spawning. The lack of this size gravel reduces the potential trout spawning habitat. The habitat assessments and onsite observations indicate little gravel sized material is present in the main stem of the Blue River until downstream of Boulder Creek, over 10-miles downstream of the Dillon Reservoir outlet. Although not specifically called out for in the restoration recommendations by sections or subreach, the placement of spawning gravels should be considered. Such gravel, if placed within the channel, would require careful analysis and placement because the regulated flow regime and potential for flooding impacts may preclude or minimize hydraulic mobilization and distribution of launchable gravel piles, requiring manual placement. Gravel placement would likely require some structure to help sort and retain gravels such as large woody debris and roughened riffles.

Kayak Park

The Town of Silverthorne is currently planning to build a whitewater park near the Wilderness Road Bridge. The course will consist of three control structures, spaced 100 to 150 feet apart and will create recreational experiences consisting of watercraft passage under low flows and whitewater kayaking at higher flow. The Town has obtained a conditional Recreational In-Channel Diversion water right of 100 cfs flow for May-September with the ability to call for up to 600 cfs during major holiday weekends to provide for enhanced recreational experiences (Brown and Figure 3. Trail Stabilization downstream water users. While there is currently little detail available regarding the three control structures, it is possible they will create fish barriers similar to the existing drop structures in this reach.

Several alternatives that could be considered include a ‘slalom-style’ kayak course near Wilderness Road or a standing wave structure at upstream of Wilderness Road closer to the Dillon Reservoir outlet structure as described below.

Slalom Course: A kayak course or kayak slalom course (**Figure 21**) should be 150-400m (500’ – 1300’) in length to comply with current course standards (ACA, 2023). Partial channel spanning structures such as rock vanes/barbs/groins should be used every 40-50’ and alternate across the channel to create local accelerations and defined eddies. Full channel spanning structures should be used cautiously as to not create a barrier for either fish or ability to paddle upstream. Pools should have a minimum depth not less than 2-3’. Any riffles or higher velocity control sections should have a minimum depth not less than 6-8”. Overall, the course should be designed to function at lower flow rates ~100cfs and not create fish barriers.

Standing Wave: A properly designed standing wave structure (**Figure 22**) should be based on appropriate hydraulic design tools, specifically a 3-D hydraulic or physical model, to ensure that the structure will perform as intended at the design flow rate. To achieve a properly functioning standing wave, key hydraulic conditions within the wave need to be paired with downstream tailwater conditions. The current recreational instream channel diversion (RICD) defines 3 separate four-day weekends of water released at 600cfs for the hours of 7am to 8pm. Ideally, to increase attraction and use of this feature, reducing the magnitude of the flow releases in order to increase the duration or frequency of the releases should be considered. However, the minimum design flow rate should not be less than 150-200cfs. The standing wave feature could be constructed immediately downstream of the dam in order to prevent any impacts to fish passage or habitat needs. The structure would typically consist of grouted boulders above the water line with the use of concrete for submerged areas of the hydraulic structure to improve performance and decrease need for post-construction modifications (i.e., tuning of the structure performance). The structure should be designed so larger flows are dispersed from drop structure and constructed with concrete to reduce uncertainty and increase performance. Consider the use of concrete versus grouted boulders to balance performance vs aesthetics.

Figure 21. Example of Slalom Course

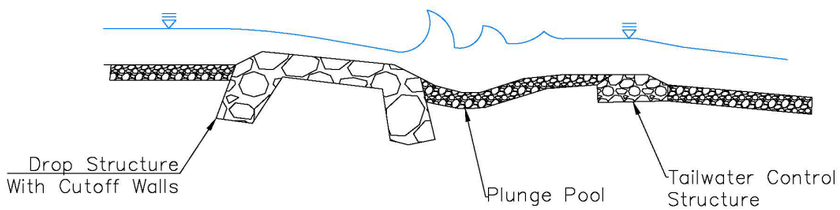

Figure 22. Example of Standing Wave

5 SITE DESCRIPTIONS AND RESTORATION RECOMMENDATIONS

Restoration plans for the Project Reach is presented in Appendix A on 16 sheets divided up in equal distance between the Dillon Reservoir outlet and the USFS Blue River Campground. Each sheet includes a plan view with existing site features, river stationing starting with 0+00 at the UFSF Blue River Campground, and proposed restoration recommendations. Each sheet also includes a write up with photos, site descriptions, a summary of analyses and key considerations and restoration recommendations.

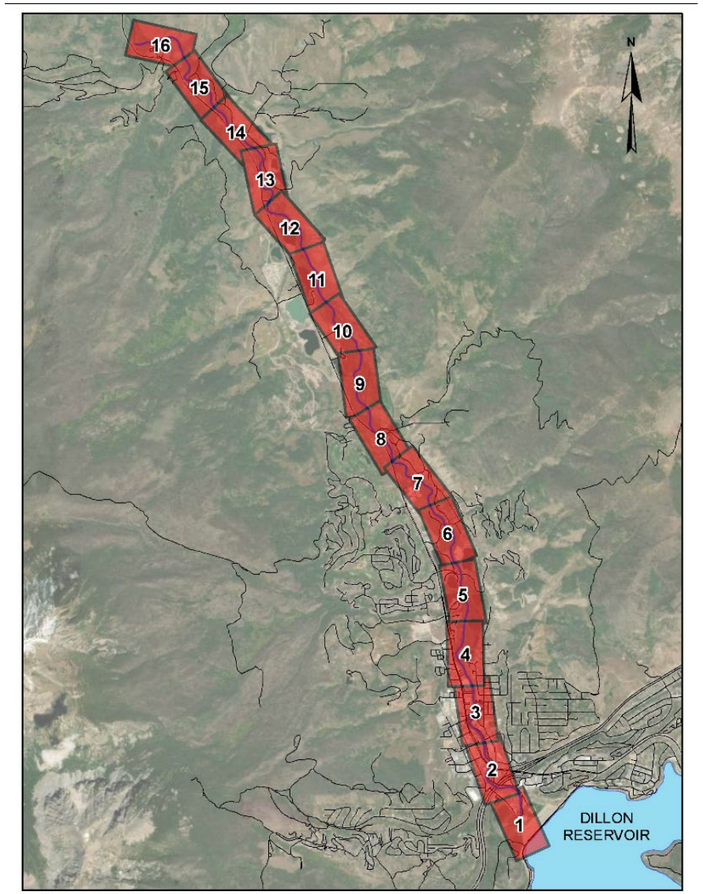

Figure 23. Cover Sheet Appendix A.

6 IMPLEMENTATION

6.1 Implementation

Many of the recommended improvements could be constructed as stand-alone projects. This is particularly true of smaller, isolated, and non-contiguous improvements. Other improvements would be better if implemented together most specifically the recommendations in Reach 2.2 in the Town of Silverthorne. Overall, implementation of the recommended improvements would be the most effective constructed as recommended and depicted on the plans in order to provide continuous and connected habitat. Improvements are shown primarily on land owned/managed by Town of Silverthorne and USFS managed lands, all within either Summit County or the Town of Silverthorne's jurisdiction. There are also improvements shown or recommended on CDOT and CPW managed lands, and some privately owned properties. All landowners, including the public agencies, the Town of Silverthorne and Summit County must be actively engaged with the implementation of this master plan, which will be one of the first steps to undertake in the next phase of work. Note that this master plan does not bind any entity or landowner to these recommendations should they choose not to participate, or alternatively, should they have additional improvements they would like to implement.

For purposes of this report, it is assumed that final design and construction would be overseen by the BRWG, possibly in partnership with a municipality, who together will reach out and form a working group comprised of all interested parties.

Further consideration is required to assess the details of implementation including the cost related to easements and agreements for construction and maintenance, which are unknown at this time and not included herein.

6.2 Floodplain Management and Development

The National Flood Insurance Program (NFIP) is a federal program created by Congress to mitigate flood losses through community-enforced building and zoning ordinances and to provide access to insurance for property protection. Participation in the NFIP requires that the community enforce a floodplain management ordinance to reduce future flood risk in the Special Flood Hazard Areas (SFHAs). The SFHA is a high-risk area defined as any land that would be inundated by a flood having a 1-percent chance of occurring in a given year. Generally, the SFHA is identified on Flood Insurance Rate Maps (FIRMs). The FIRMs may also depict a floodway, which is defined as the stream channel plus the portion of the floodplain outside the channel banks that must be kept free from encroachment so that flows may pass without increasing the flood levels by a designated amount (typically 0 to 1 foot depending on the community). Development may take place within an SFHA provided that development complies with local and Federal floodplain ordinances. Development in a floodway is discouraged unless it can be proven that the encroachment will not alter flood elevations. Both the Town of Silverthorne and Summit County participate in the NFIP and have effective FIRMs with which they have relied on to regulate development in or near the special flood hazard h area (SFHA). The Project Reach current is within a SFHA and the recommended improvements in this Master Plan are within the 100-year floodplain, requiring approval from community floodplain administrators and FEMA prior to implementation. Work in the river will be required for low-flow channel construction and/or refinement and, in some areas where bank stabilization is recommended adjacent to the river.

Site Access and Staging

Construction operations will require access to the river from public rights-of-way, space required for project staging, material lay down, and job office set-up must also be provided either on private property or in easements acquired for construction and maintenance.

Water Quality

A water control plan may be required for construction in the low-flow channel. This may require a temporary diversion of the river and should be implemented when flows are low and can easily be diverted in a culvert or temporary channel. Pumping and treatment of the discharge from pumping may be required during the construction of subgrade improvements such as scour toe protection,

Construction in the upland areas will be performed in the dry and should have minimal impacts on the river. However, to limit stormwater erosion best management practices (BMPs) such as silt fences, hay bales, sediment basins, etc. should be incorporated into the construction planning. A stormwater management plan and permit, to be developed with construction drawings, will be required from the State of Colorado for control of stormwater runoff, as well as for dewatering during excavation.

BMPs to minimize impacts to native vegetation

There are areas of riparian species which will require protection during construction. Work in and around these areas must be executed in a manner that protects the native vegetation and seed sources for natural recruitment and meets all requirements of 404 permitting. These areas should be marked with signs and/or flagging to restrict access during construction. In some cases, hand work may be required. Fisheries

Construction requirements should include techniques to minimize impacts to the fisheries, particularly if there are any protected species. Typical requirements should include techniques to minimize turbidity and dewatering conditions, and to maintain passage around in-river construction sites. The fisheries protection plan will be incorporated into the water quality control plan.

6.3 Permitting for Master Plan Implementation

The purpose of requiring permits for development in the floodplain is to ensure all construction complies with federal, state, and local requirements specified in current codes, standards, flood ordinances, and recommended construction techniques to help prevent damage in future flood events. Permitting processes, requirements, and standards that guide development in the floodplain vary from jurisdiction to jurisdiction and must be reviewed and complied with prior to construction. Some communities have adopted ordinances that enforce more stringent standards than the minimums specified by FEMA and CWCB. Possible permits may include the following:

Local Permits

- Floodplain Development Permit
- 1041 Permit
- Stormwater Quality Management Permit

State permits

- Construction Stormwater Permit (Section 401)
- Wildlife Certification (SB 40)

Federal Permits/ Certificates

- FEMA CLOMR/LOMR (Submitted through the Town or County)
- USACE Section 404 Permit
- National Environmental Policy Act (NEPA)

6.4 Next Steps

The next major step is to engage the landowners, agencies, and municipalities, and develop and complete preliminary and final plans which will require further analysis and data collection. Some of the more significant analyses and data collection needed to support plan preparation are listed below, although the list is not all inclusive.

1. Collect topographic information, survey wetlands and map, identify property information.
2. Investigate the need for cultural resources surveys and endangered species.
3. Coordinate with the Town of Silverthorne on water quality improvements and the kayak park.
4. Develop detailed hydraulic analyses and perform sediment-transport analyses.
5. Consult with the floodplain administrators to determine submittal requirements for the acquisition of a floodplain permit. Prepare required hydraulic analyses.
6. Prepare preliminary and final designs using appropriate geomorphic principles; update and refine the hydraulic analysis.
7. Identify access easements for staging and construction.
8. Evaluate potential for utility conflicts.
9. Develop preliminary plans, with grading and details. Prepare preliminary technical specifications.
10. Refine cost estimates and secure funding.
11. Consult with permitting agencies and prepare and submit permit applications.
12. Prepare final plans, construction drawings and technical specifications.
13. Develop a monitoring plan.

This Master Plan is conceptual and based on the best data readily available, a conceptual level of analysis, and field work as authorized by the scope of work. Recommendations are focused primarily on improvements of aquatic habitat. The eight study sites were selected using the best available information and knowledge at the time the assessments were undertaken. It is possible these eight sites did not capture all the characteristics along the full 10 miles, which may lead to missing opportunities or not targeting all the restoration needs. Additional assessment may be required, and additional recommendations could be developed.

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APPENDIX A

Project Descriptions and Plans

LEGEND: EXISTING FEATURES

NAME — PROPERTY OWNERSHIP

EXISTING DIVERSION STRUCTURE

LEGEND: PROPOSED RESTORATION MEASURES

POINT BAR

POOL

CONSTRUCTED RIFFLE

WETLANDS PLANTINGS AND RE-SEEDING

RE-SEED UPPER CHANNEL BANKS

CONSTRUCTED RIVER TRAIL

BANK PROTECTION

BANK PROTECTION WITH ROCK DEFLECTOR

ROOTWADS

SUBREACH BOUNDARY

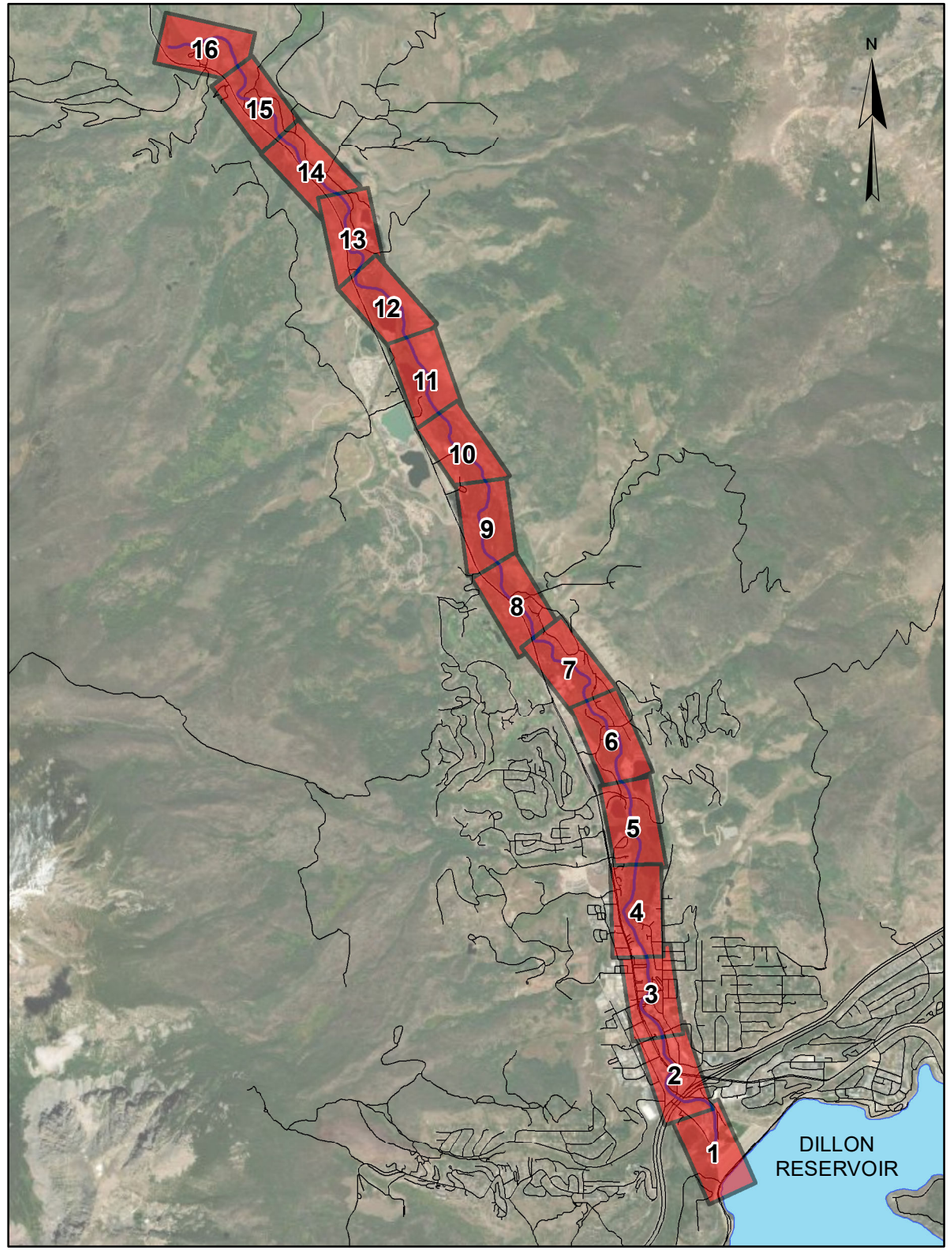
NOTES:

1. Restoration recommendations are located in accordance with the written recommendations presented in this Master Plan. Most of the recommendations are located on public lands managed by the Town of Silverthorne (TOS), Denver Water, United States Forest Service (USFS), Department of Natural Resources, Division of Wildlife (DNR), and Colorado Department of Transportation (CDOT). Some of these recommendations are shown on privately owned land and all of these improvements require coordination with the property owner, municipality, and agencies for approvals prior to preliminary and final design and prior to installation.

2. These plans are conceptual and recommendations are based on results from specific study sites. A more detailed study of the Project Reach could reveal localized areas that would benefit from restoration efforts not shown on the drawings.

3. Boulder clusters and large wood debris are recommended for installation in many of the reaches. These are described in the written description of restoration recommendations but not shown on the plans. Locations shall be determined during final design.

4. Aerial mapping date is September 13, 2019. Average daily flows were 105 cfs.



LOCATION MAP AND SHEET LAYOUT
NTS

TETRA TECH

ALDEN a verdantas company

BRWG BLUE RIVER WATERSHED GROUP

June 2023

Blue River Conceptual Restoration Master Plan

Blue River Integrated Water Management

Summit County, CO

SHEET G1

File Location: Z:\Project Files\SA-TZ\TetraTeFC\15824 - BRIWMP Phase 3\Working\GIS\Maps\Legend.mxd

Edited: 7/18/2023 User: btrabant

SHEET: 1
LOCATION: Town of Silverthorne
SUBREACH: 2.1.1
STATION: 493+00 to 509+00
REPRESENTATIVE STUDY SITE 1

This section of the Blue River lies within Subreach 2.1.1 spanning approximately 1,600 feet between stations 493+00 and 509+00. This section of the river is within the Town of Silverthorne and on land primarily owned and managed by Denver Municipal Water Works (Denver Water). The Colorado Department of Transportation also owns a small parcel along the left channel bank. Some private property is also within this section of the river. The upstream limit of this section is approximately 300 feet downstream of the Dillon Reservoir outlet. The USGS Stream Gage '09050700 Blue River Below Dillon, CO' is located on the right bank near station 495+00. This Subreach is popular for fishing and pedestrian access. It is easily accessible and close to the Town of Silverthorne and Interstate 70.


Dillon Dam Outlet

This section of the Blue River is characterized by Study Site 1 which was rehabilitated by the Town of Silverthorne in 2003. The habitat analysis conducted in 2021 indicates the hydraulic habitat parameters, primarily wetted permitter, and depth, meet, or exceed the minimum standards set by instream flow standards likely the result of the 2003 restoration efforts. Within the low flow channel, this Subreach has natural appearing habitat features, including pools, runs, and riffles along a meandering channel and a narrow band of vegetation lining the banks. This reach could be used as a reference for future restoration of other sections of the Blue River. The residual pool depth (pool depth that would be present at 'zero' flow) was measured at 2.4 feet. The area for glides and riffles was almost equal at approximately 46 percent of the total area, with pool habitat making up the remaining 7 percent. The substrate is primarily cobble and boulders with a near absence of spawning-size gravel. Channel banks in this are quite steep, and some sections have eroded due to foot traffic accessing the river.


Near Station 500+00 Looking Downstream

The Town of Silverthorne is currently planning to build a whitewater park near the Wilderness Road Bridge. While Wilderness Road is in Subreach 2.1.2, shown on Plan Sheet 2, it is possible improvements could extend into and/or impact Subreach 2.1.1 and as such is included in the summary of analysis and recommendations. Current plans for the whitewater park include three control structures near Wilderness Road, spaced 100 to 150 feet apart to '*create recreational experiences consisting of watercraft passage under low flows and whitewater kayaking at higher flow*' (Brown and Caldwell 2004). While there is currently little detail available regarding the three control structures, these structures may create fish barriers similar to the existing drop structures in Subreach 2.1.2. Several alternatives could be considered to better support fish passage into this Subreach including a 'slalom-style' kayak course near Wilderness Road and/or a standing wave structure near the Dillon Reservoir outlet structure.

Summary of Analyses and Key Considerations


Station 505+00 Looking Upstream

- The approximate length of the river on this plan sheet is 1,600 ft with an estimated average slope of 0.8 percent and a top width of 34 to 41 ft at 50 cfs as measured at the USGS Stream Gage '09050700 Blue River Below Dillon, CO'.
- The habitat analysis for Subreach 2.1.1 indicates this is one of the narrowest reaches in the Project Reach likely the result of the 2003 restoration. Pools are sparse, although the existing pools are deeper than other pools within the Project Reach.
- The FACStream analysis for Subreach 2.1.1 indicates a 'significant degree of impairment' with one of the lowest ranking functional capacity index values (FCI) in the Project Reach, due to low scores for the flow and biotic structure variables. The morphology, stability, and physical structure variables scored high, consistent with the habitat analysis. This area is popular with anglers and pedestrians.
- The Town of Silverthorne is planning to build a whitewater park in Subreach 2.1.2 which may extend into this Subreach.

Restoration Recommendations

Restoration recommendations are focused on improving channel bank conditions, maintaining fish passage, and stabilizing upper banks and recreational access locations to reduce bank erosion.

1. Construct trails to direct foot traffic to the river. Use gravel to stabilize the trail surface and minimize erosion. Include steps along the steeper bank sections.
2. Construct bank protection near station 508+00 on the right bank.
3. Lay back and reseed the eroded upper channel banks where possible. Consider structural stabilization as an alternative along the steeper sections. Revegetate banks to enhance cover using grasses and wetland plantings.
4. Plant willows along the interface between the steep channel banks and gravel bars.
5. Coordinate with the Town of Silverthorne on plans for their kayak park. Investigate the potential to incorporate the facility with other restoration recommendations including a 'slalom-style' kayak course near Wilderness Road (see details) and/or a standing wave structure upstream of Wilderness Road closer to the Dillon Reservoir outlet structure to minimize the loss of fish habitat.

TETRA TECH

ALDEN a verdantas company

BRWG BLUE RIVER WATERSHED GROUP

June 2023

Blue River Conceptual Restoration Master Plan

Blue River Integrated Water Management

Summit County, CO

SHEET 1

File Location: Z:\Project Files\SA-TZ\TetraTeFC\15824 - BRIWMP Phase 3\Working\GIS\Maps\Basemap.mxd

Edited: 7/17/2023 User: btrabant

LOCATION: Town of Silverthorne
SUBREACH: 2.1.2
STATION: 453+00 to 493+00
SHEET: 2
REPRESENTATIVE STUDY SITE 2

This section of the Blue River lies within Subreach 2.1.2 and spans approximately 4,000 feet between stations 453+00 immediately downstream of the 4th Street pedestrian bridge at the Silverthorne Pavilion, to Station 493+00 just upstream of the confluence with Straight Creek at Station 490+00. Land ownership along the river channel includes the Town of Silverthorne, CDOT, Highway right-of-way, and private properties.


Existing Drop Structure

This section of the Blue River is characterized by Study Site 2 and contains an estimated 16 to 18 drop structures including both partial- and full-channel width structures. These drop structures vary in height and typically have a scour hole formed in the center of the channel due to the scouring effects of the drop structure. The combination of the water-surface elevation drop and the fast velocity at these structures is likely an impediment to upstream fish passage. Residual pool depth (depth at near zero flow) was 1.9 feet with maximum depths ranging from 1.0 at 50 cfs to 3.7 feet at 1000 cfs. The river is very wide and shallow in this Subreach. Widths range between 54 to 92 feet compared to 50 feet in Subreach 2.1.1.

Glides made up approximately 37 percent of the habitat, riffles 55 percent, and pools 8 percent. Pool habitat quality is poor with shallow pools located in mid-channel as opposed to being located along the banks on the outside channel bends. Cobbles and boulders dominate the substrate and there is a near absence of spawning-size gravel. Subreach 2.1.2 is located within one of the more densely developed urban corridors along the Blue River with commercial and residential development. Interstate 70 and Highway 9 are adjacent to the river and floodplain corridor. Fishing is popular in this reach and the Town of Silverthorne has implemented riverbank and trail improvements that support angling and pedestrian access. The Town of Silverthorne is currently planning to build a whitewater park near the Wilderness Road Bridge. The Town has indicated the approximate location will be between Station 475+00 to 485+00. Current plans for the Whitewater Park include three control structures near Wilderness Road, spaced 100 to 150 feet apart to '*create recreational experiences consisting of watercraft passage under low flows and whitewater kayaking at higher flow*' (Brown and Caldwell 2004). While there is currently little detail available regarding the three control structures, these structures may create fish barriers similar to the existing grade control structures in this Subreach. Several alternatives could be considered including a 'slalom-style' kayak course near Wilderness Road and/or a standing wave structure near the Dillon Reservoir outlet structure. Winter operations associated with the Interstate and the State highway include using sand and deicers, impacting the Blue River's water quality. The Town of Silverthorne is currently designing and installing best management practices to improve water quality at storm sewer and swale outfalls along the river channel.

Summary of Analyses and Key Considerations

- The approximate length of river on this plan sheet is 4,000 ft with an estimated average slope of 0.8 percent and a top width of 54 to 92 ft at 50 cfs as measured at the USGS Stream Gage '09050700 Blue River Below Dillon, CO'.
- The habitat analysis for Subreach 2.1.2 indicates this is one of the widest reaches in this study. Pools are sparse and shallow.
- The FACStream analysis for Subreach 2.1.2 indicates a 'significant degree of impairment' with the lowest ranking functional capacity index value (FCI) in the Project Reach, due to low scores in all variables except stability
- This area is popular with anglers and pedestrians, and the Town of Silverthorne is planning to build a whitewater park that may affect this Subreach.

Restoration Recommendations

Restoration recommendations focus on removing the existing drop structures, narrowing the river, improving channel bank conditions, and delineating and stabilizing recreational access locations to reduce bank erosion. In addition, recommendations include teaming with the Town of Silverthorne to incorporate both the kayak park improvements and the stormwater quality improvements.

1. Coordinate with the Town of Silverthorne on plans for the kayak park. Investigate the potential to incorporate the facility with other restoration recommendations.
2. Should the town be considering a standing wave kayak feature, investigate the possibility of locating the feature as far upstream toward the dam as possible or, alternatively, consider spanning only a portion of the river with the kayak feature, leaving room for a side channel around the standing wave.
3. Remove the existing drop structures. Construct riffles as required to maintain channel slope and create macroinvertebrate habitat. Add in-channel structure using boulder clusters.
4. Narrow the channel using cobble bars and deepen pools. The locations shown on sheet 2 are placeholders and require additional study to confirm the locations, sizes, and extent of these pools.
5. Consider the addition of native bank vegetation in areas lacking cover. Revegetate and stabilize damaged channel banks. Consider flow deflectors such as rock spurs or barbs to deflect flow away from vulnerable banks.
6. Construct trails to direct foot traffic to the river. Use gravel to stabilize the trail surface and minimize erosion. Include steps along the steeper bank sections.
7. Coordinate with the Town of Silverthorne to incorporate water quality features with the Restoration Master plan.

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Blue River Conceptual Restoration Master Plan

Blue River Integrated Water Management

Summit County, CO

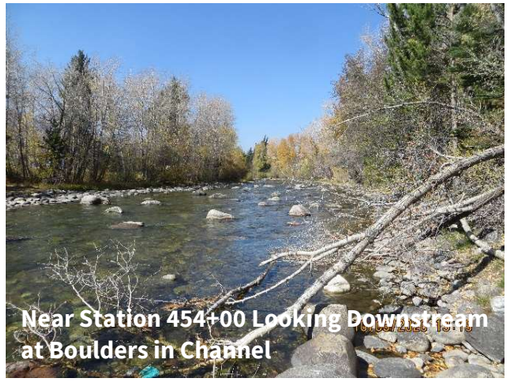
SHEET 2

File Location: Z:\Project Files\SA-TZ\TetraTeFC\15824 - BRIWMP Phase 3\Working\GIS\Maps\Basemap.mxd

Edited: 7/17/2023 User: btrabant

LOCATION: Town of Silverthorne
REACH: 2.1.2, 2.1.3
STATION: 420+00 to 453+00
SHEET: 3
REPRESENTATIVE STUDY SITE 3

This section of the Blue River includes Sub reaches 2.1.2 and 2.1.3 split by the 6th Street Bridge. This section spans approximately 3,300 feet between station 420+00 downstream of the 9th Street intersection at Highway 9 to station 453+00 immediately downstream of the 4th Street pedestrian bridge at the Silverthorne Pavilion. Land ownership along the river channel includes the Town of Silverthorne, Highway right-of-way, and private properties. Easements also exist and are managed by the Town of Silverthorne.


Near Station 454+00 Looking Downstream at Boulders in Channel

This section of the Blue River is characterized by Study Site 3. Glides made up 55 percent of the habitat area, riffles 45 percent, and no pools were identified at the flow of 88 cfs during the habitat inventory conducted in 2021. The average channel width ranged from 58 to 64 feet. Stream substrate was dominated by cobble and boulders and no spawning-size gravel was observed. Filamentous algae were observed in this reach during a field reconnaissance conducted in October 2020.

Four constructed drop structures exist within Subreach 2.1.2 upstream of 6th Street, while no constructed drop structures were identified in Reach 2.1.3. These drop structures vary in height and typically have a scour hole formed in the center of the channel due to the scouring effects of the drop structure. These drops appear smaller than the drops surveyed upstream. While these drops are shorter and narrower than the upstream drops, they are likely an impediment to upstream fish passage.

Near station 435+50 adjacent to the Town of Silverthorne library, immediately downstream of 6th Street a cobble bar and riffle formed, or may have been constructed, and for a short length the low flow channel displays natural appearing habitat features. This section could be used as a reference section to inform on developing other cobble bars and riffles along this reach.

Near Station 441+00 Looking Downstream from 6th Street at Bar and Riffle

As the river transitions from Subreach 2.1.2 to 2.1.3 the urban encroachment lessens and there is a distinct increase in channel bank vegetation including trees, shrubs, and understory vegetation. Banks are lower in this section of the Blue River with improved floodplain connectivity and overbank vegetation compared to Subreaches 2.1.1 and 2.1.2. Land use changes from an urban corridor to residential/urban mix and there is a pedestrian and bike trail along the east bank of the river. This is a popular section of the Blue River for both fishing and pedestrian access. Minor bank damage was observed from pedestrian access into the river.

Summary of Analyses and Key Considerations

- The approximate length of the river on this plan sheet is 3,300 ft with an estimated average slope of 0.7 percent and a top width of 58 to 64 ft at 50 cfs as measured at the USGS Stream Gage '09050700 Blue River Below Dillon, CO'.
- The habitat analysis for Subreach 2.1.2 and 2.1.3 indicates this is one of the wider reaches in this study. Pools are absent under the assessed flow conditions and there is an absence of spawning gravels.
- The FACStream analysis for Reach 2.1.2 and 2.1.3 indicates a 'significant degree of impairment' with a relatively low functional capacity index value (FCI) due to low scores for flow, physical structure, and biotic structure variables. Comparing Subreach 2.1.1 and 2.1.3, improvements are seen in the riparian variables due to the increase in floodplain connectivity. The scores for stability remain high.
- This area is popular with anglers and pedestrians.

Restoration Recommendations

Restoration recommendations focus on narrowing the river, creating pool habitat, and enhancing riffle habitat.

1. Narrow channel using point bars. Enhance and construct riffle habitat.
2. Construct pools of sufficient depth on the outer banks.
3. Remove the existing drop structures. Construct riffles as required to maintain channel slope.
4. Revegetate and stabilize damaged channel banks.
5. Construct trails to direct foot traffic to the river. Use gravel to stabilize the trail surface and minimize erosion. Include steps along the steeper bank sections, particularly near the Silverthorne Town Pavilion.

0 100 200 400 Feet

1 Inch = 200 Feet

PROPOSED PEDESTRIAN BRIDGE. SEE SILVERTHORNE TRAILS MASTER PLAN.

PROPOSED PEDESTRIAN BRIDGE. SEE SILVERTHORNE TRAILS MASTER PLAN.

4th St

TOS

420+00

425+00

430+00

435+00

440+00

445+00

450+00

Blue River Pkwy

6th St

USFS

Subreach 2.1.3

Subreach 2.1.2

State Hwy 9 Blue River Pkwy

State Hwy 9 Blue River Pkwy

9th St

Adams Ave

Adams Ave

TETRA TECH

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June 2023

Blue River Conceptual Restoration Master Plan

Blue River Integrated Water Management

Summit County, CO

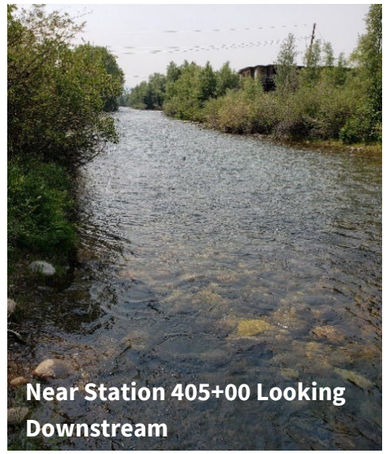
SHEET 3

File Location: Z:\Project Files\SA-TZ\TetraTeFC\15824 - BRIWMP Phase 3\Working\GIS\Maps\Basemap.mxd

Edited: 7/17/2023 User: btrabant

LOCATION: Town of Silverthorne
REACH: 2.1.3, 2.2.1
STATION: 389+00 to 420+00
SHEET: 4
REPRESENTATIVE STUDY SITE 3

This section of the Blue River lies within Subreaches 2.1.3 and 2.2.1 split by the Blue River Trail bridge. This section spans approximately 3,100 feet from station 389+00 opposite Smith Ranch Road to Station 420+00 downstream of 9th Street at Highway 9. The Blue River Trail bridge crossing is located at Station 404+00. Land ownership along the river channel includes the Town of Silverthorne and private properties. Easements also exist and are managed by the Town of Silverthorne.


Near Station 405+00 Looking Downstream

The section of the Blue River within Subreaches 2.1.3 and 2.2.1 are characterized by Study Site 3. Glides made up 55 percent of the habitat area, riffles 45 percent, and no pools were identified at the flow of 88 cfs during the habitat inventory conducted in 2021. The average channel width ranged from 58 to 64 feet. Stream substrate was dominated by cobble and boulders and no spawning-size gravel was observed. Land use consists of a residential/urban mix and there is a pedestrian and bike trail along the east bank of the river. Compared to the upstream subreaches there is a distinct increase in channel bank vegetation including trees, shrubs, and understory vegetation with improved floodplain connectivity. This is a popular section of the Blue River for both fishing and pedestrian access. Minor bank damage was observed from pedestrian access into the river.

The Blue River Trail bridge bisects a 1,500-foot-long island that splits the main channel into two side channels. These side channels appear to evenly split flows and nearly double the width of the single channel mainstem above and below the split. As a result, flows in both side channels appear to be quite shallow. There is one drop structure located along the east side channel. Increased depths and improved hydraulic conditions at low flows could potentially be achieved by confining low flows to one of the splits.


Bank damage from pedestrian use near Station 407+00

A review of historical aerial photography indicates the ponds located downstream of the Blue River Trail bridge and the island split were constructed sometime between 1954 and 1985 and are remnant gravel pits. These ponds predate Colorado's gravel pit restoration requirements to line the ponds, and as such these ponds could be hydraulically connected to the Blue River via groundwater. The historical aerial photography also shows this section of the river had multiple threads. Today the westernmost channel thread below the island is now the main stem of the Blue River and is the result of channel modifications to build the gravel pits. The floodplain spans the river and gravel pit ponds and ranges from an estimated 300 feet to over 1,000 feet wide (FEMA, 2018). In addition to the gravel pit ponds, the floodplain encompasses old remnant oxbows and dense wetland vegetation. Existing residential neighborhoods are located generally outside of the floodplain along both edges of this floodplain/wetlands area.

Near Station 404+00 Looking Downstream at right side channel

Summary of Analyses and Key Considerations

- The approximate length of the river on this plan sheet is 3,100 ft with an estimated average slope of 0.7 percent and a top width of 58 to 64 ft except along the two split channels where the combined width is estimated to be between 80 and 100 feet. Widths noted were measured with 59 cfs, measured in the river immediately downstream at Study Site 4.
- The habitat analysis for Subreach 2.1.3 and 2.2.1 indicates this is one of the wider reaches in this study including sections of the river where flows are split at the island. Pools are absent under the assessed flow conditions and there are no spawning gravels consistent with the upstream reaches.
- The FACStream analysis for Reach 2.1.3 and this portion of 2.2.1 indicates a 'significant degree of impairment' with a relatively low functional capacity index value (FCI) due to the low scores for flow, physical structure, and biotic structure. Improvements are seen in the riparian variables due to the increase in floodplain and groundwater connectivity and the stability score remains high.
- The channel is transitioning to characteristics of Study Site 4 where the FACStream analysis indicates a 'mild/significant degree of impairment' due to low rankings for flow and biotic structure and higher-ranking variables for floodplain and stability. The habitat analysis at Study Site 4 indicates this site has some of the higher percentage of cover habitat compared to other sections.

Restoration Recommendations

Restoration recommendations focus on narrowing the river, adding in-channel habitat, and creating riffles and pool habitat.

1. Narrow channel using point bars.
2. Construct pools of sufficient depth on the outer banks.
3. Add boulder clusters and large woody debris to diversify habitat within the channel bed.
4. Construct trails to direct foot traffic to the river. Use gravel to stabilize the trail surface and minimize erosion. Include steps along the steeper bank sections.
5. Consider modifying channel flow splits to confine the low flows to one of the side channels between Stations 395+00 and 404+00.
6. Revegetate disturbed areas along the east channel bank.

0 100 200 400 Feet

1 Inch = 200 Feet

BOBO STRAIGHT SPRING DITCH

RESEED CHANNEL EAST BANK
STA 405+00 TO 402+00

390+00

395+00

400+00

405+00

410+00

415+00

420+00

TOS

MODIFY LOW FLOW
CHANNEL SPLITS

TOS

TOS

BLUE RIVER TRAIL BRIDGE

Subreach 2.2.1

Subreach 2.1.3

STUDY STIE 3

Blue River Pkwy

Blue River Pkwy State Hwy 9

State Hwy 9

13th St

Adams Ave

Adams Ave

TETRA TECH

ALDEN a verdantas company

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June 2023

Blue River Conceptual Restoration Master Plan

Blue River Integrated Water Management

Summit County, CO

SHEET 4

File Location: Z:\Project Files\SA-TZ\TetraTeFC\15824 - BRIWMP Phase 3\Working\GIS\Maps\Basemap.mxd

Edited: 7/17/2023 User: btrabant

LOCATION: Town of Silverthorne
REACH: 2.2.1
STATION: 357+00 TO 389+00
SHEET: 5
REPRESENTATIVE STUDY SITE 4

This section of the Blue River lies primarily within Reach 2.2.1 spanning 3,200 feet from station 357+00, 600 feet downstream of Bald Eagle Road bridge crossing to Station 389+00 opposite Smith Ranch Road at Highway 9. Willow Creek confluences with the Blue River in this reach at Station 378+00. Land ownership along the river channel includes the Town of Silverthorne and private properties.

This section of the Blue River is characterized by Study Site 4. Site 4 had the highest percentage of cover habitat compared to all study sites. Habitat features were diverse with pools, glides, and riffles along a single thread channel and cobble bars and willows along the banks and floodplain. Stream habitat at Site 4 was dominated by pools (47.4 percent) and glides (39.9 percent). Pools were associated with the outside of the meanders and averaged 2.0 feet deep at 50 cfs. The channel substrate was small to medium size boulders and large cobble with little to no spawning gravels present. The channel width ranged from 32 to 50 feet.

Ponds are located on both sides of the river. A review of historical aerial photography indicates the ponds were constructed sometime between 1954 and 1985 and are remnant gravel pits. These ponds predate Colorado's gravel pit restoration requirements to line the ponds, and as such these ponds could be hydraulically connected to the Blue River via groundwater. The historical aerial photography also shows this section of the river had multiple threads. Today the river runs as a single thread, the result of developing the gravel pits. This section of the river is slightly narrower than the channel in Subreach 2.1.3. This is supported by the habitat assessments performed at Study Site 4. The floodplain spans these ponds and ranges from an estimated 500 feet to over 1,000 feet wide (FEMA, 2018). In addition to the ponds, the floodplain encompasses old remnant oxbows and dense wetland vegetation. Existing residential neighborhoods are located outside of the floodplain along both edges of this floodplain/wetlands area.

Summary of Analyses and Key Considerations

- The approximate length of the river on this plan sheet is 3,200 ft with an estimated average slope of 0.8 percent and a top width of 32 to 50 ft at 59 cfs, measured at Study Site 4.
- The habitat analysis for Reach 2.2.1 indicates this is one of the narrower reaches in the study with some of the highest percentages of cover habitat, pools (47.4 percent) and glides (39.9 percent). Pools were associated with the outside of the meanders and averaged 2.0 feet deep at 59 cfs.
- The FACStream analysis for Reach 2.2.1 indicates a 'mild/significant degree of impairment' with low scores for the flow and biotic structure variables. The floodplain and stability variables had the highest scores in this reach.
- The habitat analysis for Subreach 2.2.1 indicates a trend of improvements moving downstream with improvements in channel width, presence of pools, and depth of pools.

Restoration Recommendations

Consider the addition of boulder clusters and large woody debris to diversify habitat within the channel and along the banks, and to help sort and retain spawning gravels should they be added

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SHEET 5

File Location: Z:\Project Files\SA-TZ\TetraTeFC\15824 - BRIWMP Phase 3\Working\GIS\Maps\Basemap.mxd

Edited: 7/17/2023 User: btrabant

LOCATION: Town of Silverthorne
REACH: 2.2.2
STATION: 323+00 to 357+00
SHEET: 6
REPRESENTATIVE STUDY SITE 4

This section of the Blue River lies within Reach 2.2.2 and spans approximately 3,400 feet from station 323+00 downstream of Hamilton Creek Road to Station 357+00 downstream of Bald Eagle Road. Study Site 4 is located in this river section. Land ownership along the river channel includes the Town of Silverthorne and private properties.


Cobble Bar at Study Site 4

Site 4 had the highest percentage of cover habitat compared to all study sites. The channel substrate at Study Site 4 was small to medium size boulders and large cobble. Little to no spawning gravels were present. Habitat features were diverse with pools, glides, and riffles along a single thread channel and cobble bars and willows along the banks and floodplain. Stream habitat at Site 4 was dominated by pools (47.4 percent) and glides (39.9 percent). Pools were associated with the outside of the meanders and averaged 2.0 feet deep at 50 cfs. The hydraulic parameters are generally some of the better values compared to other sites including topwidth and pool depth and could be used as a reference reach for future restoration of other sections of the Blue River including channel narrowing, and pool construction.

A review of historical aerial photography indicates the ponds located on each side of the river were constructed sometime between 1954 and 1985 and are remnant gravel pits. These ponds predate Colorado's gravel pit restoration requirements to line the ponds, and as such these ponds could be hydraulically connected to the Blue River via groundwater. The floodplain spans these ponds and ranges from an estimated 500 feet to over 1,000 feet wide (FEMA, 2018) and encompasses the river, ponds, old remnant oxbows, and dense wetland vegetation. Existing residential neighborhoods are located outside of the floodplain along both edges of this floodplain/wetlands area. There is a pedestrian/bike trail to the west of the river and east of a residential development between Stations 357+00 and 350+00.

Hamilton Creek Road crosses the river near Station 334+00. Immediately upstream of the bridge, there is a large deposit of gravel. While this gravel deposit does not notably impair aquatic habitat, it is likely decreasing the bridge capacity as reflected in the current FEMA floodplain mapping (FEMA 2023). Should improvements be contemplated at this bridge crossing, consider fish-friendly techniques such as flow deflectors, reconfiguring the channel bar, and deepening the pools. Velocities through the bridge should also be reviewed.


Near Station 334+00 Looking Upstream from Hamilton Creek Drive Bridge

Summary of Analyses and Key Considerations

- The approximate length of the river on this plan sheet is 3,400 ft with an estimated average slope of 0.8 percent and a top width of 32 to 50 ft at 59 cfs as measured at Study Site 4.
- Study Site 4 also had the highest percentage of cover habitat and is dominated by pools (47.4 percent) and glides (39.9 percent). Pools were associated with the outside of the meanders and averaged 2.0 feet deep at 59 cfs.
- The FACStream analysis for Reach 2.2.2 indicates a 'mild/significant degree of impairment' with low scores for the flow and biotic structure variables and high scores for the floodplain, riparian vegetation, and stability variables.
- The habitat analysis for this section of the river indicates a trend of improvements moving downstream with decreases in channel width, increases in the presence of pools, and greater depth of pools at low flows.

Restoration Recommendations

Restoration recommendations include improvements at the upstream section of the Hamilton Creek Road bridge to increase the bridge capacity while maintaining fish passage. In addition consider the addition of boulder clusters and large woody debris to diversify habitat within the channel and along the banks, and to help sort and retain spawning gravels should they be added

0 100 200 400 Feet

1 Inch = 200 Feet

NARROW COBBLE BAR BY REMOVING COBBLE IN MID-RIVER; ADD BARGE OR SPURS ALONG LEFT CHANNEL BANK

Hamilton Creek Dr

330+00

335+00

340+00

345+00

350+00

355+00

325+00

STUDY STIE 4

TOS

TOS

Subreach 2.2.2

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June 2023

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Blue River Integrated Water Management

Summit County, CO

SHEET 6

File Location: Z:\Project Files\SA-TZ\TetraTeFC\15824 - BRIWMP Phase 3\Working\GIS\Maps\Basemap.mxd

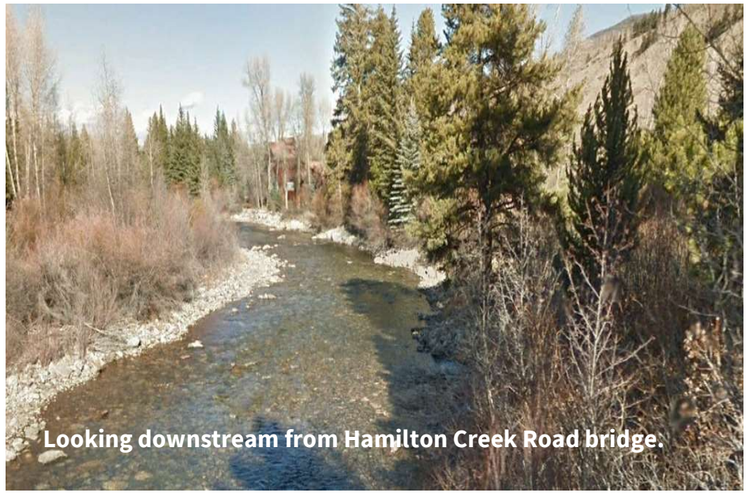
Edited: 7/17/2023 User: btrabant

LOCATION: Summit County/Town of Silverthorne
REACH: 2.2.2
STATION: 290+00 to 323+00
SHEET: 7
REPRESENTATIVE STUDY SITE 4

This section of the Blue River lies within Reach 2.2.2 and spans approximately 3,300 feet from Station 290+00 downstream of the Blue River WWTP to Station 323+00 downstream of Hamilton Creek Road. Land ownership along the river channel includes the Town of Silverthorne, Highway right-of-way, and private properties.

This area can be characterized, by Study Site 4, which had the highest percentage of cover habitat compared to the other seven sites, although aerial imagery indicates the channel is slightly wider than Study Site 4. The channel substrate at Site 4 was predominantly small to medium size boulders and large cobble with little to no spawning gravels present. Habitat features were diverse with pools, glides, and riffles along a single thread channel and cobble bars and willows along the banks and floodplain. Stream habitat at Site 4 was dominated by pools (47.4 percent) and glides (39.9 percent). Pools were associated with the outside of the meanders and averaged 2.0 feet deep at 59 cfs.

Most of this section has a wide floodplain of over 1,000 feet with several ponds and wetlands. As the river flows northwest it bends to the north and becomes narrower due to a rock outcrop and State Highway 9. Here the floodplain narrows to an estimated 200 feet. This reach of the river is bordered by large acreage single-family homes to the east and the Blue River Wastewater Treatment Plant (WWTP) to the southwest of the river. Remnant side channels in the floodplain along the upstream portion of this section of the river are visible in the aerial imagery.



Looking downstream from Hamilton Creek Road bridge.

Summary of Analyses and Key Considerations

- The approximate length of the river on this plan sheet is 3,300 ft with an estimated average slope of 0.8 percent and a top width of 32 to 50 ft at 59 cfs as measured at Study Site 4.
- The channel and floodplain begin to narrow as the river moves north and west, confined to the west by a rock outcrop and State Highway 9, and hilly terrain to the east.
- The habitat analysis characterized by Study Site 4 was assessed in a reach that was likely a side channel prior to the development of the adjacent gravel ponds. Based on a review of the aerial imagery the river section shown on sheet 7 appears to be and has been predominately a single thread channel with minor side channel splits. Thus, it is possible this section of the river is wider than characterized by Study Site 6.
- The FACStream analysis for Reach 2.2.2 informs on the southern portion of this section which indicates a 'mild/significant degree of impairment' with low scores for the flow, water quality, and biotic structure variables and high scores for the floodplain, riparian vegetation, and stability variables.
- The habitat analysis indicates a trend of improvements moving downstream with decreases in channel width, increases in the presence of pools, and greater depth of pools at low flows. Study Site 4 also had the highest percentage of cover habitat and is dominated by pools (47.4 percent) and glides (39.9 percent). Pools were associated with the outside of the meanders and averaged 2.0 feet deep at 59 cfs.

Restoration Recommendations

Restoration recommendations include the addition of boulder clusters and large woody debris to diversify habitat within the channel and along the banks, and to help sort and retain spawning gravels should they be added.

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June 2023

Blue River Conceptual Restoration Master Plan

Blue River Integrated Water Management

Summit County, CO

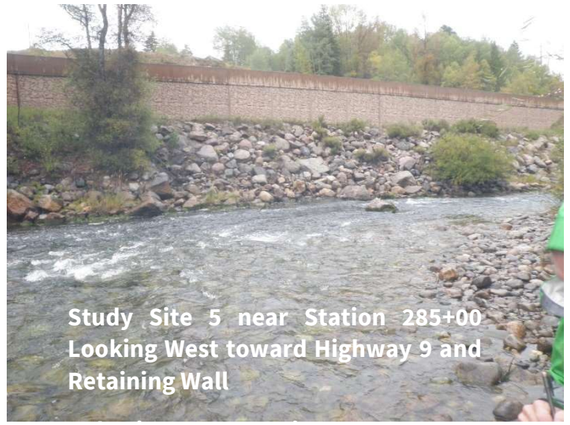
SHEET 7

File Location: Z:\Project Files\SA-TZ\TetraTeFC\15824 - BRIWMP Phase 3\Working\GIS\Maps\Basemap.mxd

Edited: 7/17/2023 User: btrabant

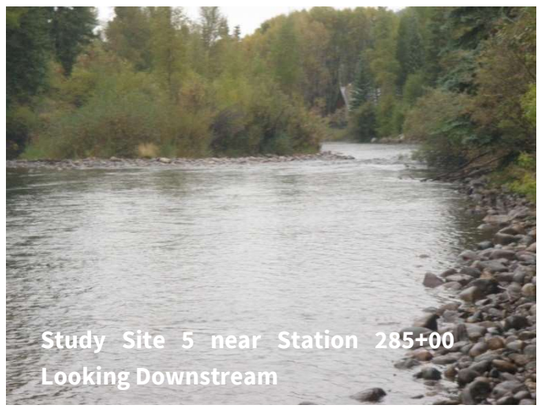
LOCATION: Summit County
REACH: 2.2.2, 2.2.3
STATION: 258+00 to 290+00
SHEET: 8
REPRESENTATIVE STUDY SITE 5

This section of the Blue River lies within Reach 2.2.2 and 2.2.3, split by the bridge at Sage Creek Canyon Drive. This section spans approximately 3,200 feet from station 258+00 downstream of Sage Creek Canyon Drive to station 290+00 downstream of the Blue River WWTP. Sage Creek Canyon Driver crosses this reach at station 269+00. Land ownership along the river channel includes the Highway right-of-way, private properties, and USFS-managed lands.



Study Site 5 near Station 285+00 Looking West toward Highway 9 and Retaining Wall

This reach includes Study Site 5 located between Stations 282+00 and 286+00. Riffle habitat dominates the features (44 percent) with pools making up approximately 30 percent of the stream reach. There is a significant reduction in cover and the stream is wider compared to Site 4. This site is approximately one-quarter mile downstream from the Blue River Wastewater Treatment Plant, and increased nutrients are evident in the form of algae on the channel substrate. The substrate is slightly embedded due to sediment additions from winter sanding operations on State Highway 9. The residents in the subdivision stock the river in this area to maintain fishing quality.



Study Site 5 near Station 285+00 Looking Downstream

Between Sage Creek Canyon Road bridge crossing at station 269+00 to station 290+00, the floodplain is narrow, estimated to be 100 feet wide, confined by a rock outcrop to the west and hilly terrain to the east. The Blue River at this location is a single thread channel with cobble bars and vegetation along the banks and no evidence of remnant side channels or gravel pit ponds. There are three small ponds located east of this reach, outside of and above the floodplain that provide storage for irrigation. Bushee Creek runs through these ponds and connects to the Blue River downstream of Sage Creek Canyon Drive.

Minor localized bank erosion is evident along the east bank of the river between stations 270+00 and 285+00. Development is present in the overbanks including single-family homes along the east bank, Highway 9 on the west bank, and the Sage Creek Canyon Drive bridge crossing downstream of the study site.

From Station 258+00 to 269+00 the channel begins to transition to characteristics of Study Site 6 located on the Eagles Nest Ranch immediately downstream, where long shallow pools make up 44 percent of the habitat surveyed, and glides make up 37 percent. The total cover is lower compared to Site 4 but higher than Site 5 and is limited to pool depth. Site 6 is the first site where cobble comprises the majority of substrate (70 percent) and gravels are present (10 percent) and available for spawning. Approximately 200 to 300 feet downstream of the bridge at Sage Creek Canyon Driver the river and floodplain valley diverge east away from the highway and the floodplain widens to approximately 500 feet. Within this wider reach, there is evidence of remnant oxbow channels and wetland vegetation.

Summary of Analyses and Key Considerations

- The approximate length of the river on this plan sheet is 3,200 ft with an estimated average slope of 0.8 percent and a top width of 55 to 73 ft at 73 cfs as measured at Study Site 5.
- The channel is narrow where the river is confined by a rock outcrop and State Highway 9, and hilly terrain to the east. Increased nutrients are evident in the form of algae on the channel substrate. The substrate is slightly embedded due to sediment additions from winter sanding operations on State Highway 9. Riffle habitat dominates the features (44 percent) with pools making up approximately 30 percent of the stream reach. There is a significant reduction in cover compared to Site 4.
- The FACStream analysis for Reach 2.2.2 applies to Stations 288+00 to 290+00 which indicates a 'mild/significant degree of impairment' with low scores for the flow, water quality, and biotic structure variables and higher scores for the floodplain, riparian vegetation, and stability variables.
- The FACStream analysis for Reach 2.2.3 applies to Statins 258+00 to 269+00 which indicates a 'mild degree of impairment' with low scores for the water quality and biotic structure and high scores for the stability variable and overall improvements in the flow and sediment variables compared to the upstream Subreach.
- Between Station 269+00 to 288+00 neither FACStream analysis is applicable as this 3,000-foot section of the Blue River is an anomaly due to the narrow floodplain confinement caused by the rock outcrop to the west and hilly terrain to the east. In addition, this section of the river is influenced by the WWTP with evidence of higher nutrients, and from State Highway 9 with evidence of sand in the river from winter road operations.
- Downstream of Sage Creek Canyon Drive the channel widens and more closely resembles the habitat of Study Site 6 with 44 percent pools, 37 percent glides, and a reduction in total cover compared to Site 4.

Restoration Recommendations

There are currently minor recommendations for restoration between Stations 258+00 to 290+00 shown on the project site plan, provided here for consideration. These include the following:

1. Investigate locations for the construction of a sediment basin along State Highway 9 to capture traction sand. Planning, design, and maintenance of the facility will be required.
2. Consider bank stabilization improvements in several isolated areas where foot traffic access has impacted the vegetation along the channel banks and add habitat diversity along the bank.
3. Add a point bar in the wider section of the river.
4. Consider the addition of boulder clusters and large woody debris to diversify habitat within the channel and along the banks, and to help sort and retain spawning gravels should they be added.

0 100 200 400 Feet

1 Inch = 200 Feet

CONSIDER THE ADDITION OF POSSIBLE BANK VEGETAION AND WOOD

BUSHEE CREEK

Sage Creek Canyon Dr

260+00

265+00

270+00

275+00

280+00

285+00

290+00

USFS

Blue River Pkwy

STUDY STIE 5

Subreach 2.2.3

Subreach 2.2.2

State Hwy 9

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Blue River Integrated Water Management

Summit County, CO

SHEET 8

File Location: Z:\Project Files\SA-TZ\TetraTeFC\15824 - BRIWMP Phase 3\Working\GIS\Maps\Basemap.mxd

Edited: 7/17/2023 User: btrabant

LOCATION: Summit County/Town of Silverthorne
REACH: 2.2.3
STATION: 225+00 to 258+00
SHEET: 9
REPRESENTATIVE STUDY SITE 6

This section of the Blue River lies within Reach 2.2.3 and spans approximately 3,300 feet from Station 225+00 east of a gravel pit pond near State Highway 9, to Station 258+00 downstream of Sage Creek Canyon Drive. Portions of this section of the Blue River are located on private lands and USFS-managed lands. A public access and parking area is located off State Highway 9 between Mile Posts 105 and 106, opposite river station 247+50.

N ear Station 245+00 Looking Downstream

This section of the Blue River can be characterized by Study Site 6, located on the Eagles Nest Ranch immediately downstream. The Blue River The floodplain is wide, typically 500 to 1,500 feet, and encompasses a reclaimed gravel pit pond, remnant oxbows, an active side channel, and wetland vegetation. The gravel pit shown on this sheet was excavated in the mid-1980s and may have been restored with a liner, thereby eliminating any groundwater connectivity to or from the river.

Study Site 6 had long shallow pools comprising 44 percent of the habitat surveyed and 37 percent glides. The total cover is lower than Site 5, Sage Creek Canyon, and is limited to pool depth. Site 6 is the first site where cobble comprises the majority of substrate (70 percent) and gravels are present (10 percent) and available for spawning. The channel planform includes several side channels with wetlands and a wide, unconfined floodplain.

Near Station 245+00 Looking Upstream

This section of the river appears to have retained much of its morphology compared to the 1954 aerial imagery, including several side channel channels and a wide floodplain. Vegetation density appears to have increased in the side channels, creating a prevalent single-thread channel. There appear to be seeps and the presence of beaver ponds along the far east side of the floodplain which can be seen in both today's imagery as well as 1954 imagery.

Summary of Analyses and Key Considerations

- The approximate length of the river on this plan sheet is 3,300 ft with an estimated average slope of 0.7 percent and a top width of 42 to 58 ft at 73 cfs as measured at Study Site 6.
- The habitat analysis is characterized by Study Site 6 which indicates the presence of long shallow pools comprising 44 percent of the habitat surveyed and 37 percent glides.
- The FACStream analysis for Reach 2.2.3 indicates a 'mild degree of impairment' with low scores in water quality and biotic structure variables and high scores in the stability variable. There is an overall improvement in the flow and sediment variables compared to the upstream Subreaches.

Restoration Recommendations

Restoration recommendations focus on narrowing the river and adding in-channel habitat.

1. Consider the addition of boulder clusters and large woody debris to diversify habitat within the channel and along the banks, and to help sort and retain spawning gravels should they be added.
2. Consider modifying channel flow splits to confine the low flows to one of the side channels between Stations 225+00 and 241+00.

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SHEET 9

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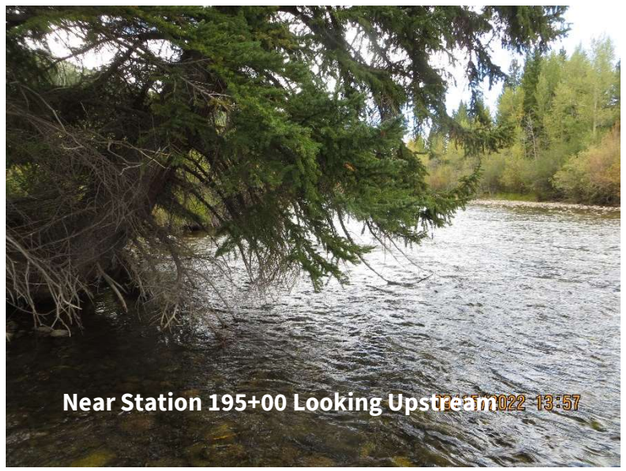
Edited: 7/17/2023 User: btrabant

LOCATION: Summit County
REACH: 2.2.3
STATION: 193+00 to 225+00
SHEET: 10
REPRESENTATIVE STUDY SITE 6

This section of the Blue River lies within Reach 2.2.3 and spans approximately 3,200 feet from Station 193+00 approximately 1,000 feet downstream of the Eagles Nest Ranch to Station 225+00 approximately 1,600 feet upstream of the Eagles Nest Ranch. Portions of this section of the Blue River are within USFS-managed lands.

Study Site 6 is located in this section of the Blue River, immediately downstream of the Eagles Nest Ranch. Long shallow pools comprise 44 percent of the habitat surveyed, 37 percent are glides, and the remaining 19 percent are riffles. The total cover is lower than Site 5, Sage Creek Canyon, and is limited to pool depth. Site 6 is the first site where cobble comprises most of the substrate (70 percent) and gravels are present (10 percent) and available for spawning. Some of the gravel material may be generated from the unstable banks along the east side of the channel immediately upstream of the ranch.



The Blue River, up and downstream of the Study Site appears to be wider and shallower than the Study Site, due to fewer cobble bars but retains habitat features, including pools, glides, and riffles with cobble bars and vegetation along the banks. The floodplain is typically 500 to 800 feet wide and encompasses remnant oxbows and wetland vegetation. Immediately west of the river floodplain is the Eagles Nest Ranch with low-lying channel banks and agricultural fields. Remnant oxbows in the agricultural fields between the river and State Highway 9 are visible in aerial imagery which shows the floodplain was significantly wider either before Dillon Reservoir was constructed and/or before the conversion to agricultural fields.

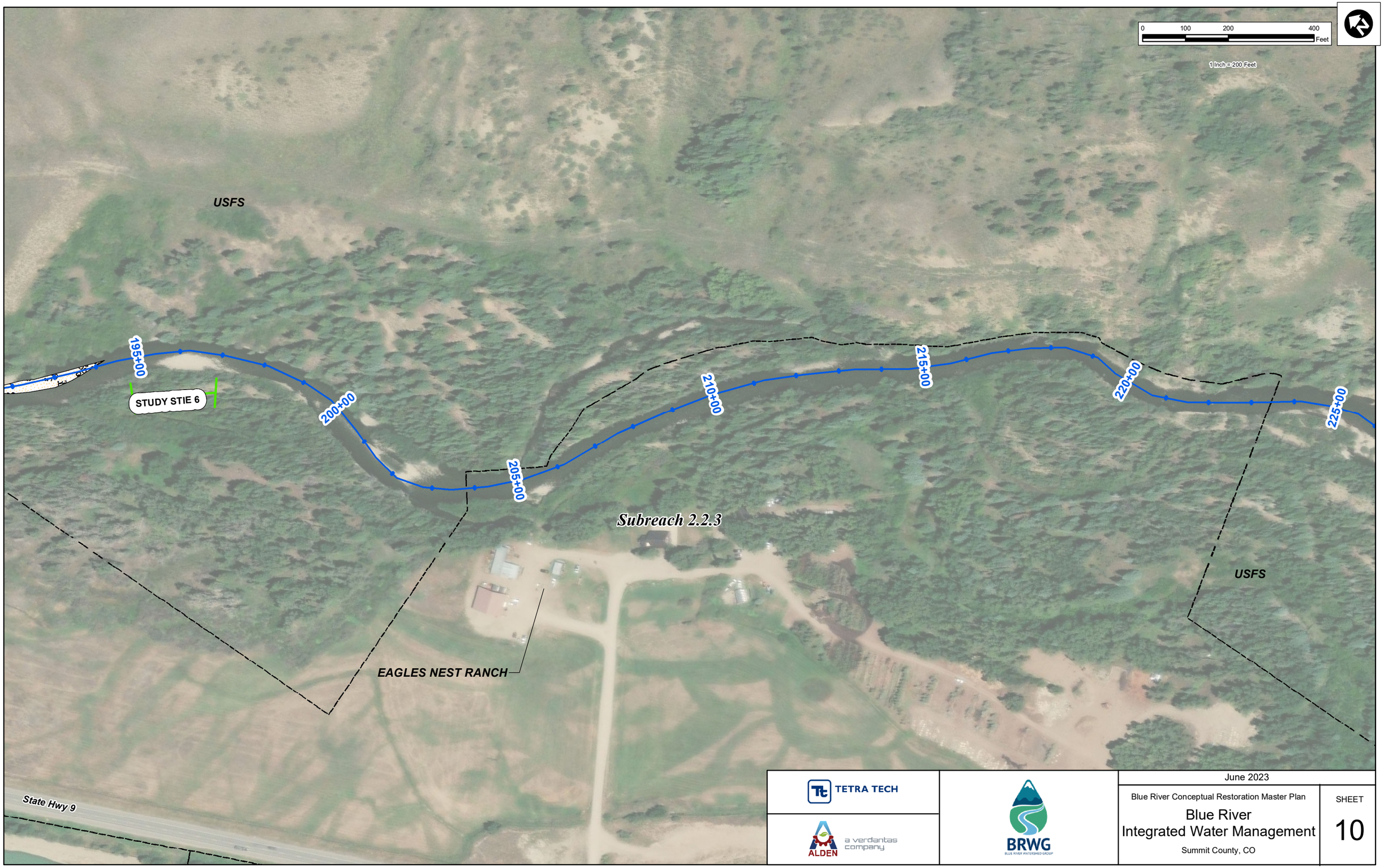
Summary of Analyses and Key Considerations

- The approximate length of the river on this plan sheet is 3,200 feet with an estimated average slope of 0.6 percent to 0.7 percent and a top width of 42 to 58 ft at 73 cfs measured at Study Site 6.
- The habitat analysis is characterized by Study Site 6 which indicates the presence of long shallow pools comprising 44 percent of the habitat surveyed and 37 percent glides. There is a trend of increasing flow due to the contributions from tributaries. However, the channel is slightly wider than the upstream reaches and the presence of pools and the depths drop slightly.
- Based on a review of the aerial imagery for this section of the river, there are some areas that have no cobble bars and is wider than characterized by Study Site 6.
- The FACSstream analysis for Reach 2.2.3 indicates a 'mild degree of impairment' with low scores for the water quality and biotic structure variables and high scores for stability and overall improvements in the flow and sediment variables compared to the upstream Subreaches.

Restoration Recommendations

Restoration recommendations include the following:

1. Consider the addition of boulder clusters and large woody debris to diversify habitat within the channel and along the banks, and to help sort and retain spawning gravels should they be added.
2. Enhance pool depths.
3. Investigate additional sections of this Subreach that could benefit from point bars to narrow the low-flow channel



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Blue River Integrated Water Management

Summit County, CO

SHEET 10

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LOCATION: Summit County
REACH: 2.2.3
STATION: 163+00 to 193+00
SHEET: 11
REPRESENTATIVE STUDY SITE 6

This section of the Blue River lies within Reach 2.2.3 and spans approximately 3,000 feet from Station 163+00 opposite the driveway to Peaks Materials off State Highway 9, to 1,000 feet upstream of a private residence. Portions of this section of the Blue River are within USFS-managed lands. The remainder is primarily privately owned land.

Near Station 195+00 Looking downstream

This reach is characterized by Study Site 6 with long shallow pools comprising 44 percent of the habitat surveyed and glides comprising 37 percent. The total cover is lower than Site 5, Sage Creek Canyon, and is limited to pool depth. Site 6 is the first site where cobble comprises the majority of the substate (70 percent), and gravels are present (10 percent) and available for spawning. Some of this material may be generated from the unstable banks along the east side of the channel upstream of Study Site 6. The Blue River at this location is wider and shallower than the upstream sections but retains habitat features, including pools, glides, and riffles with cobble bars and vegetation along the banks. This portion of the Blue River appears to be wider and shallower than the Study Site, due to fewer cobble bars, but retains habitat features, including pools, glides, and riffles with cobble bars and vegetation along the banks.

There is a gravel pit pond 200 feet west of the river, paralleling the river for approximately 1,500 feet. A review of historical aerial photography indicates the pond was constructed sometime after 1985 and is a remnant gravel pit. Because this gravel pit was restored after 1985 it was likely lined, in compliance with Colorado's gravel pit restoration requirements, and as such would not be hydraulically connected to the Blue River via groundwater. The floodplain ranges between an estimated 500 feet to over 1,000 feet wide (FEMA, 2018) and encompasses the river, ponds, old remnant oxbows, and dense wetland vegetation adjacent to the river.

Summary of Analyses and Key Considerations

- The approximate length of the river on this plan sheet is 3,000 feet with an estimated average slope of 0.6 percent to 0.7 percent and a top width of 42 to 58 ft at 73 cfs measured at Study Site 6.
- The habitat analysis characterized by Study Site 6 indicates the presence of long shallow pools comprising 44 percent of the habitat surveyed and 37 percent glides, however, based on a review of the aerial imagery there is a lack of cobble bars in this section of the river and it is likely wider than characterized by Study Site 6.
- There is a trend of increasing flow due to the contributions from tributaries. However, the channel is slightly wider than the upstream reaches and thus the presence of pools and the depths are likely lower than indicated at Study Site 6.
- The FACStream analysis for Reach 2.2.3 indicates a 'mild degree of impairment' with low scores for the water quality and biotic structure variables and high scores for stability and overall improvements in the flow and sediment variables compared to the upstream Subreaches.

Restoration Recommendations

Restoration recommendations include the following:

1. Consider the addition of boulder clusters and large woody debris to diversify habitat within the channel and along the banks, and to help sort and retain spawning gravels should they be added.
2. Enhance pool depths.
3. Add point bars to narrow channel.

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SHEET 11

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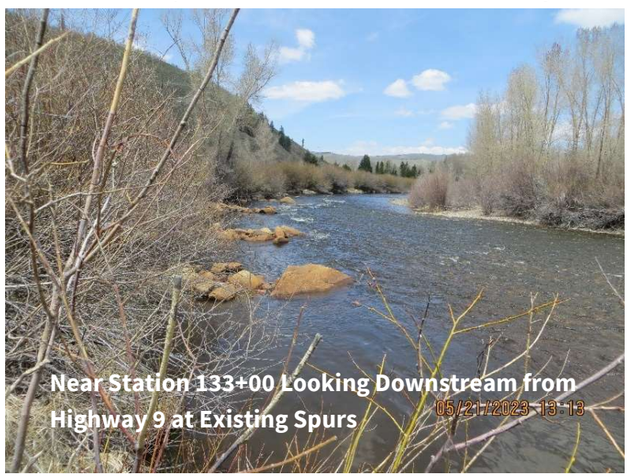
LOCATION: Summit County
REACH: 2.2.3
STATION: 130+00 to 163+00
SHEET: 12
REPRESENTATIVE STUDY SITE 6

This section of the Blue River lies within Reach 2.2.3 and spans approximately 3,300 feet from Station 130+00, 200 feet upstream of CR 1870, to Station 163+00 opposite the driveway to Peaks Materials off State Highway 9. This section of the Blue River is located on both private and USFS-managed lands.


Near Station 133+00 Looking Upstream from Highway 9

The river from Stations 134+00 to 163+00 is characterized by Study Site 6, with long shallow pools comprising 44 percent of the habitat surveyed and glides comprising 37 percent. The total cover is lower compared to Site 5, Sage Creek Canyon and is limited to pool depth. Study Site 6 is the first site where cobble comprises the majority of the substrate (70 percent) and gravels are present (10 percent) and available for spawning.

There is a gravel pit pond 200 feet west of the river, paralleling the river for approximately 1,500 feet. A review of historical aerial photography indicates the pond was constructed sometime after 1985 and is a remnant gravel pit. Because this gravel pit was restored after 1985 it was likely lined in compliance with Colorado's gravel pit restoration requirements and as such would not be hydraulically connected to the Blue River via groundwater.



The floodplain ranges between an estimated 500 feet to over 1,000 feet wide (FEMA, 2018) and encompasses the river, ponds, old remnant oxbows, and dense wetland vegetation adjacent to the river. Between

At Station 133+00 the river and floodplain begin to narrow, moving downstream, due to bedrock outcrop and State Highway 9 to the west and topography to the east. The river takes a sharp bend immediately adjacent to State Highway 9. Rock spurs have been constructed along the outside bend which serve to deflect flows away from the riverbanks and State Highway 9. Upon inspection, the spurs, to date, appear to be stable and performing the intended purpose.

Summary of Analyses and Key Considerations

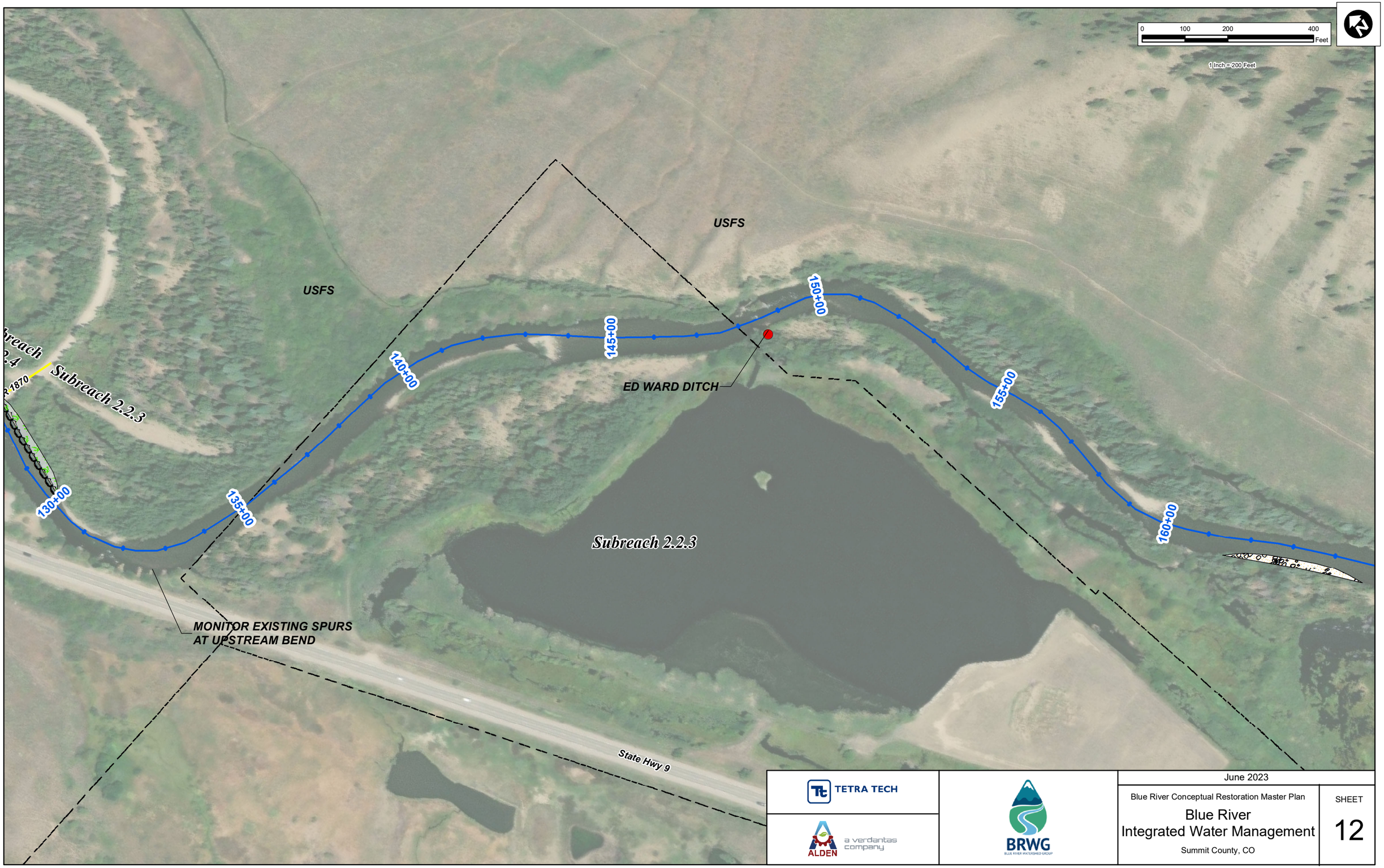
- The approximate length of the river on this plan sheet is 3,300 feet with an estimated average slope of 0.6 percent to 0.7 percent and a top width of 42 to 58 ft at 73 cfs measured at Study Site 6.
- The habitat analysis is characterized by Study Site 6 which indicates the presence of long shallow pools comprising 44 percent of the habitat surveyed and 37 percent glides. There is a trend of increasing flow due to the contributions from tributaries. However, upstream of Station 134+00, the channel is slightly wider than the upstream reaches and the presence of pools and the depths drop slightly. Between Station 130+00 and 134+00 the channel begins to narrow and veers to the north due to a bedrock outcrop.
- Based on a review of the aerial imagery there is a lack of cobble bars in this section of the river and is likely wider than characterized by Study Site 6.

- The FACStream analysis for Reach 2.2.3 indicates a 'mild degree of impairment' with low scores in water quality and biotic structure variables and high scores in stability and overall improvements in the flow and sediment variables compared to the upstream Subreaches.

Restoration Recommendations

Restoration recommendations include the following:

1. Consider the addition of boulder clusters and large woody debris to diversify habitat within the channel and along the banks, and to help sort and retain spawning gravels should they be added.
2. Enhance pool depths.
3. Monitor the integrity of spurs and bank conditions adjacent to the Highway.
4. Add point bars to narrow the channel.



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SHEET 12

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LOCATION: Summit County
REACH: 2.2.4
STATION: 97+00 to 130+00
SHEET: 13

REPRESENTATIVE STUDY SITE 5

This section of the Blue River lies within both Reach 2.2.3 and 2.2.4 spanning approximately 3,300 feet from Station 97+00 at a point mid-way between CR 1870 and 1871 (shown on sheet 14), to the bridge at CR 1870. This section of the Blue River is located on both private and USFS-managed lands.

Near Station 127+00 Looking Downstream at Diversion Structure

The Blue River valley bottom and floodplain narrow through this reach primarily due to rock outcrops to the west and hilly terrain to the east. The floodplain is typically 400 to over 1,000 feet wide and encompasses a remnant oxbow and wetland vegetation. This section of the Blue River does not include a study site and there is evidence to suggest that adjacent study sites are not applicable. This site is, however, similar to the Blue River at Site 5 at Stations 269+00 to Station 290+00 shown on sheet 8 where the floodplain is narrow, confined to the west by a rock outcrop and State Highway 9, and hilly terrain to the east. Riffle habitat at Site 5 dominates the features (44 percent) with pools making up approximately 30 percent of the stream reach. The channel is a single thread with cobble bars and vegetation along the banks. The substrate is slightly embedded due to sediment additions from winter sanding operations on State Highway 9.

Near Station 112+00 Looking Upstream at Island Split

There is one large pond east of the river and floodplain. This pond appears to have a spillway discharging into a side channel between Stations 109+00 and 119+00. There are large unvegetated cobble deposits present at this discharge point which may be in part due to the spillway and pond. A review of available aerial imagery indicates a notable increase in unvegetated gravel bars up- and downstream of the spillway. A more detailed analysis would be required to determine the causes of these deposits and possible impacts if any from the pond.

A drop structure is present immediately downstream of the CR 1870 bridge at Station 126+20. The drop structure is in a wide section of the river and has resulted in deposition immediately downstream.

Immediately upstream of the CR 1870 bridge the right channel bank is degraded and notably wider compared to upstream. There is a 500 stretch of the river between Stations 112+00 and 117+00 that abuts State Highway 9, confined by bedrock outcrop. Here the river is narrower and the banks have been stabilized with riprap. There is an existing gravel bar near Station 116+50 that nearly spans the channel. This bar should be shaved, or narrowed, to allow for a wider channel section adjacent to State Highway 9 and this critical bend in the river.

There is evidence of stream restoration from Station 105+00 to Station 95+00. Most of the observable restoration consists of boulder cluster placement and possibly wood placement.

Summary of Analyses and Key Considerations

- The approximate length of the river on this plan sheet is 3,300 feet with an estimated average slope of 0.6 percent and a top width of 55 to 73 ft at 73 cfs measured at Study Site 5.
- The habitat analysis can be characterized by Study Site 5 which indicates the riffle habitat dominates the features (44 percent) and pools make up approximately 30 percent of the stream reach. The channel is a single thread with cobble bars and vegetation along the banks and the substrate is likely to be slightly embedded due to sediment additions from winter sanding operations on State Highway 9.
- The FACStream analysis for Reach 2.2.4 indicates a 'mild degree of impairment' with low scores in water quality and biotic structure variables and a high score in stability. Scoring for flow and sediment variables continues to increase compared to the upstream Subreaches, however, the floodplain variable is lower than the upstream reaches due to encroachments and tall banks that reduced floodplain accessibility and overbank flooding.

Restoration Recommendations

Several measures should be considered to improve the channel morphology, the aquatic habitat, and bank stability.

1. Remove the grade control structure at Station 126+25, regrade and narrow the channel, and reconstruct the right channel bank.
2. Partially excavate or shave the existing gravel bar at station 116+50 to increase capacity at the narrow bend near the highway. Consider additional bank protection such as bank armoring, flow deflectors, or spurs on the left bank immediately adjacent to the highway.
3. Add a point bar to narrow the channel upstream of CR 1870.

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SHEET 13

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LOCATION: Summit County
REACH: 2.2.4 and 2.2.5
STATION: 67+00 to 97+00
SHEET: 14
REPRESENTATIVE STUDY SITE 5

This section of the Blue River lies within Reaches 2.2.4 and 2.2.5 split by CR 1871 and spans approximately 3,000 feet from Station 67+00 to 97+00. CR 1871 is in the middle of the sheet near station 83+50. The Blue River valley bottom and floodplain are narrow through most of this reach primarily due to rock outcrops and State Highway 9 to the west, and hilly terrain to the east. Most of the land within this reach of the river is privately owned except a narrow band of land managed by USFS downstream of CR 1871. There is a large tract of land to the east in agricultural use.

There are no ponds immediately adjacent to the river. On the downstream end of this reach, the valley bottom and river widen and the river diverges slightly to the east. The floodplain is narrow, between 300 and 400 feet wide, and the channel is single-thread with wetland vegetation in the overbanks. Between Stations 77+50 and 82+00 the river and highway are close, separated by a constructed wall in the overbanks and riprap channel banks.

Near Station 80+00 Looking Upstream along Highway 9

Unvegetated cobble bars are present upstream of the bridge at CR 1871. There is evidence of stream restoration throughout this section of the Blue River, primarily consisting of boulder clusters and wood placement. Monitoring of these restoration efforts provides an opportunity to assess their effectiveness, stability, and responses in aquatic health.

This section of the Blue River does not include a study site and there is evidence to suggest that the downstream study site is not applicable. This site is, however, similar to the Blue River at Site 5 at Stations 269+00 to Station 290+00 shown on sheet 8 where the floodplain is narrow, confined to the west by a rock outcrop and State Highway 9, and hilly terrain to the east. Riffle habitat at Site 5 dominates the features (44 percent) with pools making up approximately 30 percent of the stream reach. The channel is a single thread with evidence of minor braiding in the narrow floodplain. The substrate is slightly embedded due to sediment additions from winter sanding operations on State Highway 9.

Downstream of CR 1871 the channel is straight and narrow and riprap has been installed along the west channel bank for protection adjacent to State Highway 9. At Station 73+00 the channel widens and splits around an island.

Summary of Analyses and Key Considerations

- The approximate length of the river on this plan sheet is 3,000 feet with an estimated average slope of 0.6 percent and a top width of 55 to 73 ft at 73 cfs measured at Study Site 5.
- The habitat analysis can be characterized by Study Site 5 which indicates the riffle habitat dominates the features (44 percent) and pools make up approximately 30 percent of the stream reach. Cobble is the dominant substrate with gravel, sand, and silt in the areas of lower velocity associated with small pools along the right bank.
- The FACStream analyses for Reach 2.2.4 and 2.2.5 indicate a 'mild degree of impairment' due to low scores for riparian and physical structure. Watershed variables continue to improve compared to upstream reaches.

Restoration Recommendations

Several measures should be considered to improve the channel morphology and improve pool depth.

1. Narrow channel downstream of CR 1871 at Station 73+00 using a point bar. Construct a pool opposite the point bar.
2. Consider the addition of boulder clusters and large woody debris downstream of CR 1871 to diversify habitat within the channel and along the banks, and to help sort and retain spawning gravels should they be added.
3. Monitor restoration efforts upstream of CR 1871.
4. Revegetate along channel banks in areas lacking cover.
5. Reseed steep upper channel banks.
6. Monitor the integrity of the riprap channel bank adjacent to the Highway.

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SHEET 14

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Edited: 7/17/2023 User: btrabant

LOCATION: Summit County
REACH: 2.2.5
STATION: 33+00 to 67+00
SHEET: 15
REPRESENTATIVE STUDY SITE 7

This section of the Blue River lies within Reach 2.2.5 and spans approximately 3,400 feet from Station 33+00, downstream of CR 1452 to Station 67+00, 700 feet upstream of the USFS public access parking lot near Mile Marker 109. The bridge at CR 1452 is located in the downstream third of this reach near station 45+25.

Upstream end of Study Site 7

Most of this section of the Blue River is on land managed by the CPW and the USFS including the popular public access. The channel is wide compared to the upstream sites, particularly between Station 48+00 and 58+00, and channel bar formation is less evident than the upstream reaches at low flows. The left overbank and the channel show evidence of gravel and boulder deposits or mounds, lack of organic material, and little vegetation except for newly recruited lodgepole pine. Some of these deposits appear similar to the deposits created by gravel mining, however, further review indicates that this area may have been exposed at one time to a debris or avalanche event from the west drainage, resulting in these gravel deposits and contributing to an overly wide channel.

Downstream of Study Site 7 near CR 1452

The floodplain shown on this sheet is one of the wider floodplains between Dillon Dam Reservoir and the Blue River Campgrounds ranging up to 1,200 feet. A remnant oxbow channel to the east, seen in the 1954 aerial map, has since been converted to a pond, seen in current (2019) aerial imagery. The river and pond are hydraulically connected and support a floodplain with oxbows and wetland vegetation.

Study Site 7 is located in this reach. The habitat analysis at Study Site 7 indicates this section of the Blue River is overly wide and lacks connection with the floodplain that would otherwise provide nutrients and velocity shelters for various life stages of fish populations. While 36.3 percent of this site is comprised of pools, the overly wide channel and shallow pools provide no cover, except for woody debris and willows associated with the pool edge. Glides (27.7 percent) and riffles (36.0 percent) comprise the remaining habitat features. Cobble is the dominant substrate with some gravel, sand, and silt in the areas of lower velocity associated with small pools along the right bank.

Summary of Analyses and Key Considerations

- The approximate length of the river on this plan sheet is 3,400 ft with an estimated average slope of 0.6 percent and a top width of 42 to 58 ft. Widths noted were measured with 76 cfs, measured at Study Site 7.
- The habitat analysis for Subreach 2.2.5 indicates this is one of the wider reaches in this study. Pools are present but shallow and with poor to no cover. Some spawning gravels are present consistent with the upstream reaches.
- The FACStream analysis for Reach 2.2.5 indicates a 'mild degree of impairment' due to low rankings for the watershed and stream-scaled variables. The riparian stream morphology and physical structure variables decrease compared to Reach 2.2.4 the result of the debris flow impacts.

Restoration Recommendations

Restoration recommendations are limited to narrowing the river and improving pool depth as well as delineating and stabilizing access locations to reduce pedestrian impacts to the floodplain overbank vegetation.

1. Construct river trails in the areas depicted on the plans.
2. Narrow channel using cobble point bars.
3. Deepen existing pools and construct new pools on outer banks.
4. Consider the addition of wood, boulder clusters, and native vegetation along banks.
5. Revegetate and stabilize damaged channel banks.

0 100 200 400 Feet

1 Inch = 200 Feet

35+00

40+00

45+00

50+00

55+00

60+00

65+00

STUDY STIE 7

Subreach 2.2.5

DNR

USFS

ROCK CREEK

CR 1452

State Hwy 9

Co Rd 1872

TETRA TECH

ALDEN a verdantas company

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SHEET 15

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Edited: 7/17/2023 User: btrabant

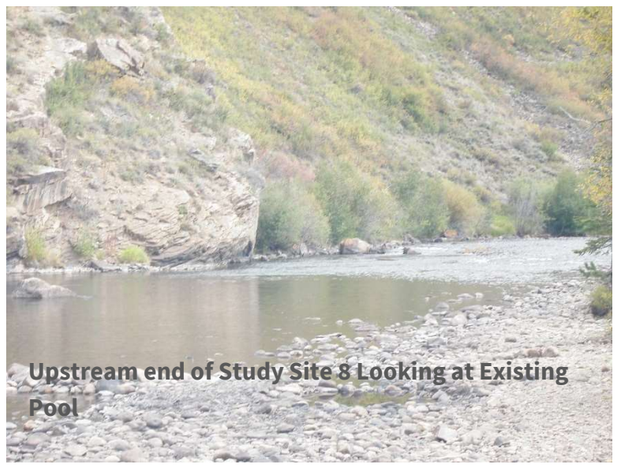
LOCATION: Summit County
REACH: 2.2.6
STATION: 0+00 to 33+00
SHEET: 16

REPRESENTATIVE STUDY SITE 8


Downstream end of Study Site 8

This section of the Blue River lies within Reach 2.2.6 and spans approximately 3,300 feet from Station 0+00 downstream of the Blue River campground to 33+00, 1,200 feet downstream of CR 1452. This site is located within USFS-managed lands including the Blue River Campground. The river at this site is wide with one deep pool formation. Campground use and pedestrian traffic to and from the river have impacted the left channel and overbanks. The upstream right channel bank is comprised of bedrock outcrops. Further downstream the right bank transitions to a wetlands bar and the channel widens. Channel bar formation is less evident than the upstream reaches at low flows. There is evidence that at one time a debris flow or avalanche occurred from a drainage to the west, forming the fan where the upper campground is located.

Study Site 8 is located in this reach. Glides (46.5 percent) and riffles (39.4 percent) dominate the habitat features. Glides are shallow and provide little cover. One large pool is present, associated with a bedrock outcrop on the right bank. This pool provides the only cover observed at this site although the residual pool depth is much better than in the upstream pools. The one large pool has several medium to large boulders providing both in-stream and boulder cover pool habitat. Overall, the cover component is lower than in upstream narrower channels, however, boulders in the glides could provide additional cover at higher flows. Spawning-sized gravels are available in small areas of the glide and riffle habitat.


Upstream end of Study Site 8 Looking at Existing Pool

Downstream of this section of the Blue River CPW has recommended additional restoration. The reach length is approximately 500-foot section. This is shown on the channel plans as a placeholder for future consideration.

Summary of Analyses and Key Considerations

- The approximate length of the river on this plan sheet is 3,300 ft with an estimated average slope of 0.7% and a top width of 76 ft with flows of 88 cfs measured at Study Site 8.
- The habitat analysis for Subreach 2.26 indicates this is a wide section of the river. Pools are absent except for one large pool associated with a bedrock outcrop. Glides comprise 46 percent and riffles 39 percent of the remaining habitat
- The FACStream analysis for Reach 2.2.6 indicates a 'mild to significant degree of impairment' due to low scores for the watershed, riparian and stream-scaled variable and high scores for stability and biotic structure. Physical structure scored low primarily due to the bank and overbank impacts from the campground.

Restoration Recommendations

Restoration recommendations are limited to narrowing the river and improving pool depth as well as delineating and stabilizing access locations to reduce pedestrian impacts to the floodplain overbank vegetation.

1. Construct trails in the areas depicted on the plans to direct foot traffic to the river. Use gravel to stabilize the trail surface and minimize erosion. Include steps along the steeper bank sections.
2. Construct bank protection near station 12+50 on the left bank.
3. Reseed the upper channel banks.
4. Create pool habitat and enhance the cover.
5. Consider the addition of boulder clusters and large woody debris to diversify habitat within the channel and along the banks, and to help sort and retain spawning gravels should they be added.

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BLUE RIVER WATERSHED GROUP

June 2023

Blue River Conceptual Restoration Master Plan

Blue River Integrated Water Management

Summit County, CO

SHEET 16

File Location: Z:\Project Files\SA-TZ\TetraTeFC\15824 - BRIWMP Phase 3\Working\GIS\Maps\Basemap.mxd

Edited: 7/17/2023 User: btrabant

APPENDIX B

Stream Health Assessments

APPENDIX B

Stream Health Assessment

B.1. PURPOSE

A stream health assessment was conducted to rate functional ecological conditions in the project reach using the level of departure from a reference reach. This assessment combines the morphological overview, the habitat assessment, hydrologic and hydraulic analyses, and field observations in a comparable format to identify some of the more impactful factors to the health of the Blue River and to inform on the prioritization of restoration.

B.2 PROJECT REACH

The Project Reach extends from the outlet of Dillon Reservoir to the USFS Blue River Campground, approximately 10 miles, divided into nine secondary Subreaches (2.1.1-2.1.3, and 2.2.1-2.2.6) as shown in **Figure 2** of the report. The Subreaches with similar planform and physical conditions are grouped together to aid in the assessments and site descriptions. These Subreaches are described in detail in the main body of the report.

B3. METHODOLOGY

This assessment utilizes the framework outlined in the Functional Assessment of Colorado Streams (FACStream) version 1.0 (Beardsley et al. 2015). FACStream is a reach-scale functional assessment tool that rates the functional conditions of a stream using the level of departure from a reference reach. A reference reach is defined as a river segment that represents a stable channel within a particular valley morphology, generally in an unimpacted condition. FACStream uses ten ecological variables and can be employed as a reconnaissance (Level 1), routine (Level 2), or intensive (Level 3) effort.

- Level 1 relies on the documentation of observable factors
- Level 2 routine assessment includes observable factors and review of existing information
- Level 3 includes observable factors, review of existing information, and the use of predictive models to further document the degree of impairment and loss of function

The Blue River project reach was originally assessed using a Level ”1 to 2” protocol utilizing observable factors and to the extent practical, existing available reports and data (Tt 2021). Following the habitat assessment and field reconnaissance conducted in 2022 (Tt, 2022 and Tt, 2023) the assessment was updated, incorporating the data, surveys, and additional observable factors gathered during the field reconnaissance. Variables were assessed generally following the guidance outlined in FACStream for the ten stream health variables summarized in Table B-1**.** These ten variables are rated on a report card grading scale relative to the degree of functional impairment or deviation from the reference standard (Table B-2). The scores for these variables are combined as a weighted average to give an overall reach condition score referred to as the functional capacity index (FCI). Details on the scoring guidelines can be found in the FACStream 1.0 (Beardsley et al., 2015).

FACStream indicates the reference standard should be thought of as “the river in its state of natural dynamic equilibrium or ‘optimal‘ functioning river system, likely present before settlement in or around the 1800s.” The use of a reference standard establishes a consistent benchmark against which to measure the different FACStream scores and provides a consistent definition of a reference standard to enable universal scoring guidelines.

Table B-1. FACStream Variables

Scores	
A	Negligible
B	Mild
C	Significant
D	Severe
F	Profound or unsustainable

Table B-2. FACStream Scoring: Degree of Deviation from Reference Reach

Scale	Variable		Metrics
Watershed	V_{hyd}	Flow Regime	Peak flow, base flow, rate of change
	V_{sed}	Sediment Regime	Land and channel erosion; transport through the reach
	V_{chem}	Water Quality	Temperature, nutrients, metals, others
Riparian	V_{con}	Floodplain Connectivity	Extent of lateral flooding and duration
	V_{veg}	Riparian Vegetation	Vegetation banks and overbanks, diversity, connectivity
	V_{deb}	Debris	Large wood, soil and duff, organic matter
Stream	V_{morph}	Stream Morphology	channel planform/dimensions, profile
	V_{stab}	Stability	channel stability and ability to recover
	V_{str}	Physical Structure	Bank and bed structures (rock and wood) supporting aquatic life
	V_{bio}	Biotic Structure	Macroinvertebrates, fishery

FACStream utilizes three stream classification systems: Rosgen Stream Classification, Stream Evolution Model Classification, and Montgomery-Buffington Classification.

> *Selecting the appropriate reference standard when doing a FACStream assessment begins with defining the reference morphological type of the assessment reach. On many reaches, the stream type may have been altered either by direct human manipulation or by channel evolution following some anthropogenic disturbance. Because of these changes, selecting the appropriate reference stream type requires some knowledge about local history and general trends in stream evolution. FACStream provides some basic guidance following the principle that certain stream types naturally occur in certain process domains (Beardsley et al. 2015).*

Based on guidance outlined in FACStream, and a broad understanding and familiarity with the watershed, an overall reference standard could be described as a single thread channel with areas of bar/island braiding. The overall slope is less than 1% and sinuosity is low. The general channel planform and alignment have changed little since the construction of the Dillon Reservoir dam, although vegetation and floodplain encroachment are visible when comparing pre-dam conditions to today’s imagery. Vegetation and floodplain encroachment have likely contributed to reducing the bar/island braiding. A summary of results by variable is discussed in the main body of the report. Rating tables for each variable by Subreach are provided in Tables B-3 through B-11.

Table B-3. FACStream Scoring by Variable Subreach 2.1.1

FACStream Summary Subreach 2.1.1					
Scale	Variable		Grade	Degree of Impairment	Confidence
Watershed	V_{hyd}	Flow Regime	D	Severe	H
	V_{sed}	Sediment Regime	C	Significant	H
	V_{chem}	Water Quality	C-	Significant/severe	H
Riparian	V_{con}	Floodplain Connectivity	C-	Significant/severe	H
	V_{veg}	Riparian Vegetation	C	Significant	H
	V_{deb}	Debris	C-	Significant/severe	H
Stream	V_{morph}	Stream Morphology	B	Mild	H
	V_{stab}	Stability	B	Mild	H
	V_{str}	Physical Structure	B	Mild	H
	V_{bio}	Biotic Structure	D	Severe	H
Overall FCI			Reach Condition Score	Degree of Impairment of Reach	
0.48			C	Significant	

Table B-4. FACStream Scoring by Variable Subreach 2.1.2

FACStream Summary Subreach 2.1.2					
Scale	Variable		Grade	Degree of Impairment	Confidence
Watershed	V_{hyd}	Flow Regime	D	Severe	H
	V_{sed}	Sediment Regime	C	Significant	H
	V_{chem}	Water Quality	C-	Significant/severe	H
Riparian	V_{con}	Floodplain Connectivity	C-	Significant/severe	H
	V_{veg}	Riparian Vegetation	C	Significant	H
	V_{deb}	Debris	C-	Significant/severe	H
Stream	V_{morph}	Stream Morphology	C-	Significant/severe	H
	V_{stab}	Stability	B	Mild	H
	V_{str}	Physical Structure	C-	Significant/severe	H
	V_{bio}	Biotic Structure	D	Severe	H
Overall FCI			Reach Condition Score	Degree of Impairment of Reach	
0.44			C-	Significant/severe	

Table B-5. FACStream Scoring by Variable Subreach 2.1.3

FACStream Summary Subreach 2.1.3					
Scale	Variable		Grade	Degree of Impairment	Confidence
Watershed	V_{hyd}	Flow Regime	D	Severe	H
	V_{sed}	Sediment Regime	C	Significant	H
	V_{chem}	Water Quality	C-	Significant/severe	H
Riparian	V_{con}	Floodplain Connectivity	B-	Mild/significant	H
	V_{veg}	Riparian Vegetation	C+	Significant/mild	H
	V_{deb}	Debris	B-	Mild/significant	H
Stream	V_{morph}	Stream Morphology	B-	Mild/significant	H
	V_{stab}	Stability	B	Mild	H
	V_{str}	Physical Structure	C+	Significant/mild	H
	V_{bio}	Biotic Structure	D	Severe	H
Overall FCI			Reach Condition Score	Degree of Impairment of Reach	
0.50			C	Significant	

Table B-6. FACStream Scoring by Variable Subreach 2.2.1

FACStream Summary Subreach 2.2.1					
Scale	Variable		Grade	Degree of Impairment	Confidence
Watershed	V_{hyd}	Flow Regime	C-	Significant/severe	H
	V_{sed}	Sediment Regime	C	Significant	H
	V_{chem}	Water Quality	C	Significant	H
Riparian	V_{con}	Floodplain Connectivity	B+	Mild/negligible	H
	V_{veg}	Riparian Vegetation	B	Mild	M
	V_{deb}	Debris	B	Mild	H
Stream	V_{morph}	Stream Morphology	B	Mild	H
	V_{stab}	Stability	B+	Mild/negligible	H
	V_{str}	Physical Structure	B	Mild	H
	V_{bio}	Biotic Structure	C	Significant	H
Overall FCI			Reach Condition Score	Degree of Impairment of Reach	
0.62			B-	Mild/significant	

Table B-7. FACStream Scoring by Variable Subreach 2.2.2

FACStream Summary Subreach 2.2.2					
Scale	Variable		Grade	Degree of Impairment	Confidence
Watershed	V_{hyd}	Flow Regime	C	Significant	H
	V_{sed}	Sediment Regime	C	Significant	H
	V_{chem}	Water Quality	C	Significant	H
Riparian	V_{con}	Floodplain Connectivity	B+	Mild/negligible	H
	V_{veg}	Riparian Vegetation	B+	Mild/negligible	H
	V_{deb}	Debris	B	Mild	H
Stream	V_{morph}	Stream Morphology	B	Mild	H
	V_{stab}	Stability	B+	Mild/negligible	H
	V_{str}	Physical Structure	B	Mild	H
	V_{bio}	Biotic Structure	C+	Significant/mild	H
Overall FCI			Reach Condition Score	Degree of Impairment of Reach	
0.64			B-	Mild/significant	

Table B-8. FACStream Scoring by Variable Subreach 2.2.3

FACStream Summary Subreach 2.2.3					
Scale	Variable		Grade	Degree of Impairment	Confidence
Watershed	V_{hyd}	Flow Regime	B-	Mild/significant	H
	V_{sed}	Sediment Regime	C+	Significant/mild	H
	V_{chem}	Water Quality	C+	Significant/mild	H
Riparian	V_{con}	Floodplain Connectivity	B	Mild	H
	V_{veg}	Riparian Vegetation	B	Mild	H
	V_{deb}	Debris	B	Mild	H
Stream	V_{morph}	Stream Morphology	B	Mild	H
	V_{stab}	Stability	B+	Mild/negligible	H
	V_{str}	Physical Structure	B	Mild	H
	V_{bio}	Biotic Structure	C+	Significant/mild	H
Overall FCI			Reach Condition Score	Degree of Impairment of Reach	
0.66			B	Mild	

Table B-9. FACStream Scoring by Variable Subreach 2.2.4

FACStream Summary Subreach 2.2.4					
Scale	Variable		Grade	Degree of Impairment	Confidence
Watershed	V_{hyd}	Flow Regime	B-	Mild/significant	H
	V_{sed}	Sediment Regime	B-	Mild/significant	H
	V_{chem}	Water Quality	B-	Mild/significant	H
Riparian	V_{con}	Floodplain Connectivity	B-	Mild/significant	H
	V_{veg}	Riparian Vegetation	B	Mild	H
	V_{deb}	Debris	B	Mild	H
Stream	V_{morph}	Stream Morphology	B	Mild	H
	V_{stab}	Stability	B+	Mild/negligible	H
	V_{str}	Physical Structure	B	Mild	H
	V_{bio}	Biotic Structure	C+	Significant/mild	H
Overall FCI			Reach Condition Score	Degree of Impairment of Reach	
0.66			B	Mild	

Table B-10. FACStream Scoring by Variable Subreach 2.2.5

FACStream Summary Subreach 2.2.5					
Scale	Variable		Grade	Degree of Impairment	Confidence
Watershed	V_{hyd}	Flow Regime	B-	Mild/significant	H
	V_{sed}	Sediment Regime	B-	Mild/significant	H
	V_{chem}	Water Quality	B	Mild	H
Riparian	V_{con}	Floodplain Connectivity	B	Mild	H
	V_{veg}	Riparian Vegetation	C	Significant	H
	V_{deb}	Debris	B	Mild	H
Stream	V_{morph}	Stream Morphology	B-	Mild/significant	H
	V_{stab}	Stability	B+	Mild/negligible	H
	V_{str}	Physical Structure	C+	Significant/mild	H
	V_{bio}	Biotic Structure	B	Mild	H
Overall FCI			Reach Condition Score	Degree of Impairment of Reach	
0.66			B	Mild	

Table B-11. FACStream Scoring by Variable Subreach 2.2.6

FACStream Summary Subreach 2.2.6					
Scale	Variable		Grade	Degree of Impairment	Confidence
Watershed	V_{hyd}	Flow Regime	B-	Mild/significant	H
	V_{sed}	Sediment Regime	B-	Mild/significant	H
	V_{chem}	Water Quality	B	Mild	H
Riparian	V_{con}	Floodplain Connectivity	B-	Mild/significant	H
	V_{veg}	Riparian Vegetation	C	Significant	H
	V_{deb}	Debris	B	Mild	H
Stream	V_{morph}	Stream Morphology	C+	Significant/mild	H
	V_{stab}	Stability	B+	Mild/negligible	H
	V_{str}	Physical Structure	C+	Significant/mild	H
	V_{bio}	Biotic Structure	B+	Mild/negligible	H
Overall FCI			Reach Condition Score	Degree of Impairment of Reach	
0.64			B-	Mild/significant	

B4. Other Data Sources

Colorado Department of Natural Resources. Colorado Water Plan Technical Update (CWP). 2019. Water Conservation Board. Available at: https://dnrftp.state.co.us/#/CWCB/Technical%20Update%20to%20Water%20Plan/1.%20Technical%20Update%20Documentation/

Colorado Parks and Wildlife. 2020. Fishing Regulations Brochure. Colorado Parks and Wildlife.

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McMillen, LLC, Tetra Tech. 2013. Blue River Section 206 Aquatic Ecosystem Restoration, Breckenridge, Colorado. Appendix B. Engineering Report.

Google Earth was utilized to estimate valley lengths, and slopes.

1954 aerial imagery was utilized to compare riparian conditions with current conditions in Reach 2 (Grand County, CO, Bureau of Land Management, Esri, HERE, Garmin, INCREMENT P, Intermap, USGS, METI/NASA, EPA, USDA | USGS The National Map: Imagery | Trout Unlimited).

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Tetra Tech and Miller Ecological Consultants (Tt & MEC). 2022. *Blue River Integrated Water Management Plan. Assessment of Current Aquatic Habitat Hydrology and Hydraulics in the Blue River Downstream of the Dillon Reservoir Dam.* Prepared for the Blue River Watershed Group. July.

Tetra Tech, Ksqrdfish Aquatics and Alden Research Laboratory, LLC (Tetra Tech, et al.). 2023. *Blue River Integrated Water Management Plan. Assessment of Current Aquatic Habitat Hydrology and Hydraulics in the Blue River Downstream of the Dillon Reservoir Dam, Subreach 2.2.* Prepared for the Blue River Watershed Group. July.