John Carron, Ph.D.

Principal, Senior Water Resources Engineer

Professional Summary

Dr. Carron is an engineer and project manager with more than 30 years of academic and professional experience in water resources planning and engineering, simulation and optimization modeling, strategic water policy, and basin-scale systems management. He has acted as a technical advisor to the River District, State of Colorado, and the Upper Colorado River Commission on matters related to the Colorado River Compact and other components of the "Law of the River." He is an expert on Colorado River operations under the 2007 Interim Guidelines, minutes of the 1944 Treaty with Mexico, and the Drought Contingency Plan and DROA. He led the multi-phase Colorado River Risk Study for the Colorado River District examining compact compliance risks to Colorado water users. He is also assisting the Colorado River District in its evaluation of the Shoshone Power Plant and Water Rights acquisition. He is a subject expert in the ongoing *Texas v New Mexico and Colorado* (No. 141 Original) before the U.S. Supreme Court.

Education

Ph.D., Civil Engineering (Water Resources), University of Colorado, 2000

M.A., Geography, University of Colorado, 1993

B.A., Mathematics, Colorado College, 1989

Recent Project Experience

Shoshone Power Plant and Water Rights Yield Analysis, Colorado River District: In support of the River District's agreement to purchase the Shoshone Power Plant water rights and modify their decreed uses to include instream flows, Dr. Carron and Hydros performed a number of analyses using the CWCB's Upper Colorado River Basin StateMod Model (UCRBM). The evaluation included both current and future demand scenarios and investigated the impacts that the so-called "Shoshone Permanency" could have on other water users and environmental objectives in the basin. The analyses used both monthly and daily versions of the UCRBM and evaluated effects on key water uses including trans-basin diversions, Reclamation projects, the Cameo Call rights, and the 15-Mile Reach, one of the key spawning and rearing areas for endangered warm-water fish species.

Colorado River Risk Study, Colorado River District: The Colorado Basin has been in a severe drought since 2000. Various management policies and actions, including the 2007 Interim Guidelines and the 2019 Drought Contingency Plan led a consortium of west- slope stakeholders to look at in-state questions related to Colorado River Compact compliance and the potential for Demand Management actions to reduce risks to water users. The study quantified the risk of a Compact deficit under different hydrology and demand assumptions and explored potential

methods for reducing consumptive uses across users and sub-basins. Using the CWCB's CDSS tools together with Reclamation's CRSS model, various compact call and demand management scenarios were evaluated. The study outcomes provided important information for Colorado River water users and highlighted the need for ongoing collaboration within Colorado and across the basin to effectively manage the limited water supply. Phase IV of this study was completed in 2023.

Water Resources Planning, City of Westminster, Colorado: Since 2013 Hydros has been providing Water Resources Planning services to the City of Westminster. As project manager, Dr. Carron was responsible for overseeing the "knowledge transition" from the previous consultant to Hydros. The initial work involved updating and expanding a legacy water rights / water supply model that the city uses for planning and operations. The modeling tool has since been used in a number of studies including a comprehensive water infrastructure needs study, evaluation of efficiency of water right exchange operations, development of a drought response program, and demand and yield risk studies. Other services have included climate change studies, and strategic planning for optimizing usage of the city's water rights portfolio.

Umatilla River Tribal Water Rights Settlement, Westland Irrigation District: Dr. Carron is providing technical expertise for Westland Irrigation District (WID) in its negotiations with the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) to settle water rights claims and execute a trade of water rights in McKay Reservoir for Columbia River water. A RiverWare model of the Umatilla was developed by the CTUIR and is being used to simulate impacts of the proposed settlement terms. Dr. Carron is the technical representative for WID in these negotiations and is assisting the WID Board and counsel in crafting settlement terms.

Litigation Support, Rio Grande Project, New Mexico Interstate Stream Commission: Dr. Carron has been providing consulting services to the New Mexico Interstate Stream Commission for over 20 years. In 2013, Texas sued New Mexico and Colorado alleging injury due to groundwater pumping by New Mexico within the Rio Grande Project, which delivers irrigation water to users in both New Mexico and Texas and also acts as the Rio Grande Compact delivery point. Dr. Carron Provided an expert report and deposition describing surface and groundwater modeling tools that Hydros developed to simulate Project operations, including alternative operating policies, historical consumptive uses, and trends in surface water / groundwater interactions that affect river flows. The litigants have reached a tentative settlement agreement as of June 2025, and the case is now expected to settle without going to trial.

Colorado River Expert, Colorado River District, State of Colorado, Upper Colorado River Commission: Beginning in 2012 Dr. Carron provided technical engineering and modeling services related to operations in the Colorado Basin resulting from the 2007 Interim Guidelines, Mexico Treaty Minutes (319 and 323), various RODs and other operating criteria, and the Drought Contingency Planning (DCP) processes. This work was funded through the River District and conducted via the UCRC Engineering Committee on behalf of Colorado and the UCRC. Dr. Carron was instrumental in the development of the Upper Basin's DCP processes and developed reservoir operating concepts that are a central part of the Drought Response Operating Agreement. He is very familiar with Reclamation's CRSS model and has used that tool to inform

policy makers regarding proposed changes to reservoir operations and impacts of long-term drought and climate change on water supplies throughout the Colorado Basin.

Forecasting and Operational Efficiency Study, Tarrant Regional Water District (TRWD), Ft. Worth, Texas: Dr. Carron was retained by TRWD in 2008 to evaluate and make improvements to the operational policies used by the District in managing its water delivery system. TRWD utilizes a RiverWare model for both daily operational decision-making and long-term water supply planning. The project involved the development of forecasting tools utilizing global climate variable downscaling techniques coupled to statistically-based hydrology generation tools. A review of operational policies, coupled with probabilistic modeling of future conditions, led to new operational policies that are expected to save the District an average of approximately $750,000 annually in pumping costs. In 2017, TRWD again retained Hydros to perform upgrades to their forecasting tools and to evaluate operational efficiency options under proposed integrated pipeline system with the City of Dallas.

Long Term Planning Model, Lower Colorado River Authority (LCRA), Austin, Texas: Dr. Carron is the project manager for a development team implementing a RiverWare model of the LCRA system intended to replace an existing planning model (RESPONSE). This ongoing project involves development of data and rules to replicate various planning and water rights modeling activities in the Colorado River basin, including priority administration of water rights, firm yield analyses, and planning scenarios for future water development activities. We recently completed a drought response and water supply forecasting analysis for LCRA using the RiverWare model. The study examined the potential impacts of drought and climatic uncertainty on LCRA's ability to meet its water supply contracts.

Milk River and St. Mary River Accounting and Canal Operation – Montana Department of Natural Resources and Conservation (DNRC) and U.S. Geological Survey: Dr. Carron has worked with the Montana DNRC for more than 15 years on a variety of projects involving the Milk-St. Mary RiverWare model. Recent work on this project has included evaluation of compliance with the Boundary waters Treaty of 1909 between the United States and Canada, and investigation into novel approaches to allow for credit swapping and new infrastructure development to help increase beneficial use of the waters of these two river systems.

Tarrant Regional Water District (TRWD) – Water Supply Reliability Study: Dr. Carron was retained by TRWD to perform a water supply reliability evaluation for the Tarrant water supply system. The project involved use of a RiverWare model of the TRWD system and development of synthetic hydrologic data to test the reliability of TRWD's water supply system under a variety of hydrologic and forecast demand scenarios. The modeling tools were also used to evaluate and refine the District's Drought Response plan and the criteria used for initiating water conservation measures.

APPENDIX 11

Final Report (CA23044)

Shoshone Reach Instream Flow Habitat Data Analysis, Habitat Simulations and Habitat Evaluation of Colorado River from the Shoshone Diversion to the Shoshone Power Plant Outfall

Submitted to:

Peter Fleming
Colorado River District
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Submitted By:

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September 30, 2024

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Executive Summary

This report documents the evaluation of instream flows for the purpose of protecting and enhancing aquatic resources in the Shoshone Reach of the Colorado River between the point of diversion for the Shoshone Water Rights at the Shoshone diversion dam and the Shoshone Power Plant outfall. The objectives were to determine the current state of the aquatic habitat and aquatic ecosystem in the Shoshone Reach and determine expected changes to the aquatic habitat and aquatic ecosystem due to hydrologic change. The hydrologic change would be from a potential dedication of the Shoshone Hydropower Plant water rights which include a senior right for 1,250 cfs and a junior right of 158 cfs for a total of 1,408 cfs to an instream flow use. This change in water right would allow the total 1,408 cfs to remain in the river as a dedicated instream flow rather than diverted through the hydropower plant.

The instream flow analysis used the general guidelines from the Instream Flow Incremental Methodology (IFIM) which was developed by the US Fish and Wildlife Service in the late 1970s and early 1980s. IFIM is a multi-disciplinary methodology based on ecosystem principles and includes analysis of hydrology, habitat suitability criteria for species of interest, channel hydraulics and predictions of hydraulic-habitat as a function of discharge. In addition, the data from an IFIM approach can be used to interpret other ecosystem responses to change in stream flow. IFIM is specifically designed to evaluate and compare alternative flow regimes. The IFIM approach has been applied to other rivers and streams throughout Colorado.

The Colorado River in the Shoshone Reach is confined on the right by the interstate highway and on the left by the railroad. Habitat within the Shoshone Reach includes rapids, high gradient riffles, deep pools and runs. The Shoshone Reach is approximately 2.4 miles long and has an elevation drop of 170 feet from the diversion dam to the Shoshone Power Hydropower Plant outfall.

One study site was selected based on habitat characteristics that were generally representative of the non-rapid sections of the reach. The site included multiple repeats of riffle, pool and run habitat. The confined, steep gradient river channel does not allow safe access for in-channel measurements at all sections of the Shoshone Reach. The final decision on study site location from those areas deemed representative was determined during the field measurements and based on representativeness of the site and safety for personnel.

Two flow regimes were compared for this analysis, which were existing flows and future flows. Existing flows for the Shoshone Reach were calculated by substracting the amount of water diverted for hydro power production from the flow at the Dotsero gage. The future flows for the Shoshone Reach were the flows that would have been diverted at the power plant but instead allowed to remain in the channel through the Shoshone Reach. The analysis included the comparison of the existing flow regime to the future flow regime for hydrology in average, dry and wet years. The existing flow regime in the

reach includes days of zero flow when the hydropower plant is operating and total river flow is equal to or less than 1,408 cfs. The proposed future flow regime would not have zero flows and the water currently diverted for hydropower production would remain in the river.

A two-dimensional hydraulic model was developed to simulate stream hydraulics for flows from 50 cfs up to 3000 cfs. Specific flows of 50, 250, 700, 1,020, 1,250, 1,400 and 3000 cfs were simulated. The model was calibrated to the field measured flow of 1,020 cfs. Predictions from the simulated flows for wetted area, depth, and velocity were used in the hydraulic habitat analysis.

The species of interest and habitat suitability criteria for the hydraulic habitat analysis were determined in consultation with Colorado Parks and Wildlife and Colorado Water Conservation Board. The species selected were Rainbow Trout, Brown Trout, Flannelmouth Sucker and Mountain Whitefish. Habitat suitability criteria came from existing data sets that were previously used in other IFIM studies in Colorado.

Wetted area predictions were used to evaluate other biota that were not specifically modeled with habitat suitability criteria. These biota included the lower trophic levels of algae and macroinvertebrates that provide food resources for fish. The wetted area for the existing flow regime has many days at or near zero area due to diversion for hydro power production. The loss of wetted area results in partial or total mortality of algae and macroinvertebrates and the loss of food resources for fish. The loss of wetted area also requires fish to move out of the reach or be stranded. Research in other portions of the Colorado River has demonstrated that 1.5 to 2 months are required for algae and macroinvertbrate productivity to recover to the density and biomass that was present prior to the loss. The future flow regime does not have zero flow days and has stable consistent wetted area in all year types. These stable flows would allow macroinvertebrates to complete their annual life cycles and provide stable habitat area for algae and macroinvertebrates.

The hydraulic-habitat analysis predicted the maximum habitat availability for fish species at flows from 700 cfs to 1,400 cfs depending on the species. The zero flow days with the existing conditions results in total loss of habitat over extended periods of time. This habitat loss coupled with the concurrent loss of food productions results in substantial impacts to fish species in the Shoshone Reach. Future condition flows result in habitat conditions that are near the maximum potential habitat for the Shoshone Reach for all fish species. The future conditions result in stable flows during base flow periods that provide stable habitat and stable food resources for the fish species in the Shoshone Reach.

Based on the available hydrology and the habitat-discharge functions, the future flows (the Shoshone Hydropower Plant water rights which include a senior right for 1,250 cfs and a junior right of 158 cfs for a total of 1,408 cfs plus the bypassed/shepherded flows, which can result in a total flow of up to approximately 2,500 cfs to 3,000 cfs at the Dotsero Gage) would provide a substantial increase in habitat and benefit aquatic biota

during summer, fall, winter, and early spring as compared to the existing conditions. These flows up to approximately 2,500 cfs to 3,000 cfs therefore will help to preserve and improve the natural environment in the Shoshone Reach.

There also are indirect benefits to other sections of the Colorado River from the Shoshone Hydropower Plant water rights. These water rights are administered at the Dotsero Gage upstream from the Shoshone Reach, however, the water is conveyed from the upper sections of the Colorado River upstream of the Dotsero gage downstream to the Shoshone Reach and benefits all of the intervening reaches of the upper Colorado River. Similarly, the Colorado River downstream of the Shoshone Reach benefits from the Shoshone Hydropower Plant water rights.

In summary, the future conditions with the Shoshone Hydro Power Plant water right in place as an instream flow in the Shoshone Reach would result in the following:

- Stable base flow conditions with no zero flow days.
- Stable wetted area during future conditions in late summer, fall, winter and spring for better conditions for macroinvertebrates and algae which are food sources for fish species.
- Average year hydraulic-habitat conditions in summer and winter base flows that provide from 81% to 99% of the potential maximum hydraulic habitat.
- Continuation of indirect benefits upstream and downstream of the Shoshone Reach from water delivered to the Shoshone Reach.
- Flows from 1,400 to 3,000 cfs provide additional benefit to the aquatic habitat in the Shoshone Reach.
- Overall improved instream conditions to preserve and enhance the aquatic habitat.

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Introduction

This report documents the evaluation of instream flows for aquatic resources in the Shoshone Reach of the Colorado River between the point of diversion for the Shoshone Water Rights at the Shoshone diversion dam and the Shoshone Power Plant outfall (Figure 1). Habitat within the Shoshone Reach includes rapids, high gradient riffles, deep pools and runs. The objectives were to determine the current state of the aquatic habitat and aquatic ecosystem in the Shoshone Reach and determine expected changes to the aquatic habitat and aquatic ecosystem due to hydrologic change. The hydrologic change would be from a potential dedication of the Shoshone Hydropower Plant water rights which include a senior right for 1,250 cfs and a junior right of 158 cfs for a total of 1,408 cfs to an instream flow use. This change in water right would allow the total 1,408 cfs to remain in the river rather than diverted through the hydropower plant.

The report and analysis included input of data from hydraulic model simulations and calculation of habitat area by life stage for each simulated flow. Hydraulic and habitat model simulations included analysis for a range of flows (50, 250, 700, 1,020, 1,250, 1,400 and 3,000 cfs). A two-dimensional hydraulic model was developed for a single study site in the reach (River Restoration 2023). The modeled site was approximately 1,850 feet long and included multiple habitat types found within the Shoshone Reach (Figure 1). The species of interest for the Shoshone Reach study were determined in consultation with Colorado River Water Conservation District (River District) and other entities (Colorado Parks and Wildlife (CPW) and the Colorado Water Conservation Board (CWCB)) as determined by River District staff. Habitat suitability criteria for the species of interest were used in previous studies on what is now the Upper Colorado River Wild and Scenic Alternative Management Plan section of the Colorado River (Miller and Swaim 2011; See also Appendix A this report) with modifications as determined by CPW staff. Hydrology data for habitat time series analysis was provided by the River District.

This study followed the general guidelines of the Instream Flow Incremental Methodology (IFIM) (Bovee et al. 1998). IFIM is a multi-disciplinary approach to evaluating instream flow alternative management scenarios and includes components of hydrology, river hydraulics, and biological data. River hydraulics include simulation of a range of discharges to predict change to the wetted area, depth and velocity that may affect the aquatic biota. The output of the combination of hydraulic model results with habitat use data is generally referred to as hydraulic-habitat. Biological data analysis included evaluation of wetted area as it may affect aquatic biota such as periphyton, macroinvertebrates and available fish habitat.

Study Area

The Colorado River in the Shoshone Reach is subject to several human induced factors. The river channel is bordered by Interstate Highway 70 on river right and the railroad on river left. River discharge is impacted by large headwater reservoirs, transbasin diversions, and diversions for off-channel uses. The Shoshone Reach study area extends from the diversion dam near the Hanging Lake Trailhead parking lot adjacent to I-70 downstream to the Shoshone Power Plant outfall (Figure 1). The total distance for the Shoshone Reach is approximately 2.4 miles. The Shoshone Reach has sections of rapids, high gradient riffles, runs and deep pools. The overall gradient is steeper than the upstream reaches of the Colorado in non-canyon reaches. The river elevation drops over 170 vertical feet over the 2.4-mile distance with extremely steep gradients in areas with rapids (Figure 2).

The total area for each major habitat type (riffle, pool and run) for the Shoshone study reach was approximated from the aerial images from Google Earth Pro based on surface characteristics. The Shoshone reach is dominated by high gradient riffle and rapids with smaller proportions of pools and runs (Table 1). The study site was selected based on the presence of multiple habitat types and the ability to safely obtain the data needed for the hydraulic and habitat models. The study site within the Shoshone Reach has multiple

repeats of habitat types of riffle, run and pool habitat that are representative of the lower gradient, non-rapids habitat within the Shoshone Reach (Figure 3). The Shoshone Reach supports multiple fish species of trout, native suckers, mountain whitefish and sculpins (Kendall Bakich CPW, personal communication 2024; CPW file data). These same species have been collected by CPW upstream and downstream of the Shoshone Reach in the Colorado River. There are no quantitative data on fish populations in the Shoshone Reach due to the river conditions that restrict safe access for population sampling efforts. Shoreline sampling by CPW in 2023 showed the presence of Brown Trout and Rainbow Trout. In addition to fish, the river also supports the lower trophic levels of periphyton, algae, and benthic macroinvertebrates. These trophic levels are important food resources for the higher trophic levels and are dependent on continuous river flow for completing their life cycle. The periphyton supports benthic invertebrates and fish, benthic macroinvertebrates support fish species.

Figure 1. Shoshone Reach study area and study site. Colorado River flows from upper right to lower left. Source: Google Earth Pro July 17, 2023.

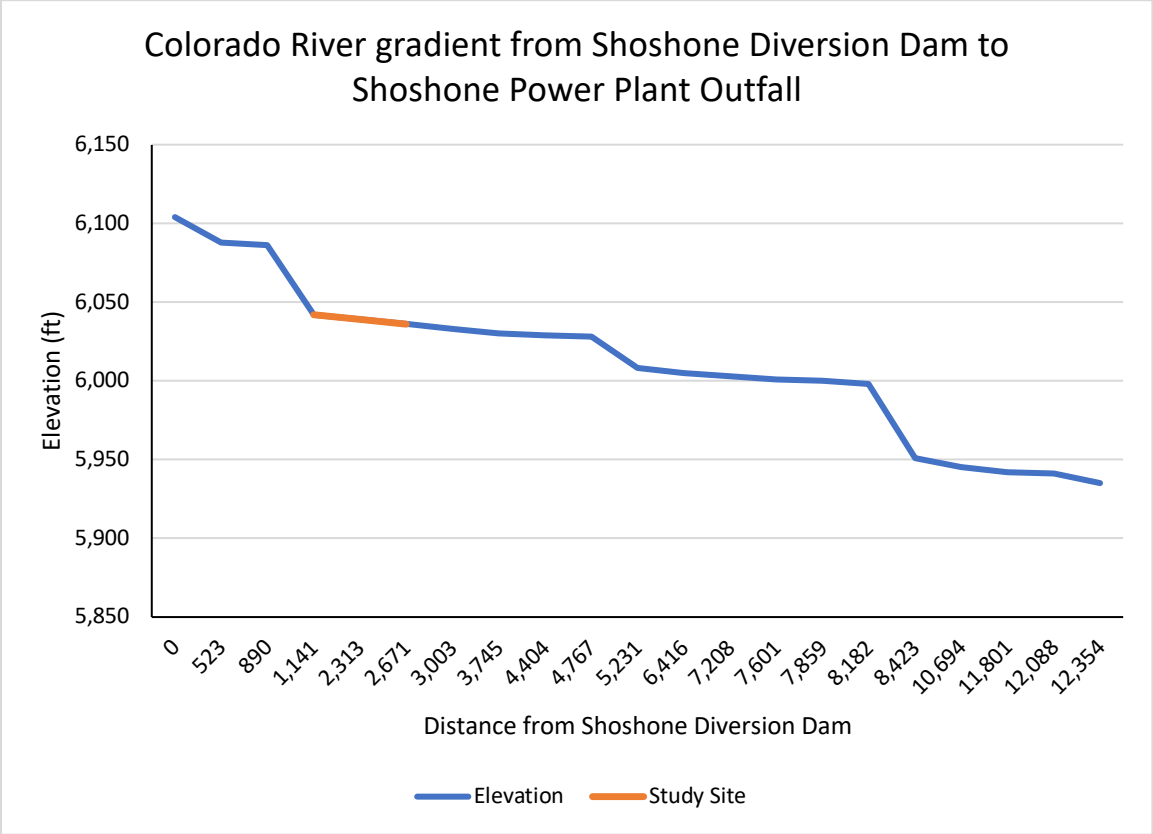

Figure 2. Approximate gradient of Colorado River in the Shoshone Reach (Shoshone diversion dam to Shoshone Power Plant outfall) Source: Google Earth Pro Aerial Image July 19, 2023.

Table 1. Habitat type and percentage for Shoshone Reach, Colorado River (source: Google Earth Pro aerial images July 19, 2023).

Habitat Type	Summed length (ft)	Percent
Riffle	5363	42%
Rapid	5045	39%
Run	332	3%
Pool	2121	16%
Total	12861	100%

Figure 3. Aerial image of Shoshone Reach Study Site with approximate delineation of habitat types. Source: Google Earth Pro Aerial Image July 19, 2023.

Methods

There are several methodologies available to evaluate riverine habitat (Annear et al. 2004; Stalnaker et al. 1995). These include simple standard setting methods such as R2Cross up to more complex methods that evaluate multiple parameters to better address complex water management problems. The Instream Flow Incremental Methodology (IFIM) is a multidisciplinary methodology and was developed to evaluate complex water management problems (Bovee, 1982; Bovee et al. 1998; Stalnaker, 1995). IFIM includes sound ecological principles in the methodology (Bovee et al. 1998). The IFIM approach has been used in other instream flow evaluations in Colorado including the Colorado River, Dolores River, Cache La Poudre River and South Platte River basins.

The general approach to evaluating instream habitat in the Shoshone Reach follows the guidelines of IFIM. The analysis sequence includes collection of field data for stream topography, bathymetry, and hydraulic parameters, and fish habitat use data. These field data are the input parameters for hydraulic modeling and habitat suitability analysis. The hydraulic model output and habitat suitability are combined to calculate habitat area as a function of discharge for a range of flows. This function is combined with hydrology scenarios to determine change in habitat over time (Figure 4). In addition to the data used for fish habitat, hydraulic model results for wetted area were used to infer changes to other non-modeled biological conditions such as changes to habitat for benthic macroinvertebrates.

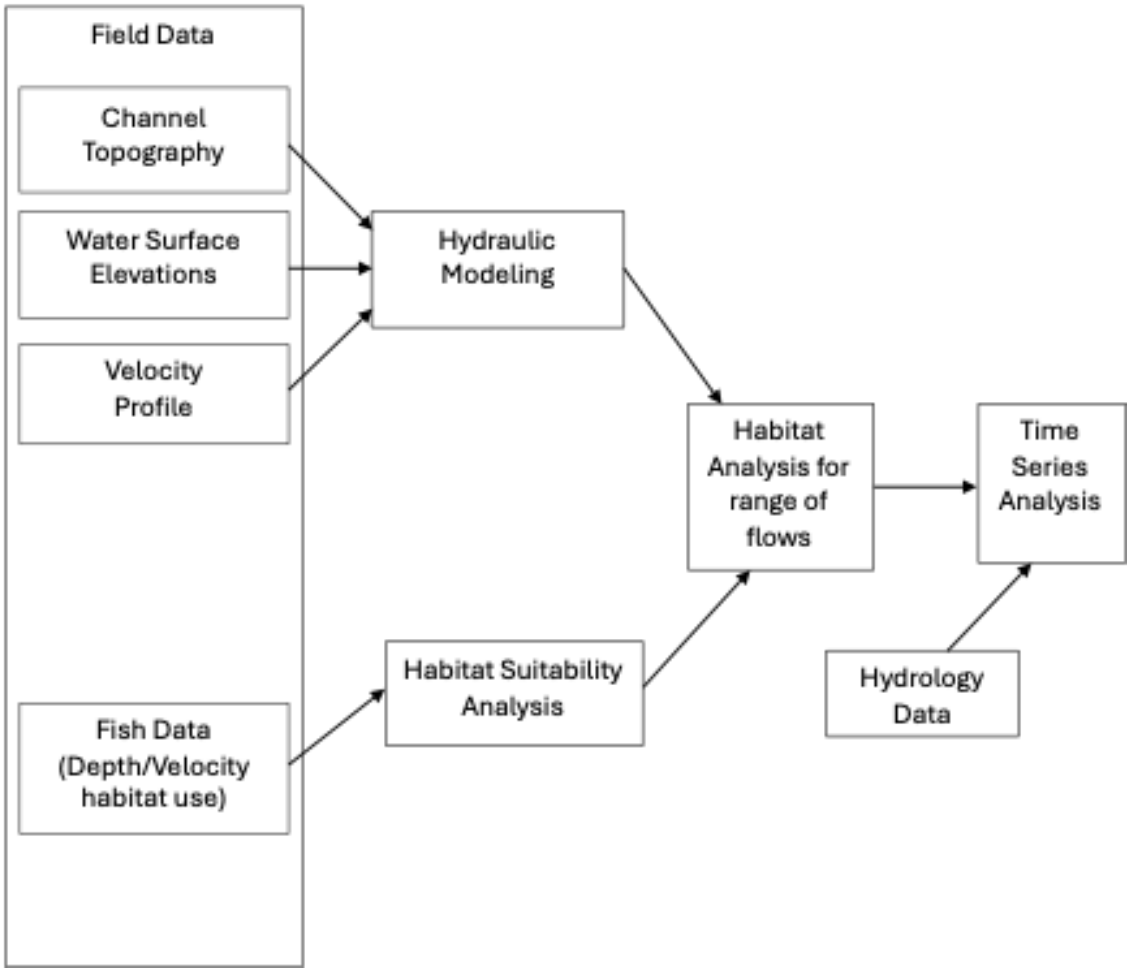

Figure 4. Flow chart of analysis sequence for instream flow study.

Two-Dimensional Hydraulic Modeling

Two-dimensional hydraulic modeling was completed by River Restoration (River Restoration 2023, See Appendix B and Appendix C). The 2-D model uses the georeferenced field data collected from the site. Data inputs include site topography, substrate, and flow impediments; a stage-discharge relationship at the downstream end of the site; and calibration and validation data throughout the site. The survey data was used to develop a grid system to represent the stream geometry as a mesh. Model mesh was approximately 4 ft by 4 ft for the site (River Restoration 2023). This mesh was combined with the hydraulic data to simulate water depths and depth averaged velocities for the range of flow conditions for 50, 250, 700, 1,020, 1,250, 1,400, and 3,000 cfs. The water depth and depth averaged velocity from the hydraulic model are required to be consistent with the data collected for the fish habitat use, which also is water depth and depth averaged velocity.

Hydrology

The River District provided the hydrology time series for the Shoshone Reach. The hydrology data included hydrology from actual gage data using the USGS Colorado River near Dotesero gage (Dotsero Gage) located just upstream of the Shoshone Reach over a period of record of 1973-2003. The data are presented as an irrigation year (Nov 1-Oct 31) with three typical hydrologic conditions based on the following years: Wet – 1997, Average – 2000, and Dry - 2001. The years were selected to get a range of hydrologic conditions from wet to dry and also were years the Shoshone Hydropower plant operated. The hydropower plant operation data was needed so "existing" conditions in the Shoshone Reach could be evaluated. Actual gage data is the "future" or proposed condition of the Shoshone Reach for each of these sample years, assuming the scenario that the Shoshone Water Rights are not used for hydro-power generation

purposes but are instead being exercised by the CWCB for instream flow purposes, causing all flow to go through the Shoshone Reach. Existing conditions were assumed to be historical flow at Dotsero Gage flow less 1,408 cfs to mimic the typical historical operations of the Shoshone Power Plant of diverting all available flow up to 1,408 cfs as described further below. The three sample year types for existing and future conditions were used in the habitat time series.

Water Right Administration

The Dotsero Gage (USGS 09070500) is an administrative point utilized by the Colorado Division of Water Resources ("DWR") to measure all streamflow in the river at the location of the gage. In addition, DWR has historically relied on the Dotsero Gage as the point of administration for the Shoshone Water Rights. DWR uses the Dotsero Gage to measure both the amount of un-depleted, natural flow as well as the amount of bypassed flow associated with shepherded releases from reservoirs located upstream of the gage. For purposes of this report, the "natural flow" includes the amount of water divertible by the Shoshone Water Rights when those water rights are in priority but does not include any bypassed water or releases from upstream reservoirs administered for downstream water use below the Shoshone Reach. Those bypass flows (i.e., shepherded releases), which are also administered at the Dotsero Gage, are those reservoir releases made for the purposes of increasing streamflow at certain downstream locations in excess of the natural flow that would exist at these locations but for the bypass water, such as releases for irrigators in the Grand Valley or for environmental flows to benefit the 15-Mile Reach.

Importantly, DWR does not administer the shepherded bypass water at the Dotsero Gage to satisfy any calls for administration of the senior and junior Shoshone Water Rights. Instead, DWR accounts only for the available natural flow at the Dotsero Gage whenever a Shoshone Call is placed to determine whether upstream junior water rights must be curtailed to ensure that sufficient natural flow is available for beneficial use at the Shoshone Power Plant where such water is diverted from the river. Similar operating

conditions have been assumed for the future-conditions hydrology in this Report such that if the Shoshone Water Rights are utilized for instream flow purposes the Shoshone Call would be based solely on the amount of natural flow as measured at the Dotsero Gage, not including the amount of shepherded bypass water. Thus, the Shoshone Reach could have flows greater than 1,408 cfs at certain periods when the Shoshone Call has been placed but is not being fully satisfied. This is because DWR administers the Shoshone Call based solely on available natural flow at the Dotsero Gage but does not administer any shepherded bypass water to satisfy the call even though such bypass water does eventually flow through the Shoshone Reach for downstream beneficial uses.

Habitat Suitability Curves

Species habitat suitability criteria are required for the hydraulic-habitat analysis. Habitat suitability criteria that accurately reflect the habitat requirements of the species of interest are essential to conducting meaningful and defensible habitat analyses (Bovee 1982). A previous study in the Colorado River from Kremling to Dotsero, Colorado (Miller and Swaim 2011) incorporated habitat suitability criteria for the same species of interest as in this study (Table 2). The habitat suitability criteria include adult trout, adult Mountain Whitefish, and adult Flannelmouth Sucker. Other species considered for this analysis were Bluehead Sucker and Mottled Sculpin. Habitat suitability criteria were not available for Mottled Sculpin. Bluehead Sucker were not explicitly modeled in the study due to a lack of sufficient number of data observations, however, the data that was available shows an overlap in the depth and velocity used with Flannelmouth Sucker (Miller 2024).

Table 2. Species of interest for habitat analysis.

Common Name	Scientific Name
Rainbow Trout	*Oncorhynchus mykiss*
Brown Trout	*Salmo trutta*
Mountain Whitefish	*Prosopium williamsoni*
Flannelmouth Sucker	*Catostomas latipinnus*

The habitat data for the species of interest came from several sources and have been used in previous studies on the Colorado River (Miller and Swaim 2011). The data for adult trout was collected by direct observation at several locations in rivers in Colorado. The data was collected by personnel from Colorado Division of Wildlife (now CPW) and US Fish and Wildlife Service in 1988 and 1989 (Colorado Division of Wildlife 1989). Those observations were used to develop habitat preference suitability indices for depth and velocity and corrected for habitat presence (Wilding 2012).

Criteria for Mountain Whitefish used for this analysis came from Bovee (1978). The criteria for adult Flannelmouth Sucker were updated in early 2024 from a combination of data from radio telemetry studies on the Colorado River near Grand Junction, existing data from a range of rivers and literature review of habitat and population studies (Miller 2024). Additional habitat criteria for Flannelmouth Sucker were incorporated into the final suitability criteria as documented by Miller (2024). The habitat suitability criteria for Flannelmouth Sucker are also being used as a proxy for Bluehead Sucker criteria for this study. Bluehead Sucker feed by scaping on hard substrates and are known to feed in faster riffle habitat with cobble and boulders whereas Flannemouth Sucker feed on softer substrates in somewhat slower velocities so the habitat response shown for Flannelmouth Sucker may approximate habitat response to flow for Bluehead Sucker but not fully depict all areas suitable for Bluehead Sucker. The suitability indices for all species are listed in Appendix A.

Habitat Modeling

The habitat modeling for this analysis will follow the concepts of IFIM (Bovee 1982, Stalnaker et al. 1995). IFIM requires hydraulic data and simulations; habitat use data expressed as habitat suitability criteria; and hydrology data for a range of stream discharge conditions. The 2-D hydraulic analysis and simulations were described above.

Habitat suitability modeling for each species of interest was accomplished through a spreadsheet model. The spreadsheet instream habitat model relies on inputs from both the two-dimensional hydraulic modeling and the habitat suitability criteria described above. Data corresponding to flow depths and depth averaged velocities provided by the two-dimensional hydraulic modeling were developed for each flow rate within the study site. Specific habitat criteria developed from the suitability analyses described above were then used to calculate habitat area. Multiple data sets of usable habitat were generated, corresponding to each species and flow of interest. The usable habitat area for each species of interest is the result of combining the hydraulic simulations for each flow with the habitat suitability function for each species. Summation of total habitat for each species and simulated flow results in a habitat-discharge relationship by species that becomes input for the habitat-time series analysis.

The habitat–discharge relationships are a set of theoretical functions based on channel shape and hydraulics. The actual habitat realized by the species is a function of the discharge at the site over time combined with the habitat–discharge function and results in the habitat time series.

Habitat Time Series

The actual habitat experienced by the fish in any river depends on the flow regime of the river. The relative abundance of habitat conditions over time is an integral part of the comparison of flow regimes. Generally, the habitat time series is the comparative

analysis used for the decision point in IFIM. Habitat time series produces the data needed to compare a range of flow conditions over time and to compare different flow scenarios. The habitat-discharge relationships for each study site were used as input data for the habitat time series. This analysis allowed a comparison between the existing flow regime and alternate flow regimes to determine available habitat with each time series.

Habitat time series evaluations were conducted on two flow regimes representing the existing hydrologic condition and the potential future condition with water flowing in the Shoshone Reach. For each flow regime assessed, we conducted both hydrology and habitat time series analysis for wet, average and dry hydrology to calculate both flow and habitat statistics. These values allowed a direct comparison of the changes that occur in both flow and habitat under a range of conditions. These tabular data were displayed for each flow scenario to represent the spatial habitat distributions.

Habitat time series was completed using a spreadsheet format that combines the hydrology over time with the habitat use as a function of discharge. These values are converted to area of habitat for the study site and then area of habitat for the Shoshone Reach to compare change in habitat over time for each flow of interest.

Results

The study components include results from the hydraulic model for depth, velocity, and wetted area at each simulated flow, available hydraulic-habitat at each modeled flow and comparison of daily habitat for a range of hydrologic year types. Wetted area is used to infer changes to the non-modeled biological data and to more fully understand the range of conditions that may be available to fish species. The hydraulic-habitat analysis provides the data needed to determine change in available habitat at specific discharges and provides the data to evaluate change in habitat with changes to hydrology on a daily time step.

The hydraulic model mesh and hydraulic parameters provide the basic physical data for the analysis. These data include the area for wetted channel area for each flow. The wetted area for the study site has the sharpest decline in area as the flow declines from 250 cfs to 50 cfs (Figure 5). Flows higher than 250 cfs have a gradual increase in wetted area up to the highest simulated flow of 3,000 cfs.

Wetted area or wetted channel perimeter is a measure of the total aquatic habitat available under varying flow levels and can also be used as an indicator of stream food web function. Primary and secondary trophic levels (algae and benthic macroinvertebrates, respectively) are positively correlated to stable wetted area (Rees et al. 2008). Many of the key macroinvertebrates such as Mayflies, Stoneflies, and Caddisflies, have annual life cycles and require continuous flow for a year or more to complete their life cycles. Any disruption or loss of habitat due to loss of wetted area during a single year results in either a decrease or total loss in productivity and directly impacts the food resources available to other species. A day or days of zero flow can eliminate primary and secondary food productivity due to mortality of algae and macroinvertebrates and take weeks to return to previous levels (Rees et al. 2008).

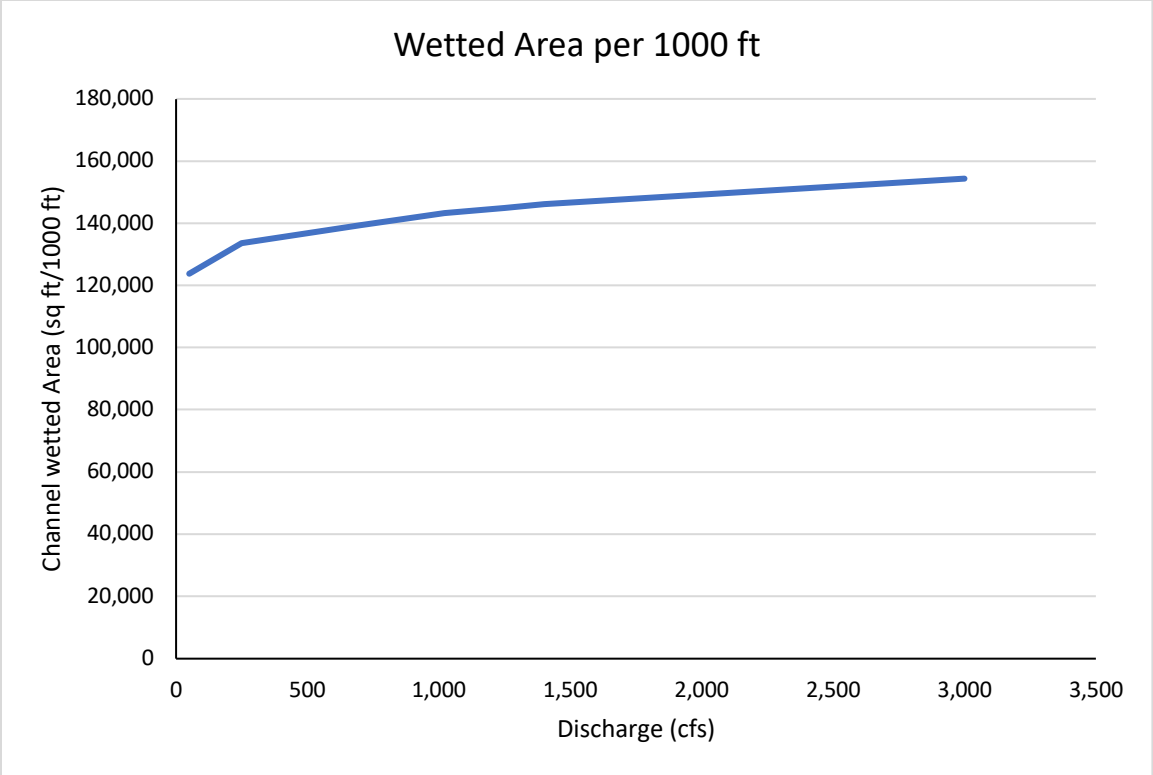

Figure 5. Shoshone Reach Colorado River channel wetted area as a function of discharge.

The hydrology for the reach was graphed to display the comparison between the existing conditions and future conditions for average (Figure 6), dry (Figure 7) and wet (Figure 8) hydrologic conditions. There are extended periods of zero flow days, particularly in winter, for the existing conditions in all hydrologic years. The number of zero flow days are 235, 183 and 134 with existing conditions for dry, average, and wet hydrologic years, respectively. Peak flows during runoff range from approximately 2,500 cfs in dry years to approximately 14,000 cfs in wet years for existing conditions. The base flows under future conditions (when the Shoshone Hydropower Plant is offline) are lowest in winter with flows ranging from approximately 750 cfs in dry years to approximately 1,000 cfs in average and wet years. There are no zero flow days in future conditions. This is a substantial change in flows during base flow periods under future conditions compared to the existing hydrologic conditions in all hydrologic years.

The hydrologic time series comparing existing and future conditions demonstrates that the existing flows result in a total loss of wetted area in all sample year types (Figure 9, Figure 10, Figure 11). Daily flows greater than 3,000 cfs (the highest flow in the 2-D model) were not plotted to limit the data analysis to the range of the hydraulic model. There are also sporadic losses to wetted area during late summer into the fall for existing conditions. There are extended periods of total loss of wetted area from late fall through spring for existing conditions. The loss of wetted area is most impactful to the algae and benthic macroinvertebrates. These species are not as mobile as fish species and require longer times to recolonize the channel after flows return. The general annual life cycle for macroinvertebrates includes adult emergence and egg deposition in late spring through summer, eggs hatch and nymph stages mature from summer through the next spring to early summer when adults emerge and the cycle repeats. Loss of wetted area, either partial or complete, results in a loss of food resource productivity and loss of habitat for mobile fish species. Stable wetted area as shown in the future condition's hydrology time series with the 1,408 cfs water right in the Shoshone Reach is beneficial to primary and secondary trophic levels and fish habitat. In addition, the bypassed/shepherded flow that is added to the 1,408 cfs water right provides an additional amount of wetted area (approximately 4% at 3,000 cfs) and is beneficial to the aquatic ecosystem. The additional wetted area provides more area for macroinvertebrate emergence. The shoreline areas with large substrate provide velocity refuge habitat for fish. The benefit to the lower trophic levels would provide improved ecological conditions for the higher trophic levels and result in more robust ecological conditions in the Shoshone Reach.

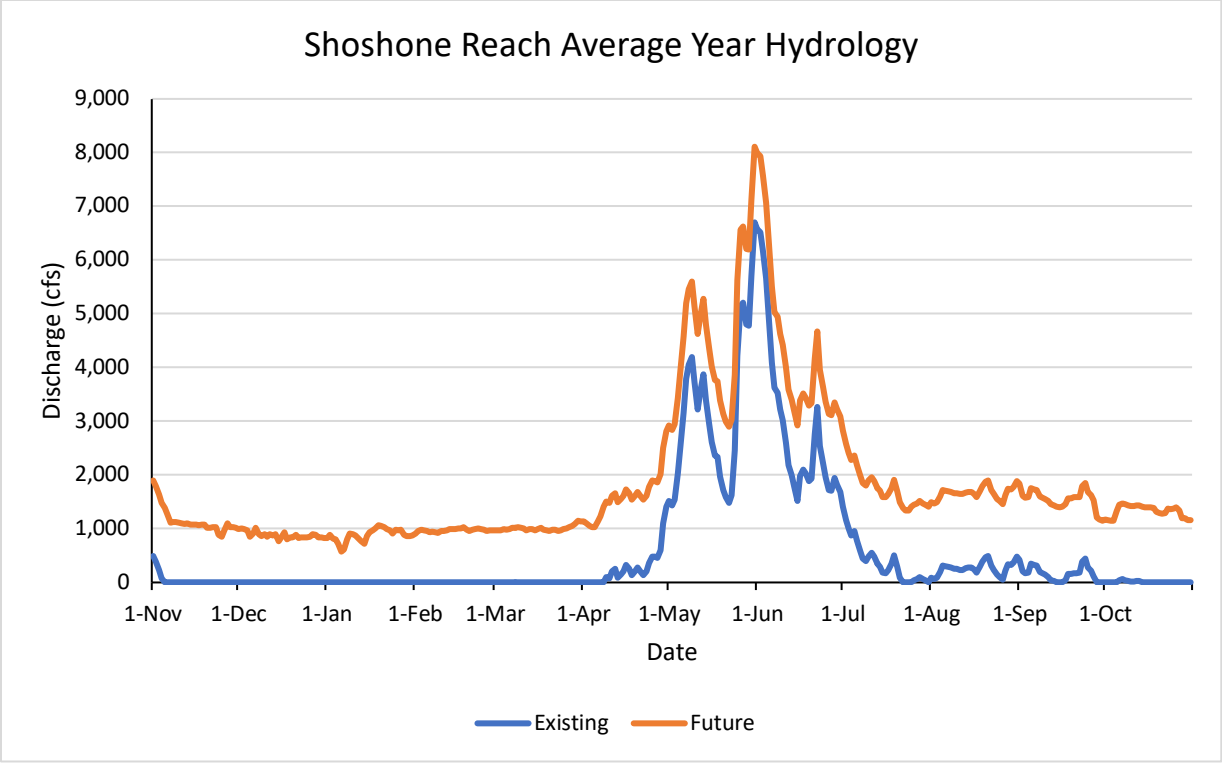

Figure 6. Shoshone Reach, Colorado River comparison of existing and future average year (2000) hydrology.

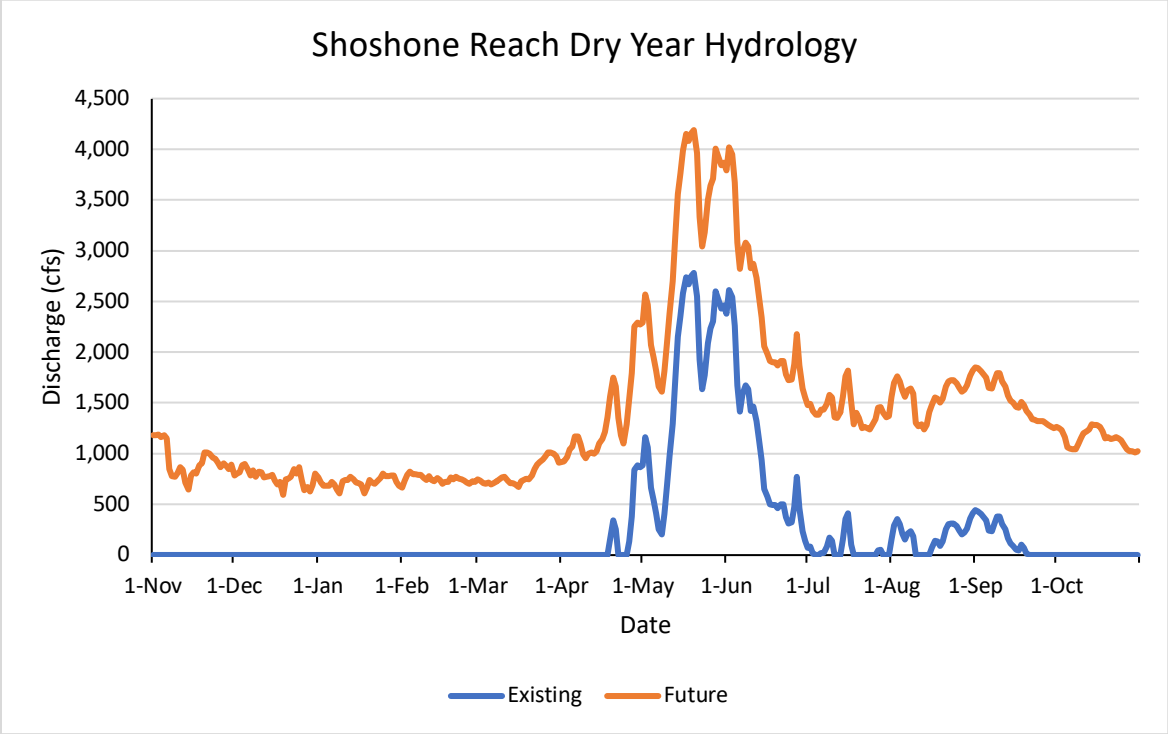

Figure 7. Shoshone Reach, Colorado River comparison of existing and future dry year (2001) hydrology.

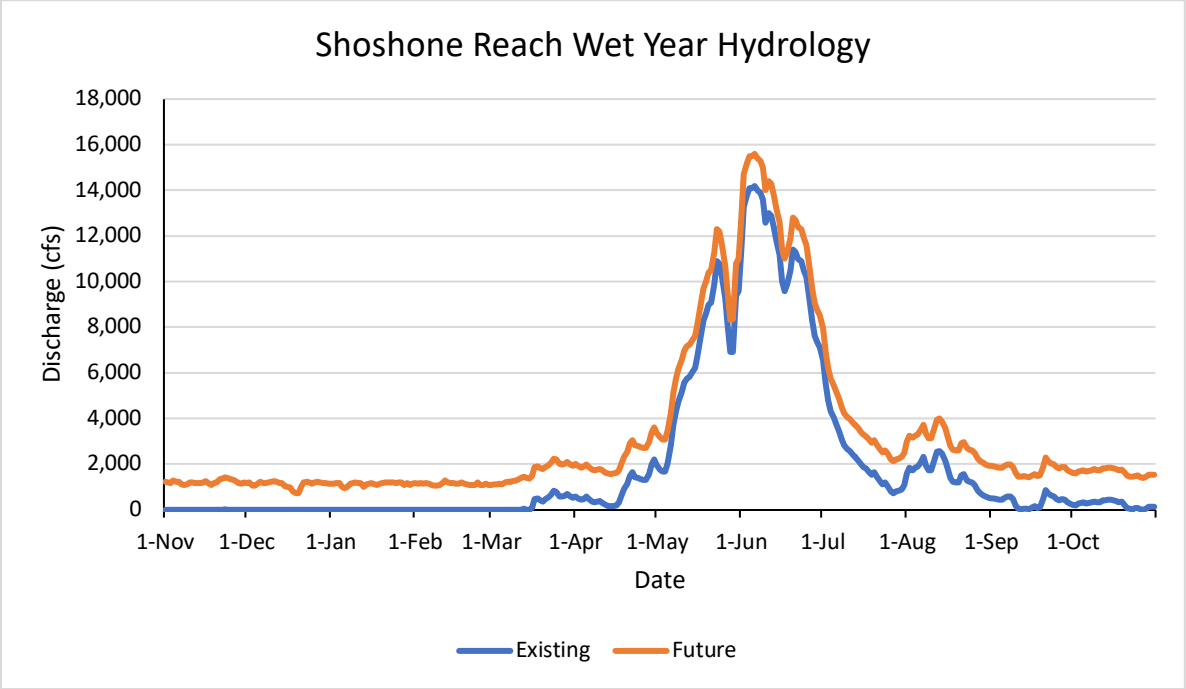

Figure 8. Shoshone Reach, Colorado River comparison of existing and future wet year (1997) hydrology.

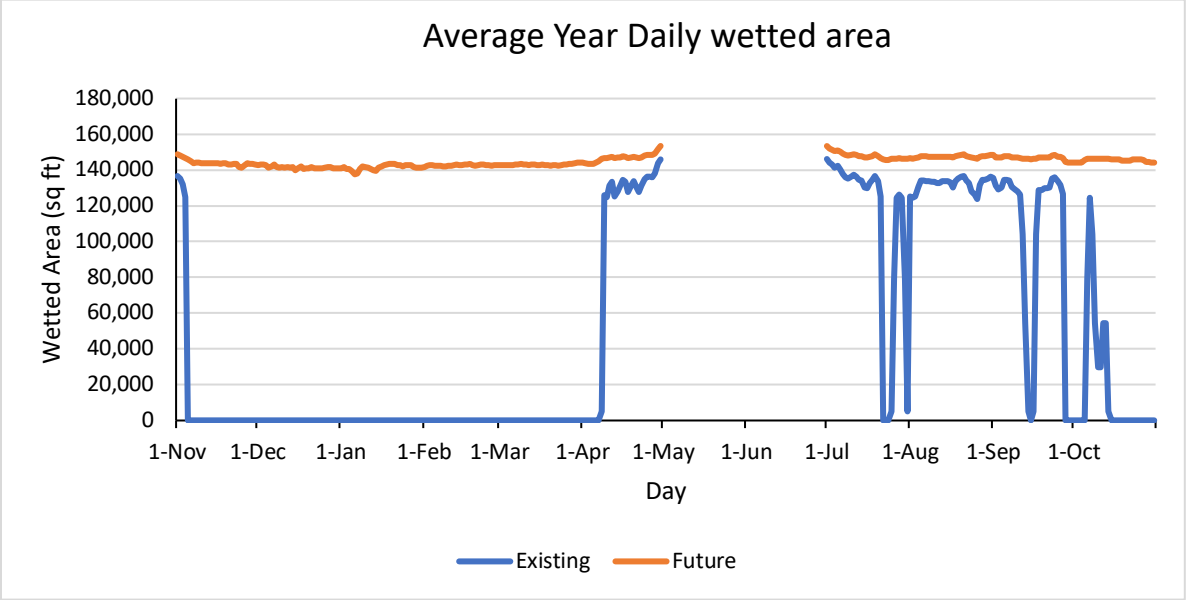

Figure 9. Shoshone Reach average year (2000) daily wetted area comparison of existing and future conditions.

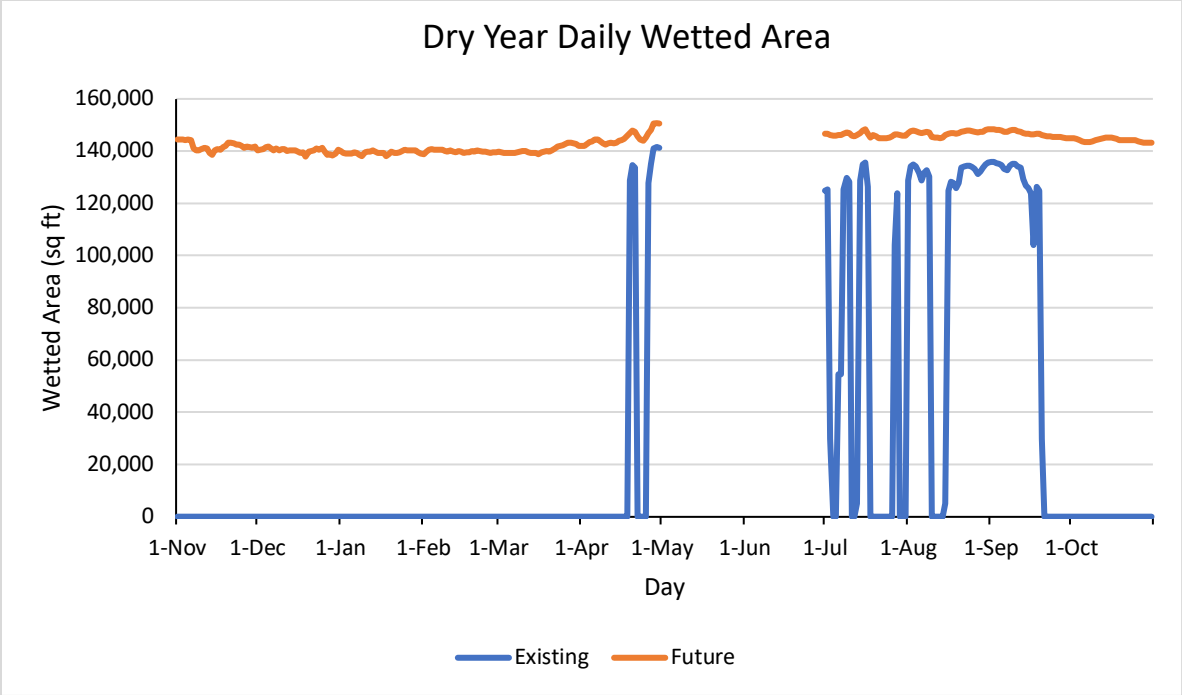

Figure 10. Shoshone Reach dry year (2001) daily wetted area comparison of existing and future conditions.

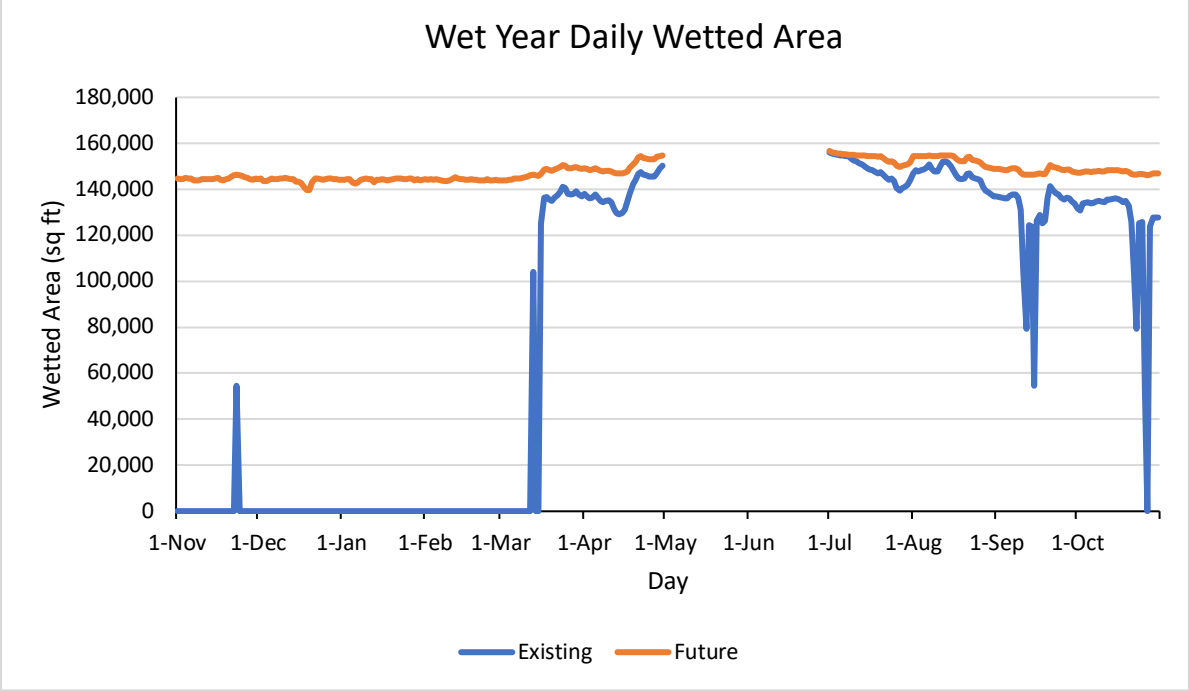

Figure 11. Shoshone Reach wet year (1997) daily wetted area comparison of existing and future conditions.

Habitat Modeling Results

Habitat for each species is a function of both habitat quantity and habitat quality. These characteristics vary with discharge. Habitat area with IFIM is an indicator of usable habitat for each species but does not directly reflect population level changes due to other contributing factors that determine population change. The amount of usable habitat area is an indication of aquatic conditions for the species and can reflect long-term population trends. Small short-term changes in habitat area (other than zero flows) should not be equated with a one-to-one correspondence to short term change in population.

The model results for Rainbow Trout, Brown Trout, Mountain Whitefish and Flannelmouth Sucker show the highest habitat availability at flows that range from 700 cfs to 1,400 cfs (Figure 12, Figure 13). Habitat availability declines quickly as flow decreases from 700 cfs likely caused by decline in wetted area and less suitable depth and velocity characteristics. There is a gradual decline in habitat availability as flow increases up to 3,000 cfs. The reduction in habitat at high flows is likely due to higher water velocities that are less suitable for the species. There is still usable habitat available for fish species as flows increase from 1,500 cfs to 3,000 cfs.

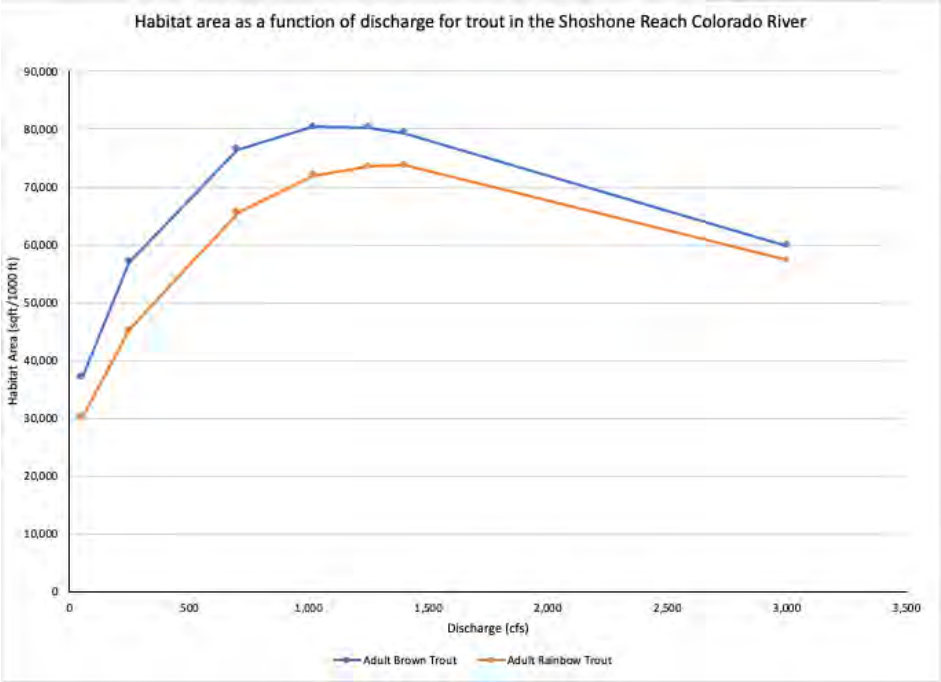

Figure 12. Habitat area as a function of discharge for trout in the Shoshone Reach Colorado River.

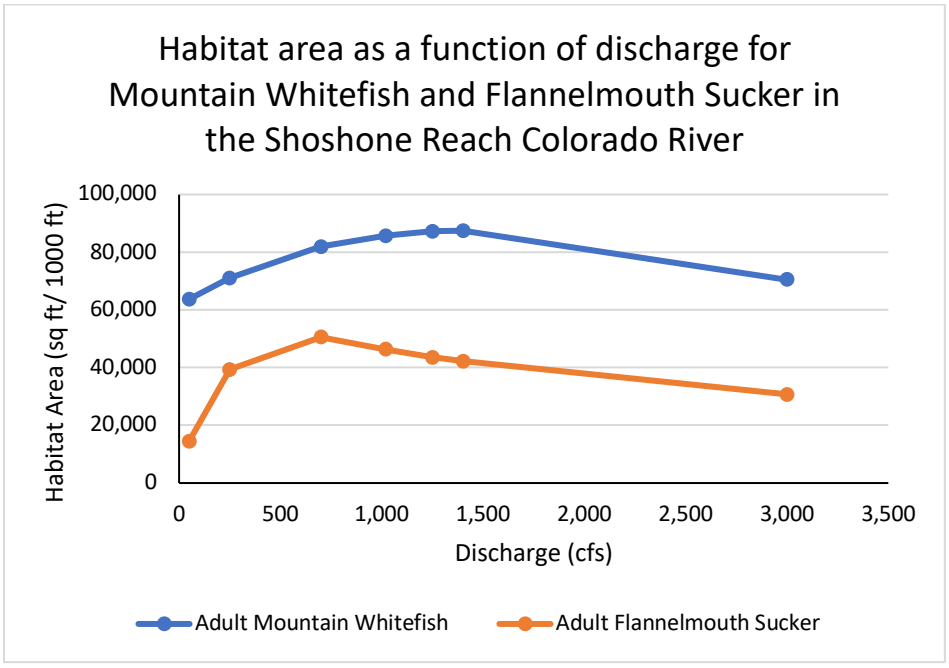

Figure 13. Habitat area as a function of discharge for Mountain Whitefish and Flannelmouth Sucker in the Shoshone Reach Colorado River.

Bypassed/sheperded flows at the Dotsero Gage may increase the discharge up to approximately 2,500 cfs to 3,000 cfs. These bypass/shepherded flows add to the wetted area, which benefits macroinvertebrates while maintaining usable habitat for fish species. The additional wetted area when flows are approximately 2,500 cfs to 3,000 cfs would also provide areas of velocity refuge habitat for fish species in the large boulders and rip-rap present in the reach.

There is a substantial amount of suitable habitat at flows of 3,000 cfs for all species. The amount of habitat for each species and life stage at 3,000 cfs compared to the maximum potential habitat area for each species ranges from 61% up to 81% of the maximum (Table 3). The higher baseflows in winter and late summer to fall are also beneficial to fish. The future condition winter base flow in average years would provide 93% to 99% of the maximum potential habitat for fish species. The future condition late summer to fall base flows in average years would provide 81% to 98% of the potential habitat for fish species (Table 3).

Table 3. Percent of habitat area provided by 3000 cfs and winter and summer average year base flows compared to maximum potential habitat by species.

Species and life stage	Percent of habitat area at 3000 cfs compared to maximum potential habitat	Percent of habitat area at average year winter base flow (973 cfs) compared to maximum potential habitat	Percent of habitat area at average year summer base flow (1581 cfs) compared to maximum potential habitat
Adult Brown Trout	74%	99%	98%
Adult Rainbow Trout	78%	96%	98%
Mountain Whitefish	81%	97%	98%
Flannelmouth Sucker	61%	93%	81%

Habitat Time Series Results

The actual habitat conditions experienced by the fish depend on the daily flows in the Shoshone Reach. These variations are shown in the time series plots of habitat. The data for dry, average, and wet year types were used to display the daily change in habitat for those hydrologic conditions.

The habitat-discharge functions were combined with hydrology data for the Shoshone Reach to display habitat over time for dry, average, and wet years. The existing flows range from zero during many days to nearly 14,000 cfs during wet year peak flows. Daily habitat at flows greater than 3,000 cfs (the highest flow in the 2-D model) were not plotted to limit the data analysis to the range of the hydraulic model. Flows higher than 3,000 cfs generally occur during runoff from May through June. The current zero flow days in the Shoshone Reach occur when the total river flows are 1,408 cfs or less which is the full capacity of the Shoshone Hydroelectric Plant. The future flow regime, if the Shoshone Plant is offline and the Shoshone Water Rights are exercised for instream flow purposes would allow the flow to remain in the Shoshone Reach channel downstream of the diversion dam. Such a flow regime would result in a substantial increase in habitat with no days of zero flow for all species in average, dry and wet hydrologic conditions (Figure 14-Figure 25). The future flows result in stable habitat conditions during all year types for all species.

The intermittent nature of the existing flow patterns with days of zero flow among the days of higher flows does not provide productive habitat. When all flow is diverted the Shoshone Reach experiences drying or zero flow which results in a loss of periphyton and macroinvertebrates. Those lower trophic levels provide the food base for the fish species in the reach. Studies on the 15-Mile Reach of the Colorado River near Grand Junction, Colorado demonstrated that the periphyton and macroinvertebrate communities require approximately two months of continuous flow to reach the same pre-disturbance biomass and density (Rees et al. 2008). The loss of the food resources is a negative impact to the fish within the Shoshone Reach. Loss of the food resources in late summer

when fish are feeding to prepare for winter could result in a substantial impact to fish condition and population size. Therefore, under the future flow regime the entire aquatic ecosystem in the Shoshone Reach would be improved with the stable flows and absence of zero flow days. The future flow regime provides consistently stable base flows at levels that provide a substantial increase in habitat for all species compared to existing conditions. Average year hydrology for future conditions show that winter and summer base flows provide 80% or more of the total maximum potential suitable habitat (Table 3).

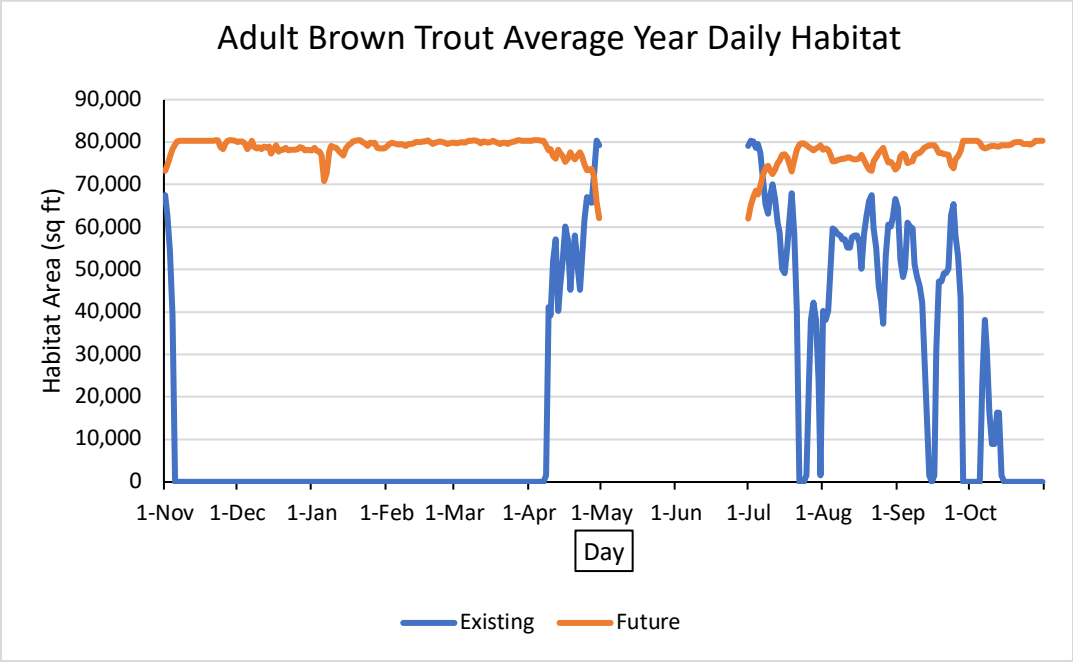

Figure 14. Adult Brown Trout average hydrologic year daily habitat for existing and future conditions.

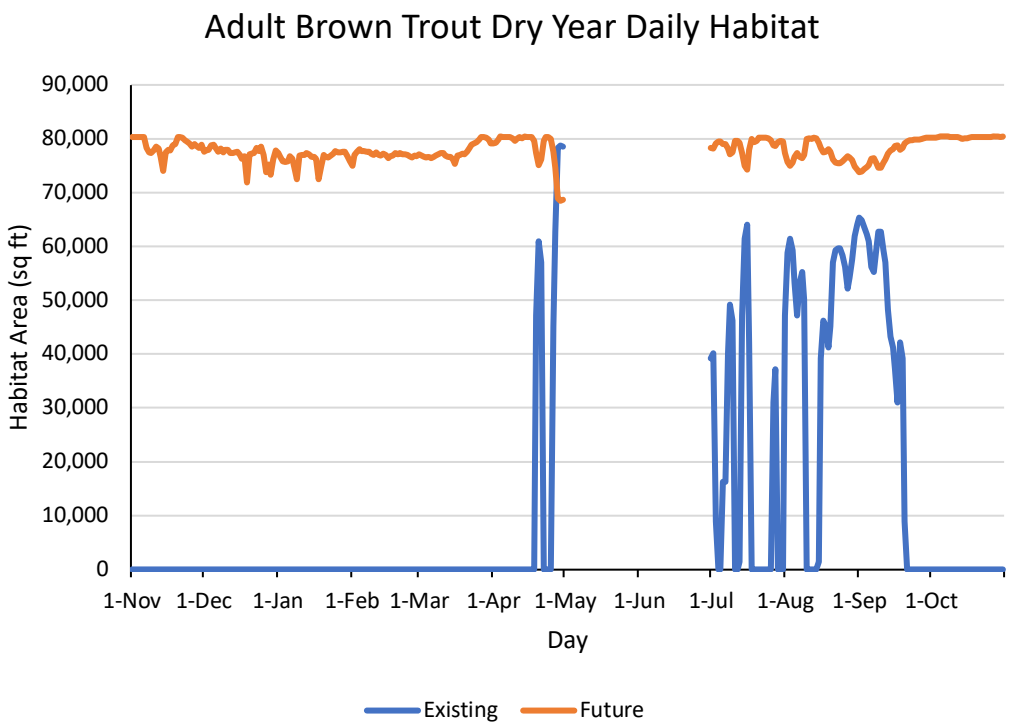

Figure 15. Adult Brown Trout dry hydrologic year daily habitat for existing and future conditions.

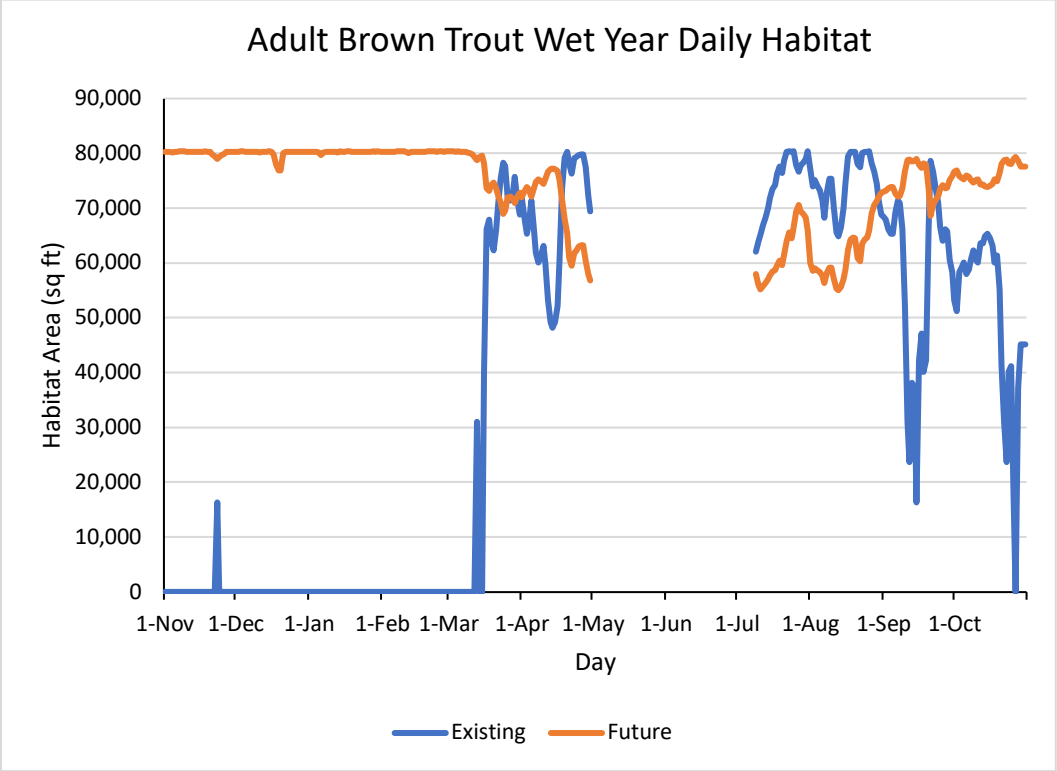

Figure 16. Adult Brown Trout wet hydrologic year daily habitat for existing and future conditions.

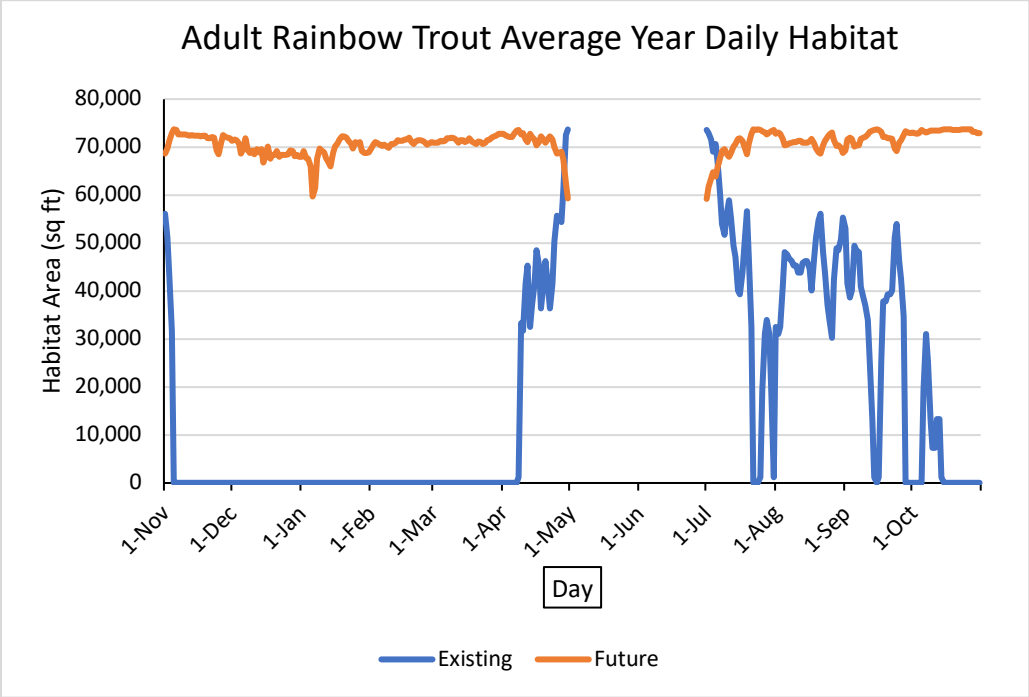

Figure 17. Adult Rainbow Trout average hydrologic year daily habitat for existing and future conditions.

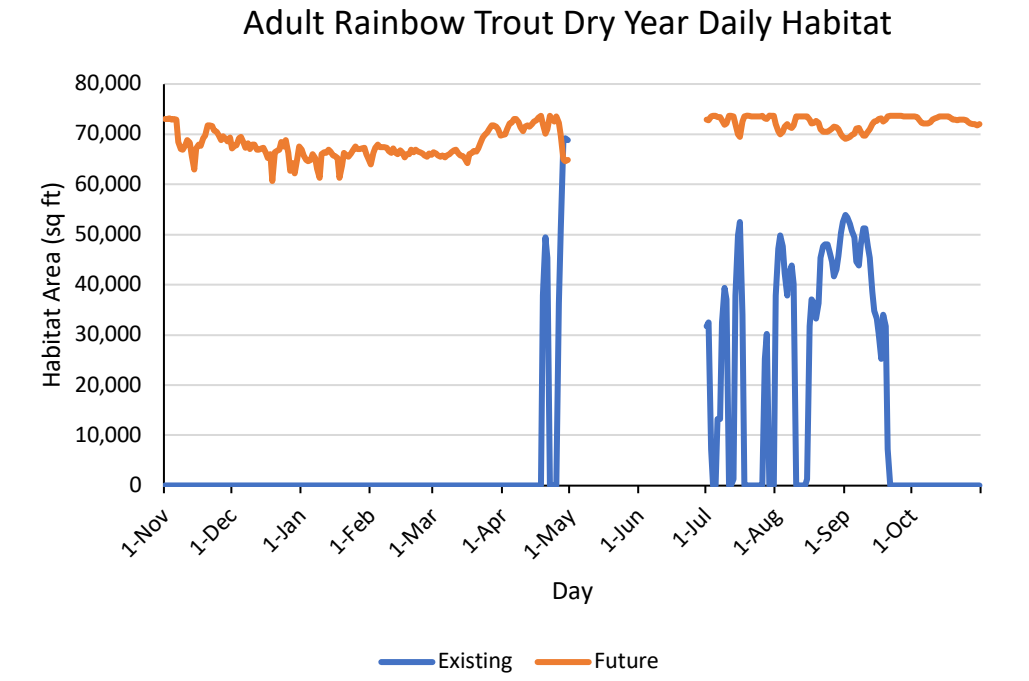

Figure 18. Adult Rainbow Trout dry hydrologic year daily habitat for existing and future conditions.

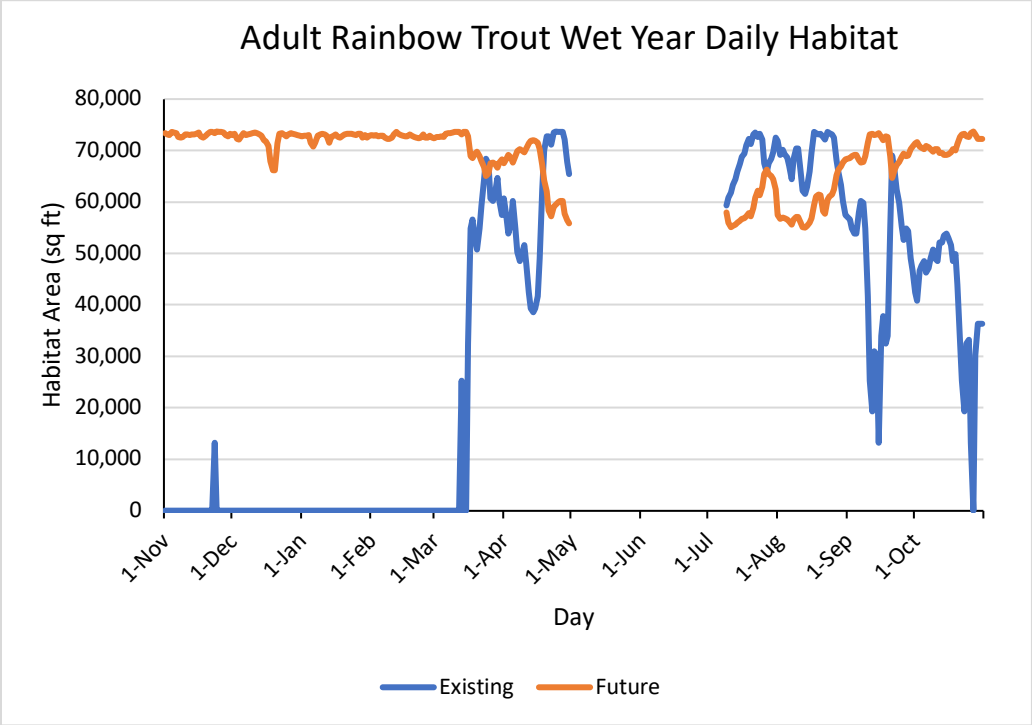

Figure 19. Adult Rainbow Trout wet hydrologic year daily habitat for existing and future conditions.

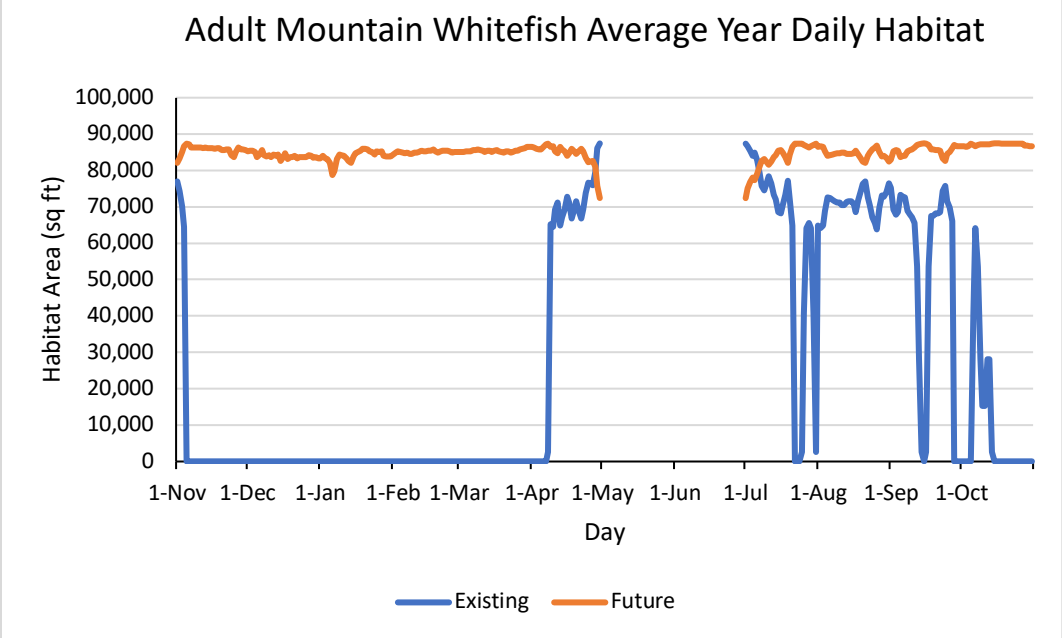

Figure 20. Adult Mountain Whitefish average hydrologic year daily habitat for existing and future conditions.

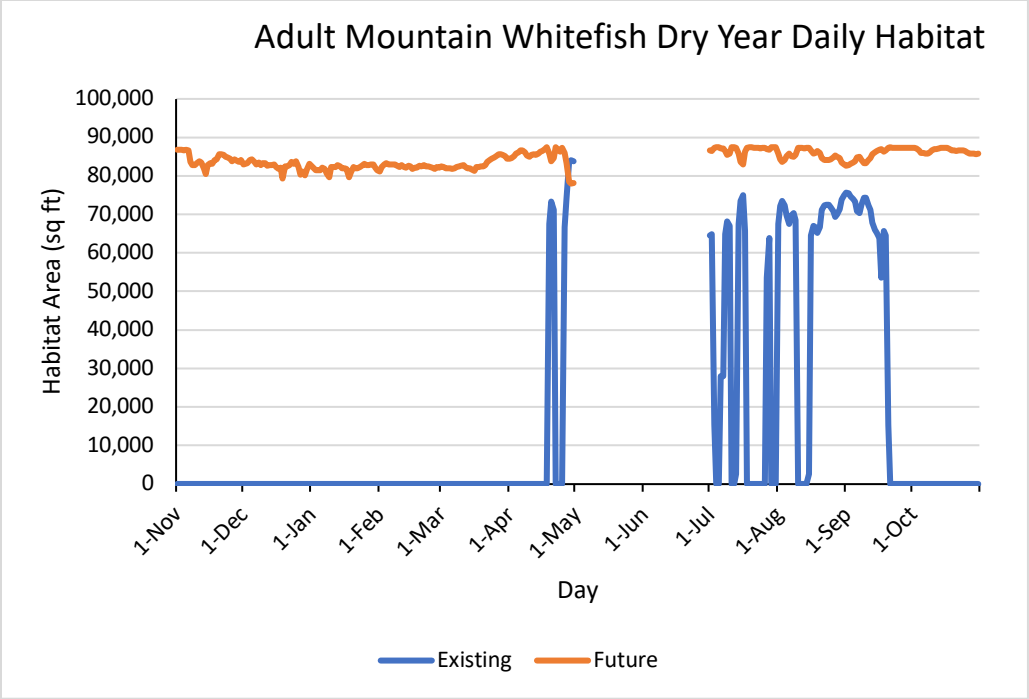

Figure 21. Adult Mountain Whitefish dry hydrologic year daily habitat for existing and future conditions.

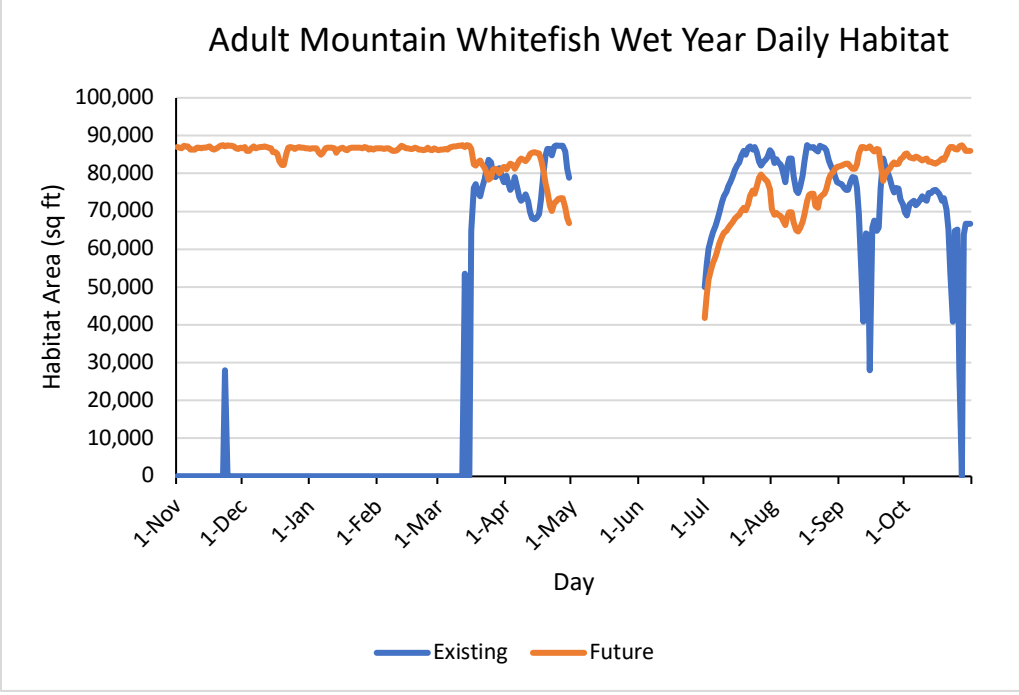

Figure 22. Adult Mountain Whitefish wet hydrologic year daily habitat for existing and future conditions.

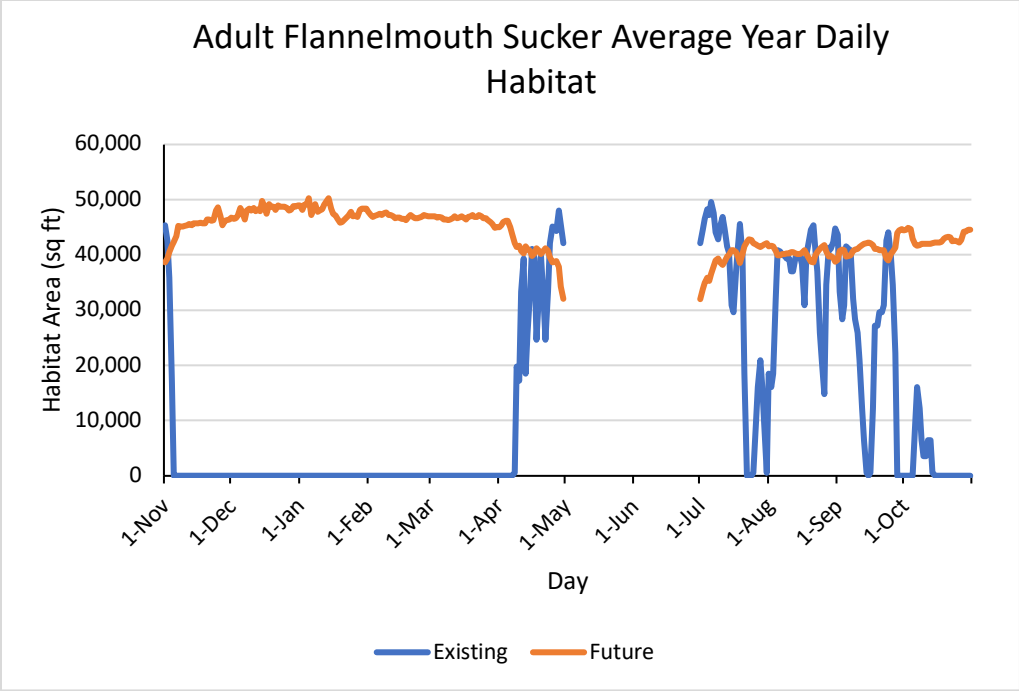

Figure 23. Adult Flannelmouth Sucker average hydrologic year daily habitat for existing and future conditions.

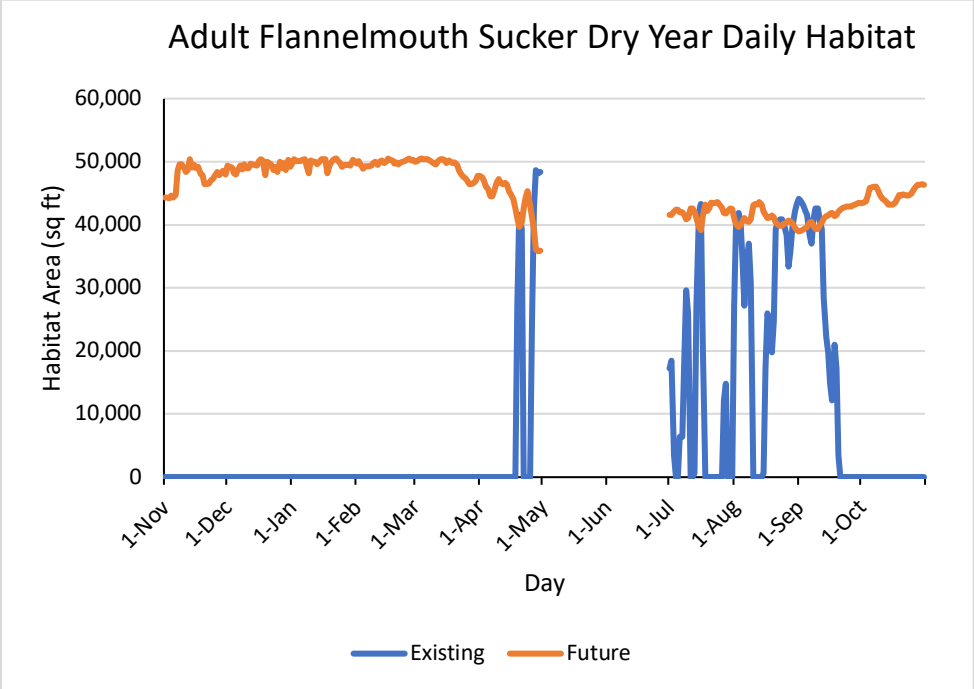

Figure 24. Adult Flannelmouth Sucker dry hydrologic year daily habitat for existing and future conditions.

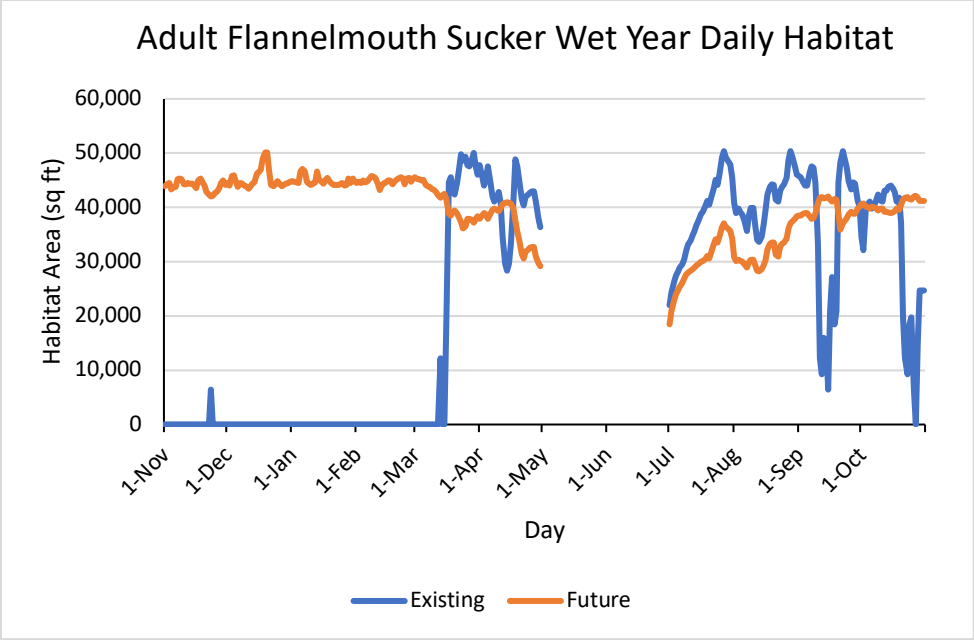

Figure 25. Adult Flannelmouth Sucker wet hydrologic year daily habitat for existing and future conditions.

Aquatic Ecosystem Considerations

Instream flow analysis with IFIM is grounded on ecological principles including flow regime (hydrology), habitat structure, water quality, food sources (trophic considerations), and biotic conditions (Bovee et al. 1998). While IFIM can provide quantitative hydraulic-habitat data from the analysis, these data require interpretation based on other ecological functions. These ecological functions are depicted in hierarchical fashion with the stream function pyramid as developed by Stream Mechanics (Figure 26). Data for all the biological conditions in the Shoshone Reach has not been collected due to logistical limitations, however, biological conditions can be inferred from data collected upstream and downstream of the reach and general knowledge on how riverine aquatic ecosystems function.

The biota in the Colordo River ecosystems and the Shoshone Reach are adapted to a snowmelt-runoff flow regime. The biological adaptation is the response to changes in the physical environment to high runoff flows and low base flows (Lytle and Poff, 2004). Another important component of river ecosystem function is connectivity. Consistent, non-interupted flow is important to connect longitudinal river reaches and allow migration for long distance directed movement such as spawning migration or localized movement of resident fish species (Annear et al. 2004; Cathcart et al. 2015; Thompson and Hooley-Underwood 2019). Colorado River native sucker larvae (Flannelmouth Sucker and Bluehead Sucker) drift downstream after hatch and upstream migration of mature life stages is needed to maintain populations. Maintaining longitudinal connectivity is important to maintaining these native sucker populations. These two sucker species occur upstream and downstream of the Shoshone Reach. A continuous flow in the Shoshone Reach would help to maintain longitudinal connectivity.

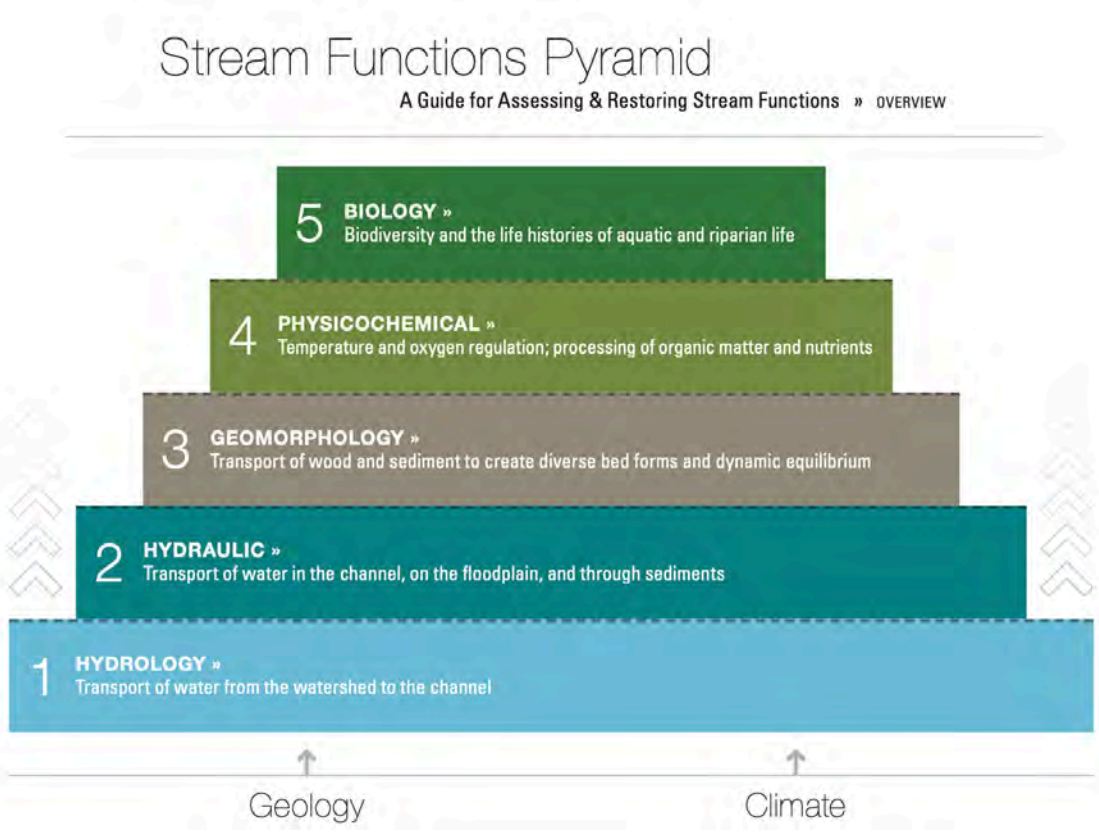

Figure 26. Stream Functions Pyramid showing hierarchical relationship of functions. (Source: Stream Mechanics https://stream-mechanics.com)

Physical components of riverine systems that affect the biota both in the riparian and instream areas include hydrology, geomorphology, and water quality. Hydrology within snowmelt riverine systems usually have spring or early summer peak flows with base flows occurring in summer through fall and winter. The species in the Colorado River are adapted to a snowmelt runoff hydrograph and have adapted their life histories to these events. Fish species use the deeper pools and velocity shelters provided by large boulders and other large instream objects as refuge habitat during high flows.

Base flows are important to maintaining stream productivity and available habitat for both macroinvertbrates and fish. Stable base flows provide consistent habitat conditions and allow long term habitat for less mobile species such as macroinvertebrates. The existing flow regime in the Shoshone Reach does not include stable base flows which are present in the Colorado River upstream and downstream from the Shoshone Reach. The higher, stable future condition base flow could also have a beneficial effect on water temperature in the Shoshone Reach. There are areas with hot springs in this canyon reach of the Colorado River. Higher summer base flow would provide more flow volume and deeper habitats which could provide thermal refuge for aquatic species in the Shoshone Reach.

Conclusions

The Colorado River in the Shoshone Reach is confined by canyon or steep topography throughout the reach and is bounded on the north by the interstate highway and on the south by the railroad. Canyon-bound confined reaches have steeper gradients and larger bed material on the river bottom than the lower-gradient meandering reaches in other sections of the river. These confined reaches have less lateral space for floodplains and less lateral channel movement than lower gradient meandering reaches.

Hydrology in the reach is typical of snowmelt-dominated rivers. Peak flows occur during May and June. Stable flows during non-runoff months provide the conditions needed for

productive food sources for fish and other trophic levels. The existing flow regime in the Shoshone Reach has both sporadic times in summer of zero flow and extended winter periods of zero flow. Zero flow is detrimental to primary and secondary trophic levels, is a negative impact to species that rely on these trophic levels for food and eliminates fish habitat which results in outmigration of fish or mortality. The stable flow regime and stable wetted area under the future conditions are beneficial for productivity at all trophic levels.

Habitat for most species and life stages is most abundant at flows between 700 and 1,400 cfs. Habitat abundance for most species and life stages decreases rapidly at flows less than 700 cfs. There is a gradual decrease in habitat as flows increase from 1,400 cfs to 3,000 cfs when the bypassed/shepherded flows are present in late summer, however, there is still much greater habitat availability compared to the habitat availability for flow less than 700 cfs. The future condition summer and late summer wetted area is relatively stable for the flows from 1,400 cfs to 3,000 cfs and provides stable habitat for algae, macroinvertebrates and fish.

Based on the available hydrology and the habitat-discharge functions, the future flows (the Shoshone Hydropower Plant water rights which include a senior right for 1,250 cfs and a junior right of 158 cfs for a total of 1,408 cfs plus the bypassed/shepherded flows, which can result in a total flow of up to approximately 2,500 cfs to 3,000 cfs at the Dotsero Gage) would provide a substantial increase in habitat and benefit aquatic biota during summer, fall, winter, and early spring as compared to the existing conditions. These flows up to approximately 2,500 cfs to 3,000 cfs therefore will help to preserve and improve the natural environment in the Shoshone Reach. The higher continuous summer base flow for future conditions would benefit all aquatic biota and eliminate the abrupt loss of food and habitat as seen during the zero flow days with existing condition flows. Stable winter flows would allow macroinvertebrates to complete their life cycles within the Shoshone Reach, which increases overall trophic productivity, and provide over winter habitat for all fish species.

There also are indirect benefits to other sections of the Colorado River from the Shoshone Hydropower Plant water rights. These water rights are administered at the Dotsero Gage upstream from the Shoshone Reach, however, the water is conveyed from the upper sections of the Colorado River upstream of the Dotsero gage downstream to the Shoshone Reach and benefits all of the intervening reaches of the upper Colorado River. Similarly, the Colorado River downstream of the Shoshone Reach benefits from the Shoshone Hydropower Plant water rights.

In summary, the future conditions with the Shoshone water right in place as an instream flow in the Shoshone Reach would result in the following:

- Stable base flow conditions with no zero flow days.
- Stable wetted area during future conditions in late summer, fall, winter and spring for better conditions for macroinvertebrates and algae which are food sources for fish species.
- Average year hydraulic-habitat conditions in summer and winter base flows that provide from 81% to 99% of the potential maximum hydraulic habitat.
- Continuation of indirect benefits upstream and downstream of the Shoshone Reach.
- Flows from 1,400 to 3,000 cfs provide additional benefit to the aquatic habitat in the Shoshone Reach.
- Overall improved instream conditions to preserve and enhance the aquatic habitat.

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Appendix A – Habitat Suitability Criteria for Trout, Flannelmouth Sucker and Mountain Whitefish.

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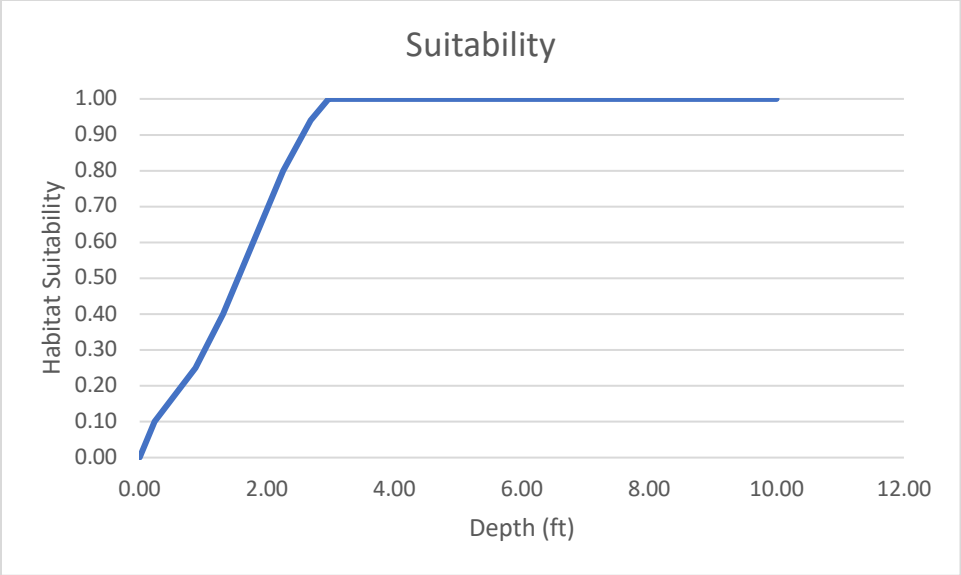

Figure A-1. Adult Brown Trout Depth Suitability Criteria.

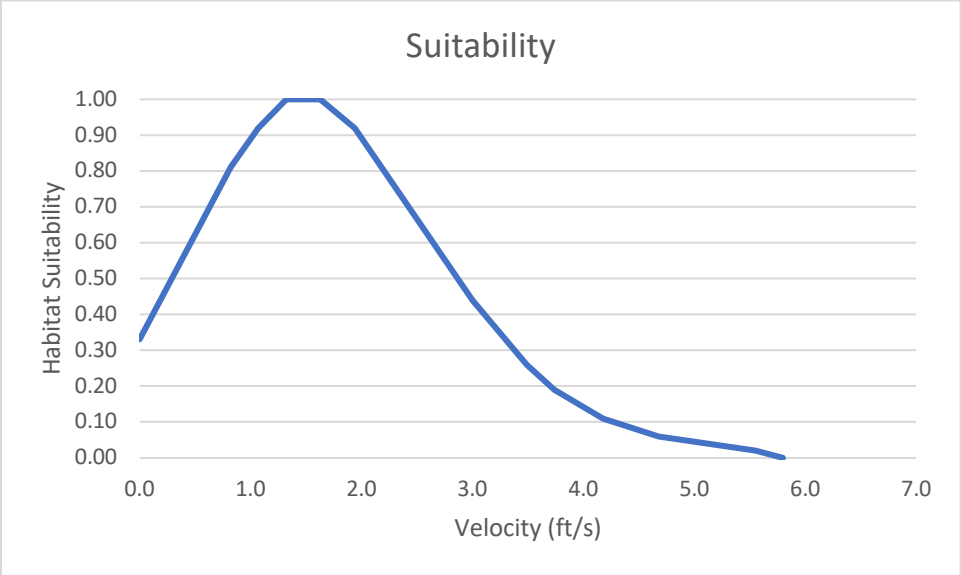

Figure A-2. Adult Brown Trout Velocity Suitability Criteria.

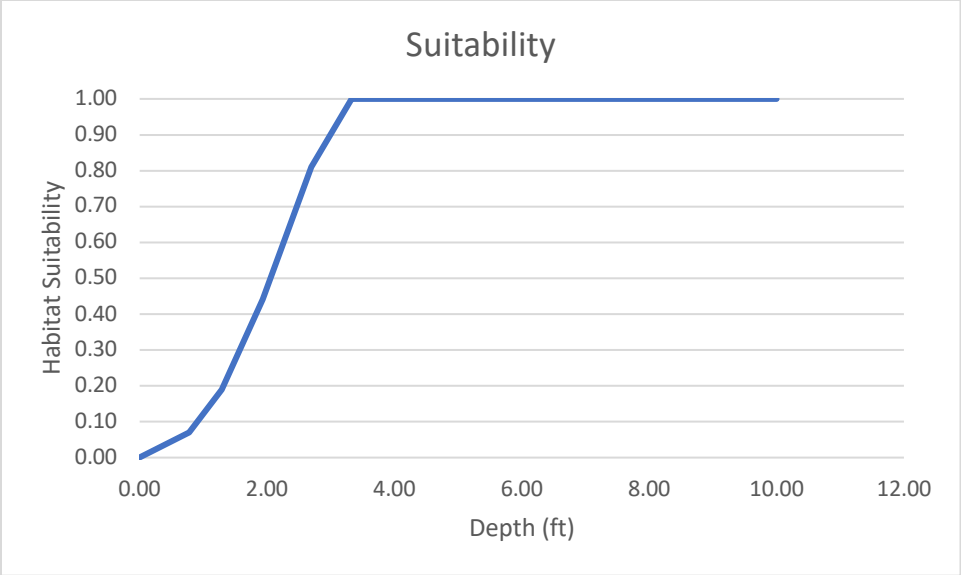

Figure A-3. Adult Rainbow Trout Depth Suitability Criteria.

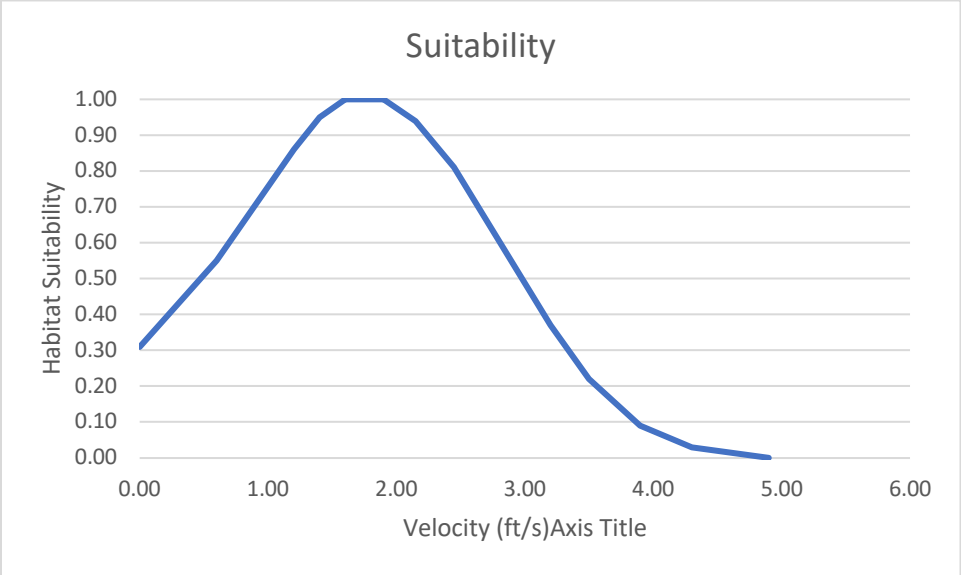

Figure A-4. Adult Rainbow Trout Velocity Suitability Criteria.

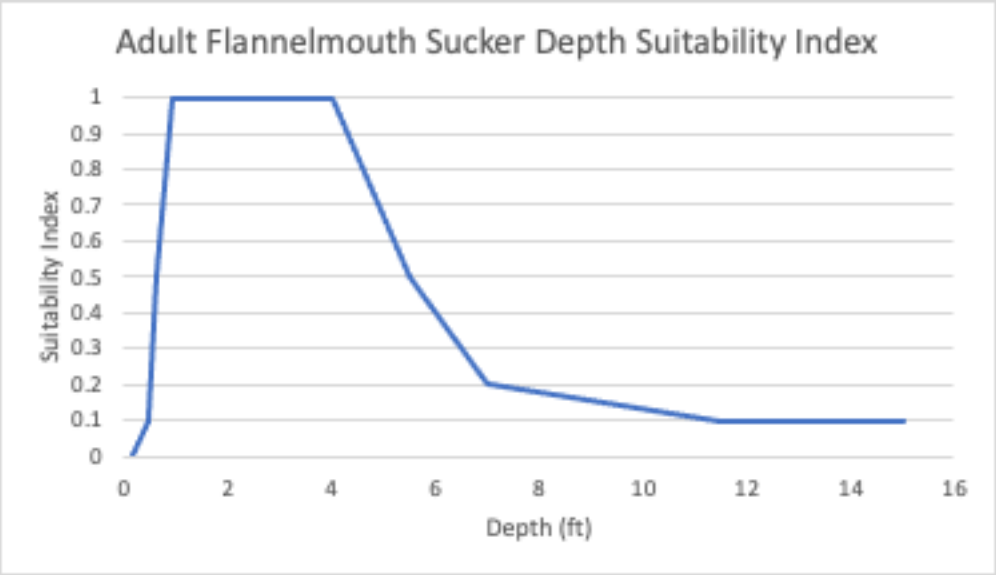

Figure A-5. Adult Flannelmouth Sucker Depth Suitability Criteria

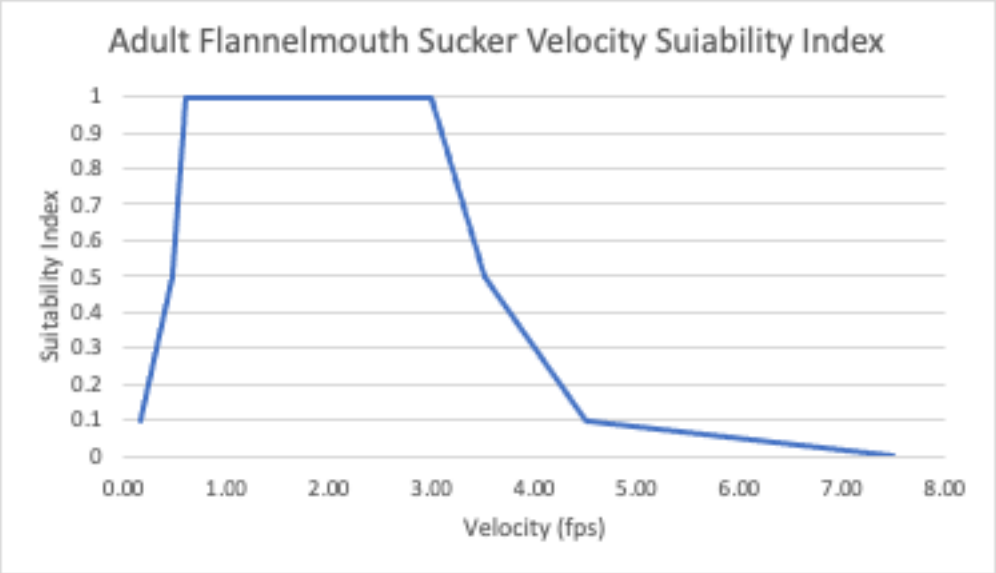

Figure A-6. Adult Flannelmouth Sucker Velocity Suitability Criteria

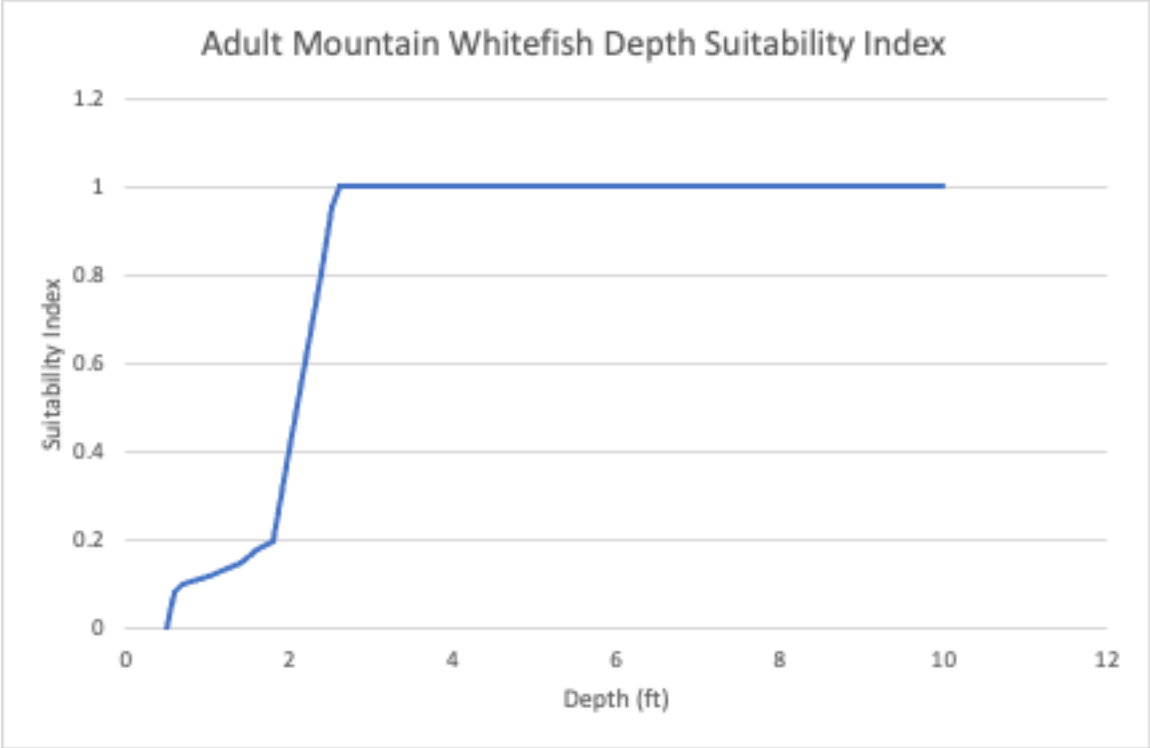

Figure A-7. Adult Mountain Whitefish Depth Suitability Criteria.

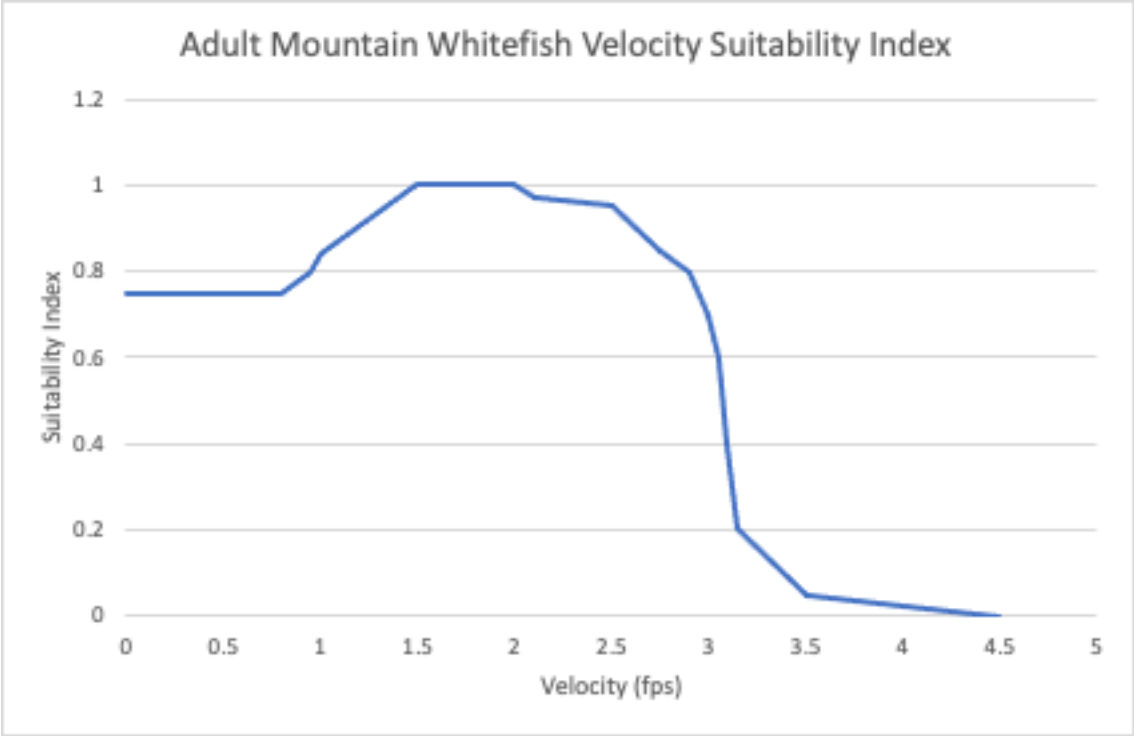

Figure A-8. Adult Mountain Whitefish Velocity Suitability Criteria.

Appendix B – Hydraulic Modeling Report

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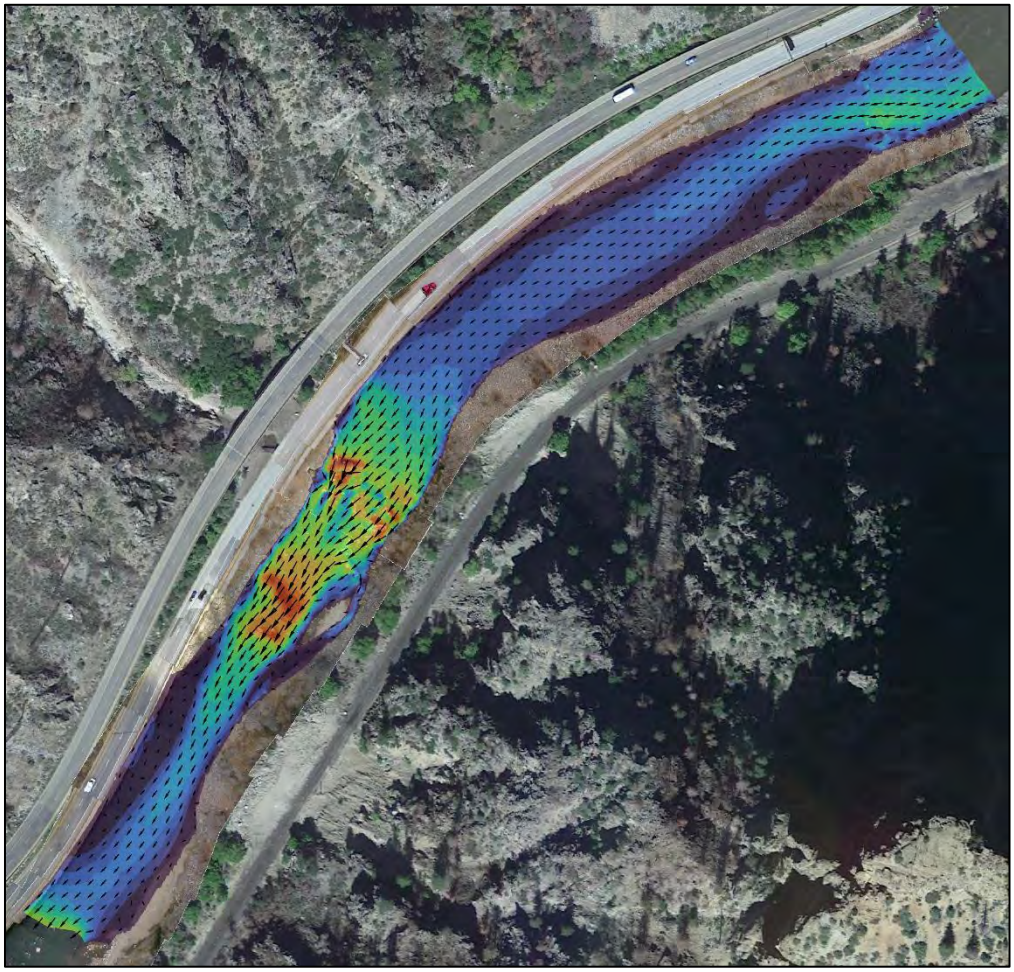
GLENWOOD CANYON AQUATIC HABITAT STUDY
COLORADO RIVER, COLORADO

HYDRAULIC MODELING REPORT – 2023



PREPARED BY RIVERRESTORATION.ORG, DECEMBER 2023

Corresponding authors: Jason Carey, PE – Project Manager – jason.carey@riverrestoration.org
Russell Bair, PE – River Engineer; russell.bair@riverrestoration.org

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700cfs_results.xlsx
1020cfs_results.xlsx
1250cfs_results.xlsx
1400cfs_results.xlsx
3000cfs_results.xlsx

1. INTRODUCTION

A 2 dimensional (2D) hydrodynamic model was used to simulate a variety of low flow conditions for a study reach on the Colorado River in Glenwood Canyon. The model was based on a digital elevation model (DEM) developed from hydrographic survey data collected over an 1854 foot reach (Figure 1). The goal was to provide spatially discrete data and weighted values of water depth, velocity, shear stress, and a Froude value for use in a usable habitat analysis.

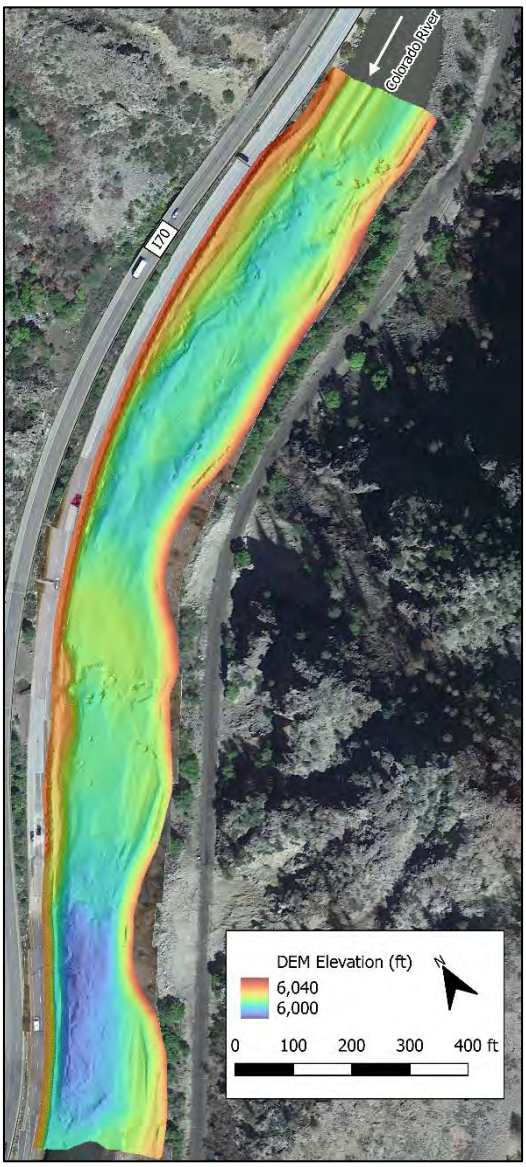

Figure 1. Glenwood Canyon model domain DEM

2. MODELING METHODOLOGY

2.1. Model Overview

Hydrographic survey data (see Glenwood Canyon Survey Report) was used to develop a DEM for the study reach. Point elevations and breaklines were used to characterize bed features like pools, rapids, and individual boulder features. This DEM is available in a geotiff format in the associated data appendices. This DEM was converted into an irregular 2D mesh with a cell sides targeted to a length of 4' within the channel using SMS software. Due to the SMS software interpolating an irregular mesh, a range of cell side lengths were modeled. Both three and 4 sided cells exist in the irregular grid, leading to a range in cell areas. These cells represent the elevations of the bed and provides calculations locations with discrete boundaries for a solver to calculate a depth-averaged result within. Depth-averaged two-dimensional velocity modeling simulates hydraulics in the streamwise and lateral directions, averaging values through the water column in the vertical. SRH-2D is a two-dimensional numerical model widely implemented for hydraulic applications and was used to simulate conditions within the project reach.

The SRH-2D model requires a spatially distributed friction element in addition to elevation for each cell. This can be provided in the form of a Manning's n value layer. For the model, we used spatially discrete Manning's n values based on the bed sediments observed during the survey. The final values for each area can be found in Figure 2, these values were adjusted within a reasonable range during the model calibration process, discussed below.

The upstream end of the 2D mesh was artificially extrapolated 100' upstream. This is visible in Figure 1 where the channel geometry appears stretched. The extra 100' was added to provide an area for the modeled inflow to non-uniformly distribute before entering the area of interest in the model domain. The extrapolated geometry was developed with the upstream cross section of survey data copied to the

upstream location and directly interpolated in between. Results provided from the modeling process used for the habitat analysis excluded all values in this extrapolated area.

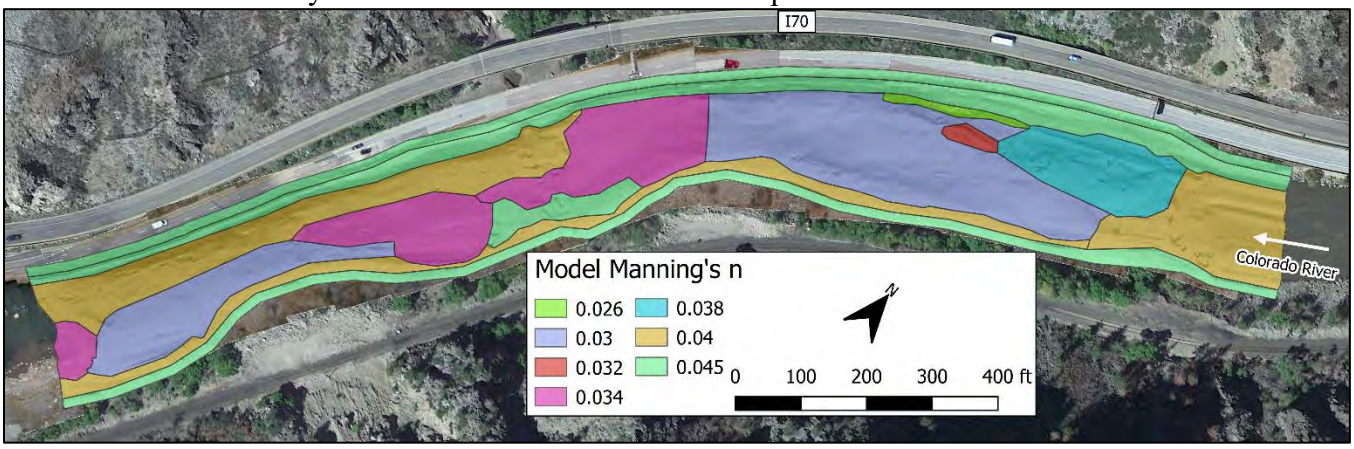

Figure 2. Final spatially distributed Manning's n values used in the SRH-2D hydraulic model

SRH-2D requires an upstream and downstream boundary condition. A steady flow rate was used as the upstream boundary condition for each different flow of interest and the model time was run until a steady state was achieved throughout the model domain. A constant water surface elevation (WSE) was used as the downstream boundary condition for each flow. The downstream boundary in the model domain was set at the crest of a rapid, where the flow exited the pool and passed through the critical state. A known water surface elevation was measured for the survey flow (1020 cfs) and used during the calibration process (discussed below). A 1D critical flow area equation (Eq. 1) based on the geometry of the downstream section of the model was used to calculate the water surface elevation boundary condition for each additional flow of interest. Flows of interest for this study were: 50 cfs, 250 cfs, 700 cfs, 1020 cfs (survey flow), 1250 cfs, 1400 cfs, and 3000 cfs.

Eq. 1 $$Q = \left(\frac{Area^3 * g}{Top\ Width}\right)^{1/2}$$

2.2.Model Calibration

The 2D hydraulic model was calibrated to WSE points captured during the survey flow of 1020 cfs. Calibration consisted of adjusting Manning's n values for different areas of the model within a reasonable range and adjusting the geometry of the DEM at observed control sections that were not sufficiently surveyed for bathymetric data. DEM adjustments were primarily focused on the grade controlling rapid in the middle of the survey area that impacted the large pool upstream and were a challenge to survey in great detail due to safety concerns in the field. The largest adjustment was made on the thalweg on the left side of the channel near the crest of each rapid, where conveyance needed to be increased to match the surveyed upstream water surface slope exiting the pool. After the calibration adjustments were made, the majority of the WSE calibration points were within +/- 0.2' of the model result (Figure 3), which is in line with the expected vertical accuracy of the survey. The majority of the outliers from this range, and the largest outliers, were in the steepest section of the rapid. Here, any given WSE in the model represents a smaller area of the channel. Additionally, less consistent WSE in rapids in the field decreases the accuracy of a given survey value. The large pools and areas of more gradually varying WSE slope all were well matched within the model. Mannings 'n' values were held consistent for all model runs between 50 cfs and 3,000 cfs based on the calibration at 1,020 cfs.

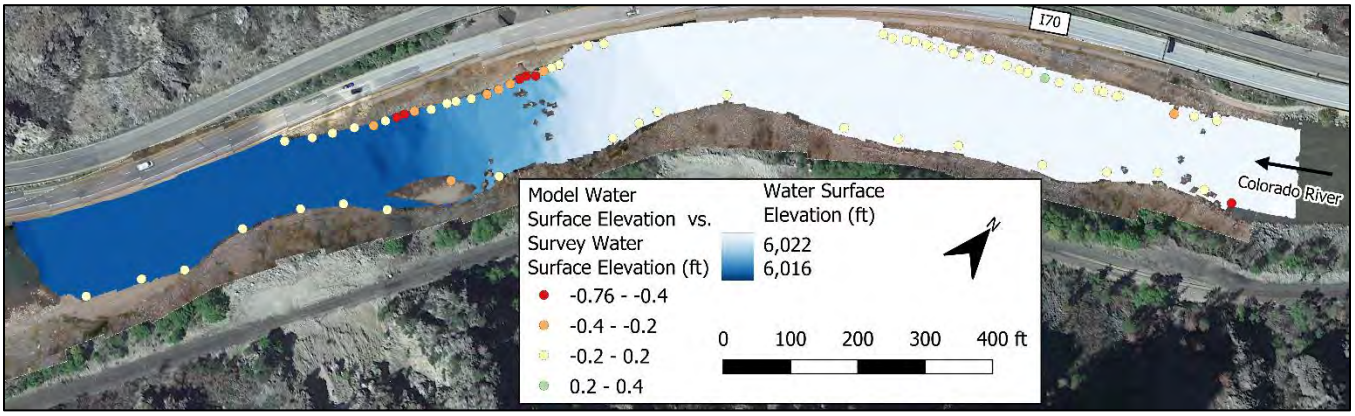

Figure 3. Model Calibration Results

3. RESULTS

3.1. Model Outputs

The model simulations were run until the flowrate into the model came to an equilibrium with the flow rate out of the model and was considered steady state. Results for each were then output for use in the habitat analysis. Results were sampled at the centroid location of each computation cell in the model 2D mesh (Figure 4). These cells represent areas ranging from less than 1 ft^2 to 70 ft^2, with the majority of the cells in the active channel between 5 ft^2 and 15 ft^2. Table 1 lists each of the hydraulic outputs that were sampled at the centroid of each cell.

Table 1. Model Outputs

Output	Unit
Cell Area	ft^2
Centroid X Coordinates	ft
Centroid Y Coordinates	ft
Bed Elevation	ft
Water Surface Elevation	ft
Water Depth	ft
Velocity in X direction	ft/s
Velocity in y direction	ft/s
Velocity Magnitude	ft/s
Froude Number	Dimensionless
Shear Stress	lb./ft^2

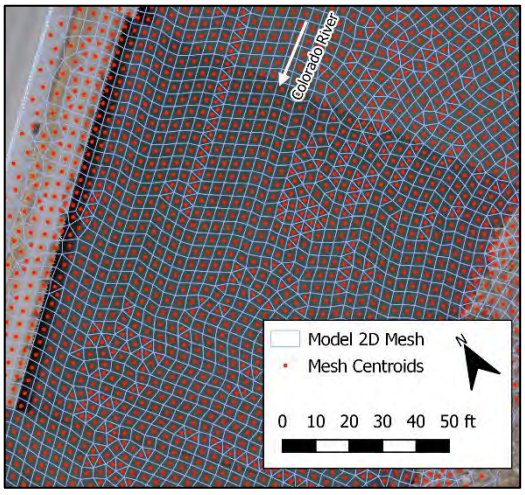

Figure 4. Glenwood Canyon model domain

3.2. Model Results Discussion

The model reach is bound on both sides by steep banks, including areas of vertical concrete in the highway embankment. Across the flow range evaluated the wetted flow area increased 23%. The largest changes in flow area occur around shallow areas of sand deposits near the up and downstream ends of the model as well as in some of the shallow cobble areas of the riffle in the middle of the model. The flow generally increases in velocity and depth as discharge increases (Figure 5). At the lowest modeled flow of 50 cfs

some unwetted areas emerge at the top of the rapid grade control that are larger than just single elevated boulders. At such extreme low flows, it may be reasonable to assume that some of the control section flow would be hyporheic flow between the large bed materials and infiltrate subsurface. The model also represents areas where the channel geometry is overhung by a suspended concrete bike path on the right bank in both pools. The modeled WSE in these areas remains several feet below the path elevations at the highest flow modeled for this analysis, 3000 cfs, but field observations have shown that extreme high flows in the river can reach these vertical obstructions, limiting the applicability of this model to flow levels less than or equal to 3,000 cfs.

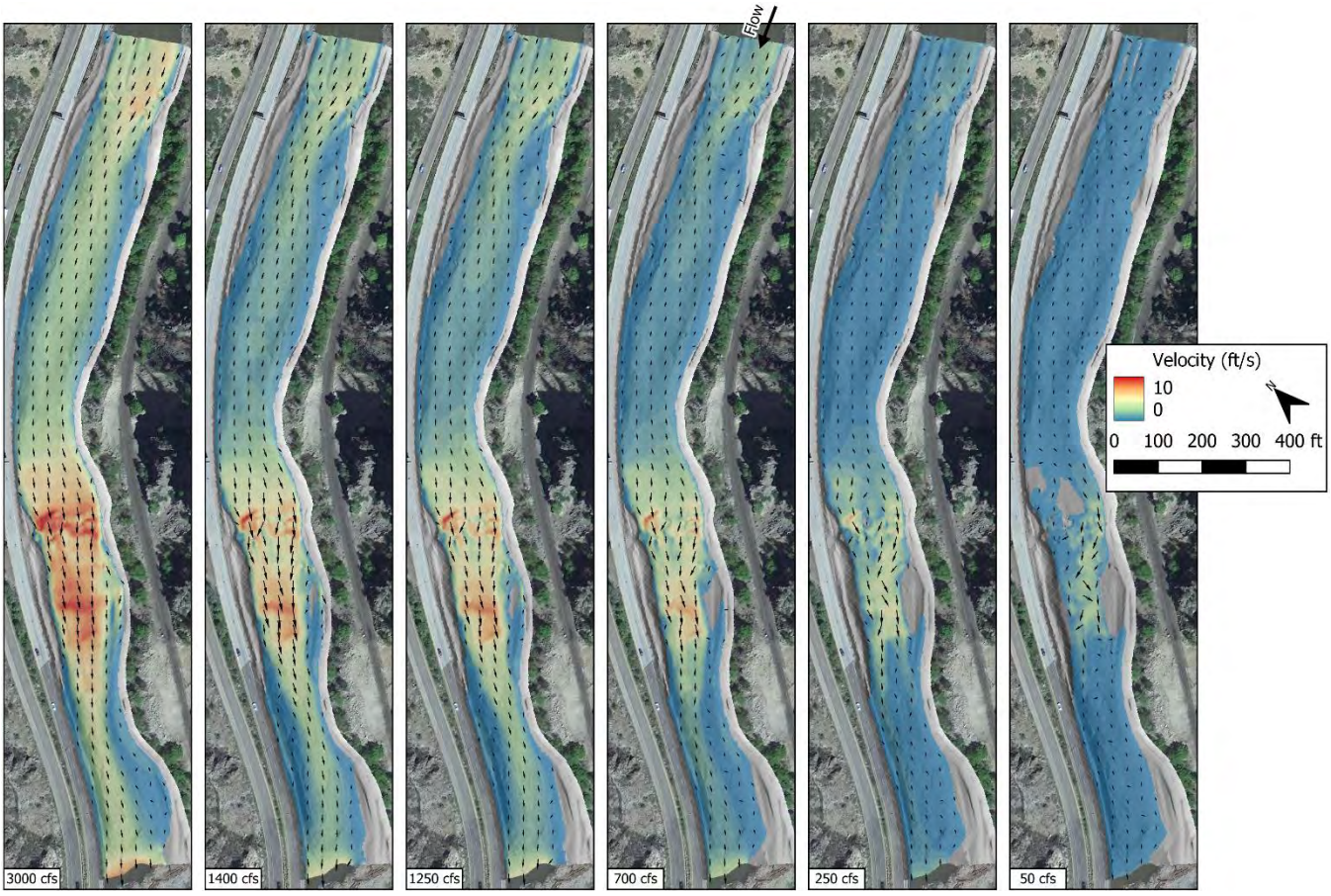

Figure 5. Model results showing velocity at the flows of interest

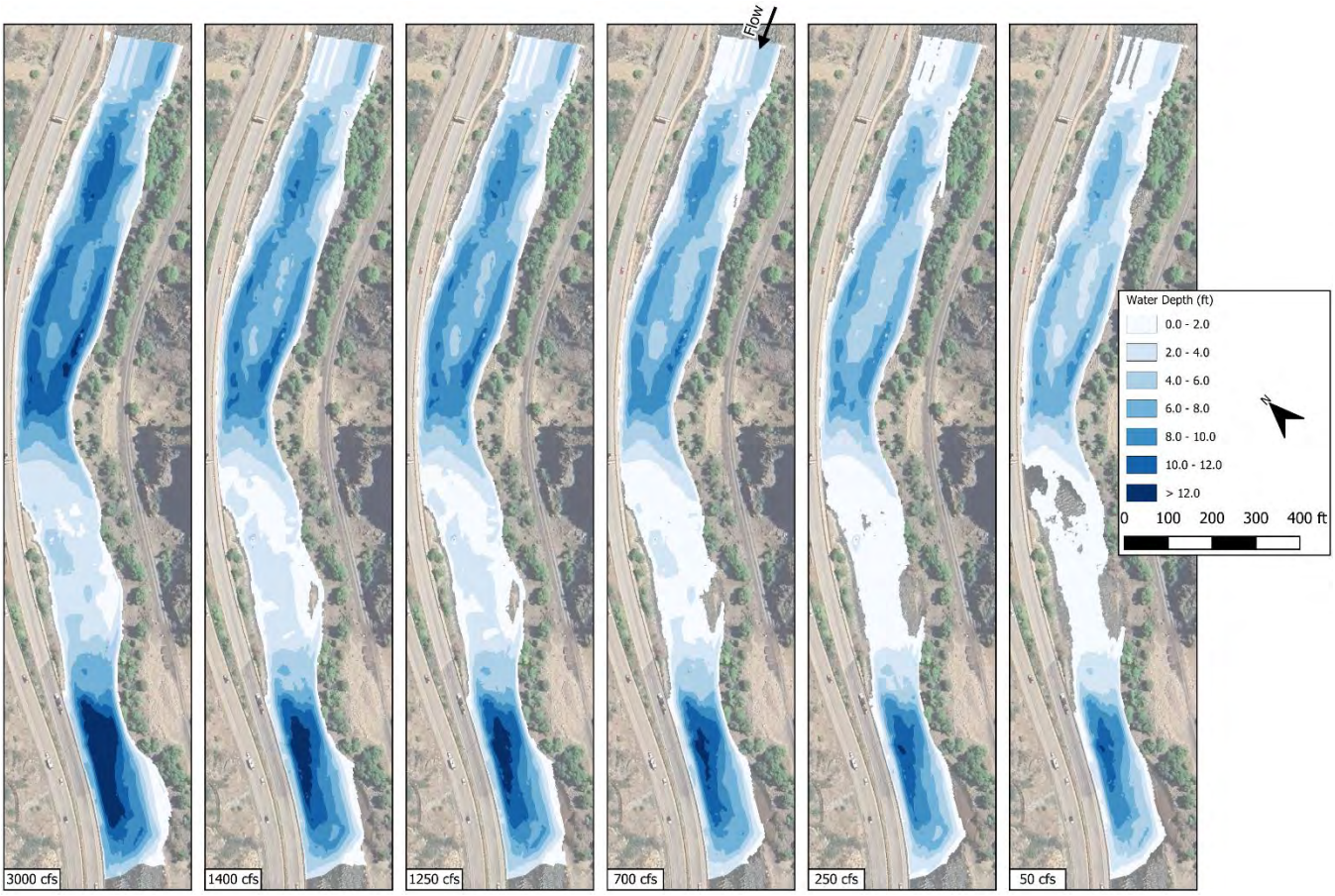

Figure 6. Model results showing depth at the flows of interest

4. SUMMARY

This report explains how survey data collected in Glenwood Canyon were used to create a calibrated 2D hydraulic model. This model was then used to predict hydraulic conditions of the study reach at a range of flows of interest to aquatic habitat at a resolution of approximately 4 ft x 4 ft. The model may have limitations at resolutions less than 4 feet length scale or at flows less than 50 cfs or greater than 3,000 cfs. Results available in the included data appendices can be used in an analysis of the available habitat within the study reach at the specified study flows.

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Appendix C – Hydrographic Survey Report

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GLENWOOD CANYON AQUATIC HABITAT STUDY
COLORADO RIVER, COLORADO

HYDROGRAPHIC SURVEY REPORT – 2023

PREPARED BY RIVERRESTORATION.ORG, DECEMBER 2023

Corresponding authors: Jason Carey, PE – Project Manager – jason.carey@riverrestoration.org
Russell Bair, PE – River Engineer; russell.bair@riverrestoration.org

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1. INTRODUCTION AND SURVEY METHODS

A hydrographic survey covering 1854 feet of the Colorado River in Glenwood Canyon was conducted on November 6th and 8th, 2023. The survey extent encompassed two pool sections divided by a boulder/cobble rapid and bounded by a rapid on the downstream end. Survey was conducted in the channel up the ordinary high water mark (OHWM) evident in the field. A combination of wading and boat-based survey was used to cover the areas of various depths and velocities (Figure 1). The survey was performed using a combination of RTK GNSS, Single Beam Echo Sounder (SBES), and total station. The survey was conducted using the NAD83 State Plane Colorado Central coordinate reference system (CRS) in US survey feet, vertical datum of NAVD88, and using the CONUS18 geoid model. Survey control was based on points provided by CDOT and tied in local control monuments via GNSS observations. Instruments utilized included Trimble R780 and R10 GNSS units, a boat mounted Ohmex SonarMite SBES, and a Trimble 5603 DR 200+ total station.

In addition to the bathymetric survey, the bed material was characterized at each topographic survey point throughout the survey reach and high-resolution ortho imagery was captured from 100’ and 200’ AGL throughout the reach.

Figure 1. Survey Area Overview Map

Figure 2. Survey Methods. GNSS rover (left) and boat mounted GNSS integrated SBES (right)

2. SURVEY CONTROL

The survey was based on control provided by CDOT for monuments recovered in the vicinity of the Hanging Lake rest area. Two control monuments were utilized with the coordinates provided in Table 1; Point 2528 was held as the location of the RTK GNSS base station during both days of the survey and point 2541 was used to check the initial base set up with RTK GNSS rovers. Eight additional control monuments were found and tied into the control network using 180 second RTK GNSS observations. These monuments were on the bike path that paralleled the survey reach and consisted of brass survey markers and "X" marks scrawled in the concrete placed by CDOT. These monuments were used for internal survey checks and as the basis for a total station set up and backsight but coordinates in Table 1 should not be considered survey control quality based on the limited GNSS constellation observed at the bottom of the Glenwood Canyon. Single beam sonar sound speed was adjusted in the field to match stadia rod depth measurements and integrated with either a total station prism or a RTK GNSS rover at different times to measure locations.

Table 1. Control Point information. NAD83 State Planes Colorado Central US Survey Feet, NAVD88, Geoid CONUS18. Coordinates are based on RTK GNSS survey holding 2528 and should not be considered survey control quality for future surveys.

Source	Point	Northing	Easting	Elevation	Description
CDOT	2528	1643610.52	2523096.51	6125.178	CDOT 1075--Type 5S IN CONC BIKE PATH
CDOT	2541	1644023.31	2523811.81	6117.827	CDOT 1075--Type 5S IN CONC BIKE PATH
GPS est.	193	1640379.889	2519661.18	6023.026	Brass Marker PT 193
GPS est.	194	1640815.124	2519923.869	6027.73	Brass Marker PT 194
GPS est.	195	1641175.599	2520304.564	6026.45	Brass Marker PT 195
GPS est.	196	1641401.255	2520778.948	6029.373	Brass Marker PT 196
GPS est.	300	1641308.444	2520530.666	6027.274	Concrete Scrawl X
GPS est.	301	1641008.418	2520098.404	6027.054	Concrete Scrawl X
GPS est.	302	1640601.825	2519781.121	6024.546	Concrete Scrawl X
GPS est.	303	1640170.93	2519540.383	6022.625	Concrete Scrawl X

3. SURVEY CONDITIONS

Site survey took place on November 6th and 8th, 2023. November 6th conditions were cold and clear while on November 8th, scattered snow showers fell throughout the day. The project reach is located approximately 8.5 miles downstream of USGS stream gage 09070500 on the Colorado River near Dotsero, CO. Shoshone Power Plant was shut down during survey and no diversions were expected between the gage and the site during data collection efforts. There are no major inflows between the project reach and gage, so the gage is assumed to well represent the project reach flows. Figure 3 shows the range of flows during the survey, as well as the slightly lower flows during the acquisition of aerial imagery.

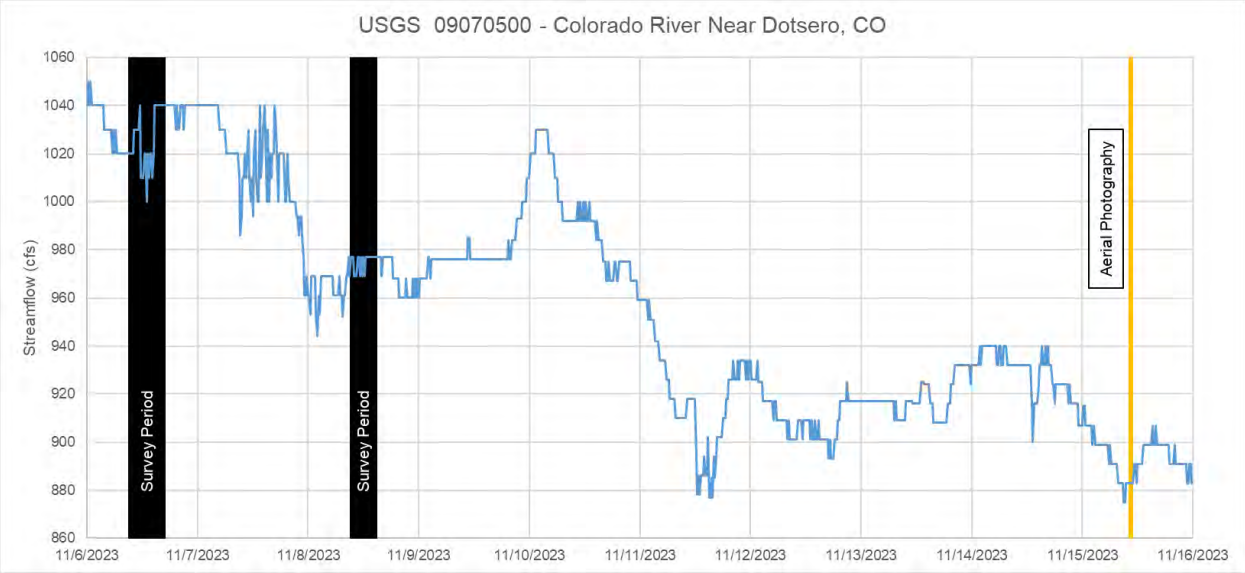

Figure 3. Discharge of Colorado River near Dotsero, Colorado (USGS Gage 09070500) during survey and data aquisition

4. SURVEY RESULTS AND OBSERVATIONS

The survey reach was selected to represent hydraulic characteristics present in the pool/rapid Glenwood Canyon reach of the Colorado River. The survey included two pools divided by one cobble/boulder rapid and was bounded by rapids on the upstream and downstream ends. The rapids generally comprised of large colluvial, and mud and debris flow materials supplied to the main channel from tributaries. Bathymetric and topographic data points were collected to represent bed elevations throughout the survey reach. Information on bed materials including sediment classes and vegetation types were recorded with the points. Areas with depositional sediments and signs of recent maximum high water levels were also recorded, as were water surface elevations (WSE) throughout the reach for the survey flow. There were areas within the survey extent where water was too deep and swift to safely survey on foot or via boat, particularly in some areas around the rapid in the middle of the project reach. Survey was completed to allow for the most accurate interpolation possible in these areas. Additionally, aerial ortho-imagery was collected to help locate larger topographic features such as mid channel boulders.

Survey observations revealed that the bed material varied throughout the study reach. Longitudinal and lateral influences impacted the bed composition. Higher up elevations near the OHWM on each bank consisted of mechanically placed riprap rock materials supporting the highway on river right and railroad on river left (Figure 5). A substantial portion of the river right bank was a vertical concrete wall under a cantilevered bike path with riprap along the right toe (Figure 5). The midchannel consisted of areas of

boulder and large cobbles on the outside of the bend and through the rapids, and large areas of sand deposition on the inside of bends in the pools. Depositional sand included areas of transporting sand over boulders in the upstream pool and also large areas of sand dunes in each pool. A large sandy beach deposit was observed on the inside river left side of the downstream pool. The rapid in the middle of the survey reach and the rapid at the downstream end both consist of large cobble and boulder material (Figure 5) that was delivered from steep tributaries that were impacted by the Grizzly Creek Fire in 2020 and the subsequent debris flows during heavy rain in 2021. The crests of these rapids act as grade controls controlling the water surface elevation of the pools immediately upstream. Sand deposits transition to a lens of alluvially transported large cobble material on the upstream approach of each rapid crest. These cobble materials acted as the hydraulic grade control of each pool at the survey flow. Larger boulders deposited by the tributaries define the main drop in WSE across the rapids. A matrix of small boulders and large cobbles surround the largest boulders with minimal areas of finer depositional material through the rapids until the hydraulic gradient reaches the next pool elevation controlled by the downstream rapid crest and the flow slows. Figure 4 shows the different substrate areas that were identified during the survey overlaid on the final digital elevation model that was created.

Riprap banks throughout the reach were not densely vegetated, but a variety of riparian plant species including willows and cottonwoods were scattered on the banks in pockets around boulders and riprap. Willows, grasses, shrubs, and smaller trees dominated the right bank, while the left bank had more mature cottonwoods.

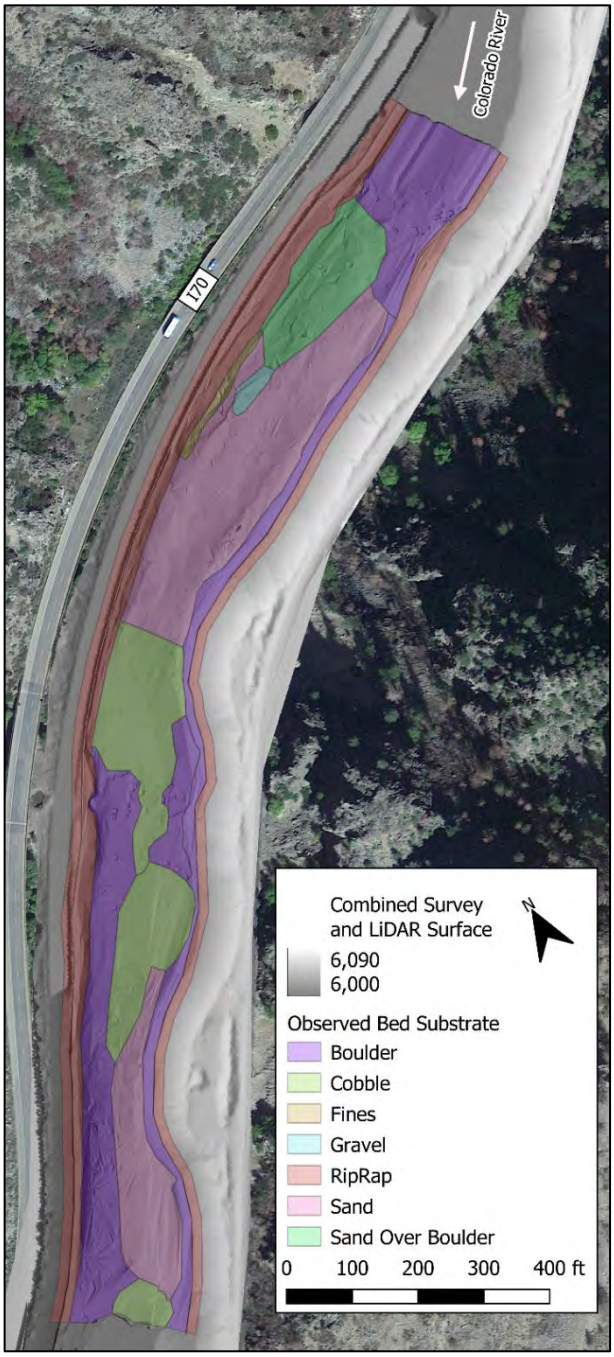

Figure 4. Substrate Areas and DEM

Figure 5. (Left) Looking downstream from the right bank at the rapid in the middle of the survey area. (Right) Aerial oblique drone photo looking downstream from near the upstream end of the survey area. The riprap and concrete nature of the banks can be seen.

5. BASE MAP AND DEM DEVELOPMENT

Survey data were post-processed to remove potential spurious data, mostly in the form of inaccurate SBES depth readings. Interpolation of some topographic data was required in areas that were unsafe to survey, but this was expected from the outset, and the majority of the survey extent was covered by on the ground field survey. A digital elevation model (DEM) was created for the entire surveyed project reach using a triangular irregular network (TIN) to connect surveyed points along with breaklines to represent the existing conditions in the field. Additional breaklines were included to represent boulder clusters and pour overs in rapids based on the collected aerial ortho-images. Elevations for some of these features had to be estimated based on nearby similar elevation features that were surveyed or nearby water surface elevations.

Field survey only took place up to the OHWM. For areas above this elevation, LiDAR data was added to the DEM. This LiDAR DEM data is publicly available data collected on flights in June of 2016 for the Colorado Water Conservation Board (https://coloradohazardmapping.com/lidarDownload). The data is formatted as a geotiff with 3 ft resolution. The LiDAR survey was carried out in the same coordinate reference system as this ground based survey; State Plane Colo. Central, NAD83, NAVD88. The LiDAR survey used the 12B geoid model as opposed to the more recent CONUS18 geoid model, but in the area of interest, this difference is not expected to have an impact. The LiDAR data inserted was well aligned with the surveyed ground elevations and required minimal editing of the DEM to mesh to two surfaces. Because the ground survey went to the elevation of the OHWM, the LiDAR based data inserted at elevations higher than this are not expected to have a meaningful impact on the flow levels of interest for this project.

A continuous bathymetric and topographic DEM surface was created using these data described above. This DEM was used in hydraulic modeling efforts, discussed in the Hydraulic Modeling Report.

6. SUMMARY

This survey was successful in collecting sufficient data to develop a detailed DEM of the study reach in Glenwood Canyon. The DEM developed from this survey and the bed material observations were used to model 2D river hydraulics, which is described in the Hydraulic Modeling Report. The data collection described in this report was sufficient for modeling 2D river hydraulics at, or finer than the target resolution for the habitat analysis which was specified as a 25 sqft computational cell size area.

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Freshwater Consulting LLC

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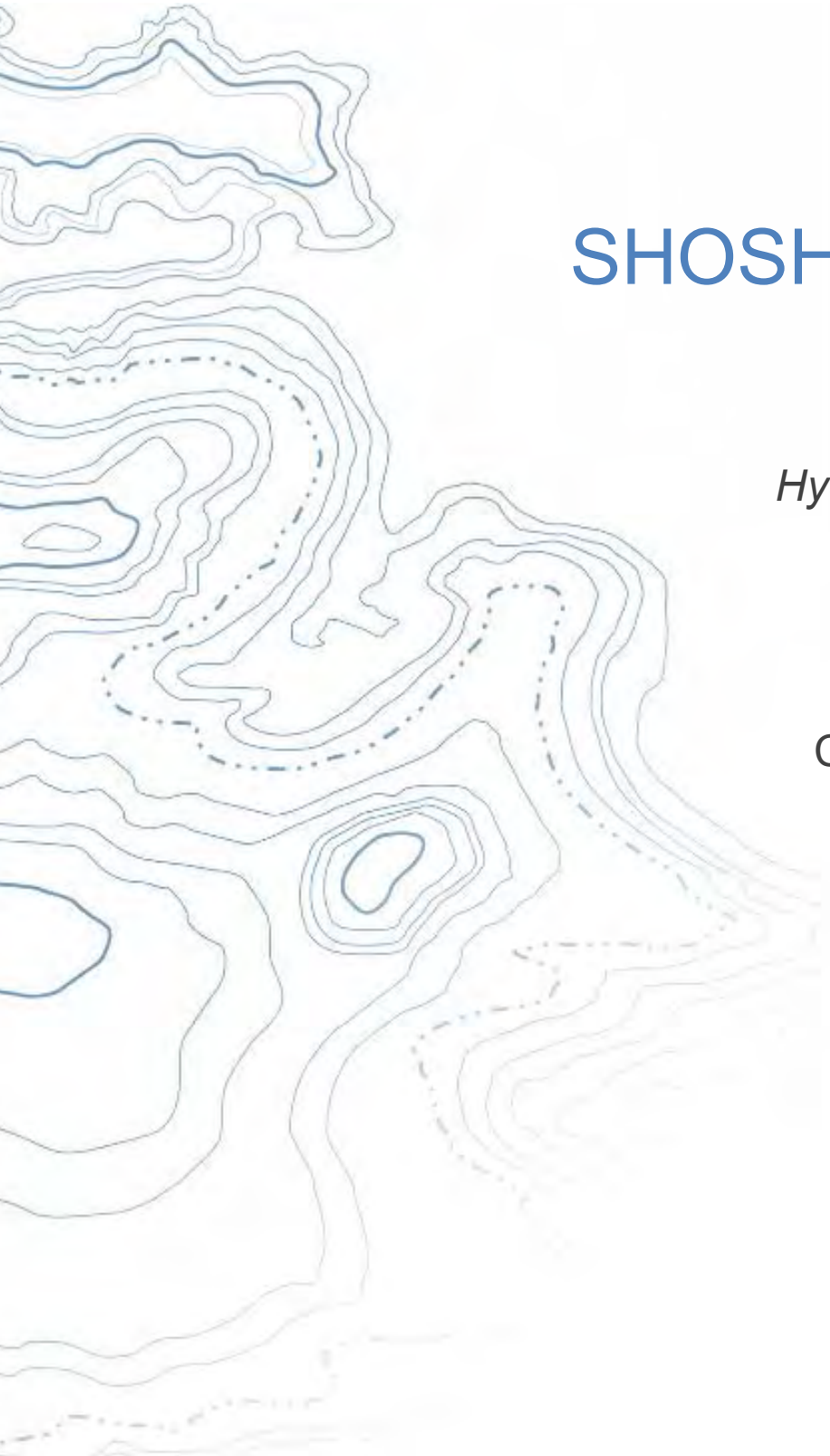

SHOSHONE REACH

Instream Flow
Beneficial Use and
Hydraulic Habitat Suitability
Assessment

Shoshone Reach,
Colorado River, Colorado

April 22, 2025

Ecosystem Sciences, LLC
Science · Planning · Design

Shoshone Reach Colorado River

Instream Flow, Beneficial Use and

Hydraulic Habitat Suitability Assessment

Prepared:

April 22, 2025

Prepared for:
Colorado River Water Conservation District

Prepared by:

Ecosystem Sciences

Science · Planning · Design

Ecosystem Sciences, LLC | 202 N. 9th Street, Suite 400 Boise, ID 83702

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EXECUTIVE SUMMARY

The Colorado River Water Conservation District (River District), in collaboration with partners and stakeholders within the Colorado River watershed, is currently working to acquire the water rights (Shoshone Water Rights) associated with the Shoshone Hydroelectric Power Plant (Shoshone Power Plant), located on the Colorado River, in Glenwood Canyon, Colorado. The Shoshone Water Rights are some of the most senior water rights in the Colorado River Basin, making them a central component in future water management strategies and the protection of ecological, economic, and recreational resources in the region.

Currently, Public Service Company of Colorado (PSCo), an Xcel Energy company, owns and operates the Shoshone Power Plant and Shoshone Water Rights. There are two Shoshone Water Rights totaling 1,408 cubic feet per second (cfs), which may be diverted from the river for non-consumptive hydropower generation and returned to the river 2.4 miles (3.8 km) downstream (Shoshone Reach).

The River District proposes to purchase and change the Shoshone Water Rights to include instream flow use. The River District will dedicate the exclusive right to use the Shoshone Water Rights for instream flow purposes to the State of Colorado to protect the non-consumptive flows associated with these rights which will benefit aquatic and terrestrial ecosystems. This assessment includes an instream flow assessment to evaluate the Hydraulic Habitat Suitability (HHS) benefits of various flow scenarios through the Shoshone Reach. This assessment examines the potential effects of a wide range of flow conditions, from very low flow (50 cfs) up to 3,000 cfs. This approach aims to provide a comprehensive understanding of how varying flows would preserve and improve aquatic habitat for species in the Shoshone Reach under different hydrologic scenarios resulting from the Shoshone Water Rights. The flow regime is analyzed in increments to explore the effects of both reduced and increased flows on habitat availability and suitability, with an emphasis on maintaining ecological integrity.

The assessment utilizes broadly accepted scientific procedures for two-dimensional hydraulic habitat suitability modeling. The HHS criteria used for the Shoshone Reach are specific to the fish species of interest. The selected modeling locations include habitat types that are representative of Glenwood Canyon, including pools, riffles, rapids, and runs. This assessment conducts HHS modeling for two study sites within the Shoshone Reach (Site 1 and Site 2). Assessment results include habitat suitability, weighted useable area, and available wetted area for each flow and fish species.

Several fish species occupy the Shoshone Reach, but for this assessment, the primary interest is in determining the needs for adult Rainbow Trout (*Onchoryncus mykiss*), Brown Trout (*Salmo trutta*), Mountain Whitefish (*Prosopium williamsoni*) and Flannelmouth Sucker (*Catostomus latipinnis*). The species of interest were selected by Colorado Parks and Wildlife (CPW) biologists and represent a range of species, including native non-game fish.

The main conclusions of the assessment are strongly supported by habitat modeling results from two representative sites (Sites 1 and 2) in the Shoshone Reach. Together, these sites characterize 29% of the total Shoshone Reach and are highly representative of the overall reach area. At Site 1, habitat suitability and weighted useable area (WUA) scores increase with flow, up to the high range of discharge modeled flows. At the high discharge range modeled, the WUA scores plateau and moderate.

In comparison, Site 2 shows ongoing improvements in habitat suitability and WUA as discharge flows increase, due in part to its greater habitat complexity. Features like large boulders, cobble substrates, islands, high-flow channels, and deep pools create diverse conditions suitable for fish across a wider range of flows than Site 1, providing critical refuges and feeding zones during high flows.

The geomorphic characteristics of Site 2 promote gradual changes in hydraulic parameters (depth and velocity) and wetted extent as flow increases. The progression in overall wetted area as flows increase allows fish to exploit newly wetted areas, that support both primary (e.g., algae) and secondary (e.g., macroinvertebrates) production that underpins the food web.

While Site 1 exhibits higher suitability and WUA at the median range of evaluated flows, Site 2 maintains consistent upward suitability trends at all flows due to its complexity, highlighting the ecological advantages of the physical diversity in the Shoshone Reach. Although hydraulic suitability and WUA scores are useful, they may underestimate the ecological benefits of increased flows. The velocity refuges created by boulders and cobble substrates provide essential microhabitats that the hydraulic model does not fully capture. Higher flows increase wetted area and improve habitat diversity and connectivity, benefiting fish populations and overall aquatic ecosystems.

Under the proposed scenario where the Shoshone Water Rights are permanently protected as an instream flow water right, habitat suitability and WUA for fish in the Shoshone Reach would be higher annually, providing more habitat for all species over current flows. Based on the analysis, the proposed scenario of permanent protection as an instream flow water right would provide the most habitat on an average annual basis (measured by WUA sq. ft. / 1,000 linear feet (LF) of stream) compared to the other scenarios analyzed. Flow levels would more often remain within an optimal range for extended periods and would provide greater flow during the critical late summer and early fall seasons when temperatures and other stressors are at their peak. Additionally, the seniority and non-consumptive nature of the Shoshone Water Rights would yield a benefit to the Colorado River upstream and downstream, extending these advantages beyond the Shoshone Reach. This assessment's findings indicate that the instream flow use of the Shoshone Water Rights would preserve and improve the natural environment through the Shoshone Reach for all modeled species.

The non-consumptive Shoshone Water Rights, if used for instream flow purposes, would not deplete the river’s water supply but would instead maintain river flows that support instream benefits in the Shoshone Reach. However, if these rights were to be diminished or lost, the river would face increased water quality impacts, and habitat loss. Consequently, the Shoshone Water Rights can serve as a critical instream flow tool for balancing water use with environmental conservation, preserving and improving the natural environment.

1.0 INTRODUCTION

The Shoshone Water Rights are comprised of two rights, a 1905 right for 1,250 cfs, and a 1940 right for 158 cfs. The River District is proposing to purchase and change the Shoshone Water Rights to add instream flow as a beneficial use. The River District will dedicate the use of the rights to the Colorado Water Conservation Board (CWCB) for instream flow use to preserve and improve the natural environment of the Shoshone Reach. The CWCB has the authority to acquire water rights, or interests in water, in such amount as the CWCB determines is appropriate for streamflows or for natural surface water levels or volumes for natural lakes to preserve or improve the natural environment to a reasonable degree.

This assessment has been produced to describe conditions and assess the habitat and hydraulic benefits of various flow scenarios in the Shoshone Reach. Using the Instream Flow Incremental Methodology (IFIM), the assessment evaluates the current aquatic ecosystem and evaluates three flow scenarios for the Shoshone Reach: (1) Baseline – representing flows in the Shoshone Reach under existing conditions; (2) Baseline with permanency – representing a future condition where the Shoshone Power Plant is no longer operating and the Shoshone Water Rights are used for instream flow purposes in the Shoshone Reach; and (3) No Permanency – representing a future condition where the Shoshone Power Plant is no longer operating and the Shoshone Water Rights are no longer exercised. The evaluation also considers the potential effects of a broader range of flow conditions, from very low (50 cfs) to 3,000 cfs, to provide a more comprehensive understanding of how varying flows may preserve and improve the natural environment through the Shoshone Reach. These flow levels were selected to reflect both the low and high flow conditions that may occur seasonally or as part of flow management strategies.

This assessment builds on a recently completed instream flow analysis of the reach performed by Dr. William Miller (2024 Miller Report). In the 2024 Miller Report, one study site was selected for modeling based on habitat characteristics that are generally representative of the Shoshone Reach. The study site included multiple habitat types including riffle, pool, and run habitats. The 2024 Miller Report modeled seven discharge flow scenarios, focusing on four species of fish, and utilizing habitat suitability curves for the adult life stages of each species. This assessment retains several features from the 2024 Miller Report and adds a second study site and increases the number of discharge scenarios for both sites. This assessment includes the four fish species and uses the adult life stage HHS curves for each species utilized in the 2024 Miller Report.

The addition of the second study site (i.e., Site 2) doubles the total modeled assessment area for the Shoshone Reach, thus enhancing the spatial representation of the habitat suitability assessment. Overall, this assessment includes two study sites, four fish species, and twelve flow scenarios, leading to a total of 96 HHS results along with wetted available area results for each flow at both study sites.

Glenwood Canyon and Shoshone Reach

The Colorado River flows west-southwest through Glenwood Canyon for approximately 18 miles, from west of Dotsero to Glenwood Springs, Colorado (Figure 1). The river is confined by a narrow limestone canyon and further constrained by a four-lane highway, a railroad, and a bike path. Notable infrastructure includes power lines, Colorado Department of Transportation (CDOT) rest areas, the Shoshone Power Plant and Dam, and the small community of No Name located downstream of the Shoshone Reach. Several tributaries known to contain spawning habitat for Rainbow Trout, Brown Trout, Mountain Whitefish, and other fish species flow into the Colorado River below the Shoshone Reach, notably Grizzly Creek and No Name Creek. The 2020 Grizzly

Creek Fire burned through the canyon, leading to debris flows that significantly impacted the river, highway, and power plant.

Despite human modifications, Glenwood Canyon is ecologically significant, supporting native and sportfish populations, Rocky Mountain bighorn sheep, and unique plant communities. CPW monitors fish and big game in the area, though studies on non-game species are limited. Most of the canyon is managed by the White River National Forest (WRNF) in partnership with CDOT, while the Bureau of Land Management (BLM) oversees smaller sections. Together, these agencies focus on managing recreation while maintaining ecological integrity.

The Shoshone Power Plant has operated for over a century and holds senior water rights in the watershed, ensuring stream flows during priority calls. The operation consists of the Shoshone Dam and a gravity-fed tunnel leading to two penstocks supplying water to two turbines at the Shoshone Power Plant, which can call for the two Shoshone Water Rights. The river in Glenwood Canyon can be divided into three reaches (Figure 1) by Shoshone Power Plant facilities:

1. *Immediately Upstream of the Shoshone Dam*: The impounded water substantially reduces water velocities in this reach. The reduced flow velocity and increased sedimentation within this reach limits aquatic habitat diversity while the dam fragments fish movement upstream and downstream.
2. *Shoshone Reach:* The Shoshone Reach encompasses approximately 2.4 miles of river between the Shoshone Dam and the Shoshone Power Plant return flow outlet. During seasonal low flow periods the reach is dewatered when the plant is operating, though habitat in the Shoshone Reach is connected by small inflows of groundwater and tributary streams that fill pools and flow through the large boulder and rock substrate. This reach contains both the lower and higher gradient sections that provide a complexity of habitat. Habitat persists even during low flow periods, though wetted area in the stream channel is substantially reduced; however, habitat becomes fragmented for upstream fish movement at low flows.
3. *Downstream of the Shoshone Power Plant*: At this point river flows return, stream gradient gradually decreases, enhancing channel complexity and biodiversity. The river regains its natural character with a mix of riffle, run, and deep pool habitats that all contribute to increased habitat diversity in the mainstem. Two tributaries, Grizzly Creek and No Name Creek, provide important spawning habitat for Rainbow Trout, Brown Trout, and Mountain Whitefish resident to the Colorado River, as reproductive habitat is limited by the geofluvial morphology in the mainstem river in Glenwood Canyon. These tributaries also contribute coldwater inputs as their headwaters originate at elevations well over 10,000 feet in the Flat Tops that encompass the northern edge of Glenwood Canyon.

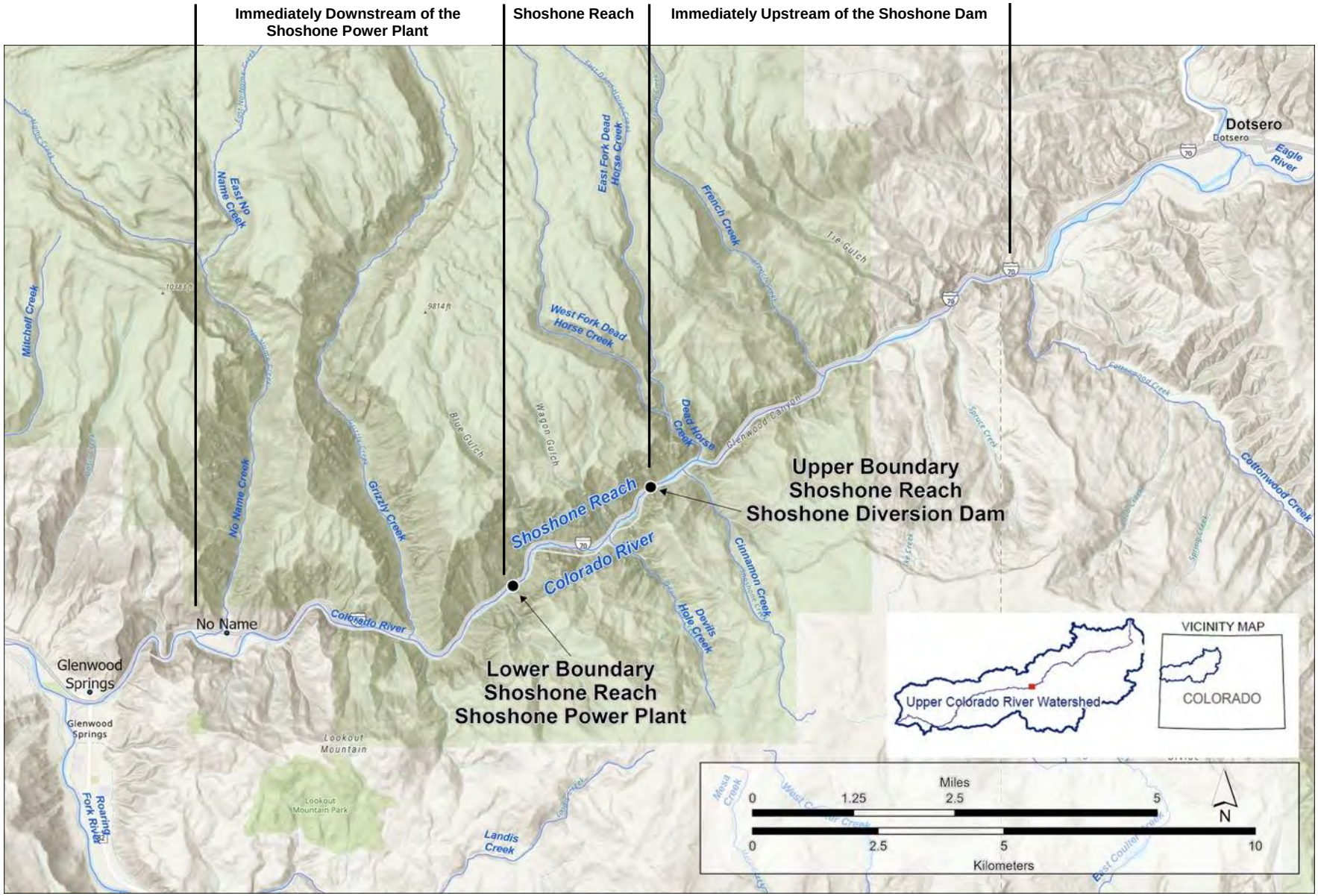

Figure 1: Map of Glenwood Canyon and Location of Shoshone Reach

2.0 SETTING AND CONTEXT

The Colorado Basin is an important watershed in Colorado, extending from the high altitudes of Rocky Mountain National Park to the Utah state line. Covering approximately 9,830 square miles, this basin is vital for both the environment and the economy of the region as stated in the Colorado Water Plan, 2023.

The Colorado Basin features diverse terrains, starting with mountainous areas that are the source of major snowpack, which contribute to the basin's primary water supply, flowing downstream to the dry desert climates of the Colorado Plateau. These snowpacks are crucial resources for water users on both sides of the Continental Divide. Snowmelt, particularly in spring, serves as a key source of water for the basin's tributaries, providing critical seasonal runoff. Geothermal springs in Glenwood Canyon introduce naturally heated water into the Colorado River. While these springs contribute warm water, their effect on the river's overall temperature is relatively localized and minimal due to the river's substantial flow rate. However, during periods of low flow, the influence of these geothermal inputs can become more pronounced, and even lethal, as fish kills have been documented for both Trout and Sculpin below the Shoshone Reach when the river flow was constrained at the dam (CPW, personal communication, 2024).

Nearly three million acres of land in the basin are federally owned. The U.S. Forest Service (USFS) manages the largest share, while the BLM oversees significant rangelands. These public lands serve various purposes. In the upper counties of the basin—such as Grand, Eagle, Summit, and Pitkin—tourism is a dominant industry. Attractions like ski resorts, state and national parks, scenic rivers, and world-class fishing substantially contribute to the local economy. The region also has deep agricultural roots, with ranching and livestock production common in the upper reaches, while the Grand Valley is well-known for its agriculture and cultivation.

The Colorado River Basin encompasses a variety of ecosystems, ranging from alpine environments in the headwaters to desert landscapes in the lowlands. It supports diverse wildlife species and plant communities, many of which depend on the available water from the basin. Maintaining the flow and quality of water in the basin is essential for the health of these ecosystems.

Most of the Colorado's precipitation falls on the western slope of the state. However, most of the population lives on the eastern, front range of the state. This requires up to 50% of the water used in the front range to be transferred from the Colorado Basin in the state's western slope. Transbasin diversions transport water from one geographically distinct river basin to another via pipeline or other engineered methods. The transfer of water out of the Colorado Basin plays a critical role, with considerable amounts of water being exported annually to other basins like the South Platte and Arkansas for agricultural and municipal uses on Colorado's eastern slope. Not only are the Colorado River flows reduced by extensive transbasin diversions throughout its headwaters, like much of the western United States, the river is experiencing the impacts of climate change, including reduced snowpack, earlier spring runoff, and longer, more frequent severe droughts. These changes threaten the predictability of water availability and exacerbate tensions among water users. Key challenges include balancing water usage with the needs of river ecosystem function.

2.1 SHOSHONE WATER RIGHTS

The Shoshone Water Rights were established in the early 20th century, during a significant period of expansion for irrigation and hydropower infrastructure in the western United States. The

Shoshone Power Plant, originally constructed in 1909 and still operational today, was one of the first large-scale hydropower facilities in the region. At the time of its establishment, the water rights associated with the plant were among the earliest granted within the Colorado River watershed. These more senior Shoshone Water Rights (decreed for 1,250 cfs) is consistently one of the foremost calling water rights on the mainstem of the Colorado River, making it extraordinarily important to the flow regime, especially considering the ongoing pressures from increased demand and climate variability within the basin.

The Shoshone Water Rights include two separate absolute water rights associated with the Shoshone Power Plant. The more senior, original Shoshone Water Right was decreed for 1,250 cfs with a priority date of December 5, 1905. The junior Shoshone Water Right was decreed for 158 cfs and is administered with a priority date of May 31, 1940. Together, these water rights total 1,408 cfs. The Shoshone Power Plant operates year-round and when in operation it can lead to dewatering of the 2.4-mile Shoshone Reach shown in Figure 2.

Figure 2: Shoshone Reach - Location of Dam, Intake and Power Plant / Return

The Shoshone Water Rights ensure a consistent flow of water in the Colorado River outside the Shoshone Reach, resulting in positive ecological outcomes, such as maintaining water quality, and flow regimes essential for the resiliency of fish and other aquatic life. If the State of Colorado were to acquire the right to use the Shoshone Water Rights for instream flow purposes, these current benefits would be preserved and the Shoshone Reach itself would experience higher flows and the associated environmental benefits.

Additionally, the Shoshone Water Rights support numerous recreational activities in the region. The steady flow of water in the Colorado River, facilitated by these rights, enables activities like rafting, kayaking, and fishing, which are vital for tourism and local economies. These recreational pursuits rely on reliable water flows to ensure safe and enjoyable conditions for participants.

2.2 INSTREAM FLOW ACQUISITIONS TO PRESERVE AND IMPROVE

The Shoshone Water Rights, under a dedicated instream flow scenario, would play a vital ecological role in preserving and improving the natural environment of the Colorado River. As shown in this assessment, the Shoshone Water Rights would help to preserve and improve habitat for aquatic species, including parts of the natural flow regime which supports the river's ecological functions within the Shoshone Reach. The CWCB may:

> *Acquire, by grant, purchase, donation, bequest, devise, lease, exchange, or other contractual agreement, from or with any person, including any governmental entity, such water, water rights, or interests in water that are not on the division engineer's abandonment list in such amount as the board determines is appropriate for streamflows or for natural surface water levels or volumes for natural lakes to preserve or improve the natural environment to a reasonable degree. CRS 37-92-102(3).*

The concept of environmental or instream flow water rights has gained importance across the western United States, with Colorado leading efforts to protect and restore river ecosystems through recognized water law. This legal framework is crucial in addressing concerns regarding the depletion of freshwater resources and balancing ecological sustainability with development needs. In this way, water law reforms in Colorado, such as the CWCB's Instream Flow Program, have been recognized as successful models for integrating environmental concerns into water management systems.

Under a dedicated instream flow scenario, the Shoshone Water Rights would play a crucial role in ensuring adequate flows are preserved within the Shoshone Reach of the Colorado River at times when the Shoshone Power Plant is not operating. The flow of water that would be provided by instream flow use of the Shoshone Water Rights under these conditions would be essential for preserving and connecting habitats for fish and aquatic invertebrates in the Shoshone Reach, preventing the formation of dry sections in the river that disrupt these ecosystems as discussed further in Section 3.0.

Preserving reliable water flow through Shoshone Water Rights can greatly benefit fish species by keeping water levels and temperatures within the ranges necessary for survival, spawning, and thriving. Healthy stream flows are essential for creating and maintaining a diversity of habitats for reproduction, recruitment, and seasonal needs of fish, ensuring resiliency in a dynamic environment.

2.3 SHOSHONE REACH HISTORICAL CONDITIONS, HYDROLOGY, AND HABITAT

The Shoshone Reach has undergone significant ecological and hydrological changes due to the development of hydropower infrastructure, and water diversions. Before significant changes were made to the Colorado River system, including the construction and operation of the Shoshone Power Plant in 1909 and other water management structures (such as irrigation development, transmountain diversions, and upstream reservoirs), the river's flow was characterized by natural seasonal fluctuations caused by snowmelt in the Rocky Mountains. Without physical barriers and with higher natural water flow, the Shoshone Reach would connect fluvial habitats throughout the entire reach, including high-gradient sections.

Historically, the Shoshone Reach was a confined, high-gradient segment of the Colorado River, that has been further constrained by the construction of an interstate highway and railroads. The natural hydrology and geomorphology of this reach plays a crucial role in shaping habitat availability and aquatic species dynamics. The Colorado River experiences annual high flows driven by snowmelt. Annual spring runoff maintained diverse habitats, such as riffles, pools, and

runs, which allowed a wide range of fish species to thrive. The riparian zones, though limited in extent within the Shoshone Reach, likely provided important habitats for fish refuge, insect populations, and wildlife. These zones supported various plant species adapted to the river's seasonal flooding, contributing to the ecological richness of the area. Additionally, natural thermal gradients in the river created different thermal habitats for cold-water species. The cooler waters from spring snowmelt and the warmer conditions in summer and fall supported the reproduction and growth of fish species. The high-gradient nature of the reach contributes to increased oxygenation of the water, which is beneficial for aquatic life. Large pools within the reach may have offered velocity refuges and important holding habitats for fish during periods of elevated flow.

2.3.1 Changes After the Shoshone Power Plant and Other Water Diversions

The construction of the Shoshone Power Plant, along with other water management projects (such as upstream irrigation, reservoirs, and transmountain diversions), significantly changed the hydrology of the Colorado River, particularly in the Shoshone Reach. These developments altered both the flow patterns and the aquatic habitats of the river.

The Shoshone Reach is impacted by the hydropower operations at the Shoshone Power Plant via reduced and highly variable flows depending on the plant’s operational status. Within the Shoshone Reach, when the plant is fully operating (i.e., when water is diverted into the tunnels and penstocks, bypassing the natural channel), and during natural seasonal low flow periods, sediment transport is inhibited, wetted habitat is reduced, and longitudinal channel/flow connectivity is impaired. The intermittency and loss of wetted habitat limits aquatic invertebrate productivity, the primary food source for resident fish. At low flows, the Shoshone Reach becomes fragmented due to large bed drops in the high-gradient cascade and rapid sections. Additionally, the Shoshone Dam acts as a barrier to upstream fish movement.

Natural high-flow events that once cleared sediment and created essential habitats for native species have declined. Regulated river flows have stabilized riverbed features, altered sediment transport, and reduced ecosystem dynamism. These changes affect spawning habitats and biodiversity. The regulation of the Colorado River and its tributaries has also led to water quality challenges, including temperature fluctuations which impact aquatic ecosystems. Altered flow regimes and habitat modifications have influenced sediment deposition, nutrient cycling, and habitat availability for both native and non-native species (Van Streeter and Pitlick, 1998).

3.0 SHOSHONE INSTREAM FLOW USE BENEFITS

Instream flows are a critical topic in water management, driven by concerns over ecological preservation and improvement. In the 1970s, the CWCB was authorized to appropriate water for instream flow purposes, marking a significant shift in water management that recognizes the importance of healthy river ecosystems. Research shows that maintaining adequate instream flows is crucial for the health of riverine ecosystems, as it supports biodiversity and the overall ecological function of rivers (Rushforth et al., 2022; Martin et al., 2015; Poff et al., 2009).

3.1 WATERSHED BENEFITS

The Shoshone Water Rights are a crucial legal and ecological asset for both the upstream and downstream reaches of the Colorado River. While the Shoshone Water Rights are used for hydroelectric power production, the water rights also play a significant, though indirect, role in maintaining the health and functioning of the ecosystems along the Colorado River.

3.1.1 Upstream Reaches

The Shoshone Water Rights are one of the primary means of controlling water flow in this region. By maintaining reliable flows that stabilize upstream low flow conditions and support vital ecosystem functions.

Wild and Scenic Rivers Management: BLM and WRNF amended their respective resource management and forest plans to incorporate management prescriptions for Wild and Scenic Rivers in Glenwood Canyon and segments of the Colorado River from Dotsero to Kremmling. The agencies identified that these river segments support Outstandingly Remarkable Values (ORVs), which are unique or exemplary river-related values within the region. As a result, the agencies concluded that four river segments are eligible for inclusion in the National Wild and Scenic Rivers System.

During the evaluation of whether the river segments are suitable for this designation, the agencies received an alternative management plan proposal from the Upper Colorado River Wild and Scenic Stakeholder Group.

The BLM and WRNF plan specifically focuses on protecting and enhancing the ORVs that are most dependent on flow conditions. The intent behind adopting this plan is to ensure it is consistent with BLM and WRNF land use authorities and decisions, thereby enabling the federal agencies to better fulfill their management obligations under the Wild and Scenic Rivers Act. The plan includes monitoring streamflow through the Wild and Scenic segments, supplemented by coordinated, cooperative, and voluntary water deliveries when available. This approach aims to balance the permanent protection of ORVs with the needs of stakeholders, the yield of water projects, and the flexibility required by water users.

It is important to note that the plan relies on the existing water rights of the Shoshone Power Plant as a primary long-term protection measure:

> *Existing senior water rights: The Shoshone and Cameo groups of senior water rights generally control the administrative call within the Colorado River Basin. These water rights are located downstream of the subject stream reaches; therefore, an administrative call during dry or average conditions by these water rights can curtail diversions from upstream junior water rights or require the release of water from storage to replace those junior diversions. This administrative call generally results in stream*

flow through the subject stream segments in amounts greater than would exist in the absence of the administrative call.[1]

Aquatic Habitat Health in the Upper Colorado River: The health of aquatic habitats upstream of the Shoshone Reach significantly depends on consistent water flow. Species such as the Colorado River Cutthroat Trout, Rainbow Trout, and various macroinvertebrates rely on reliable flow conditions for survival. The Shoshone Water Rights call down water to the Shoshone Reach (whether through releases from reservoirs or curtailment of junior rights). The Shoshone Water Rights are instrumental in ensuring reliable flows, thus preventing conditions that could threaten these species. Reliable flows promote the development of proper habitats within the river channel and adjacent riparian zones, providing aquatic species with access to food, refuge shelter, and spawning areas. By facilitating regular releases from upstream reservoirs and providing reliable flow, the Shoshone Water Rights helps support the necessary hydrological conditions for a diverse range of plant and animal species to exist. Without these steady water releases, upstream habitats could become vulnerable to drying out, especially during droughts, leading to habitat loss for aquatic species.

Low Water Flow Periods: The Shoshone Water Rights seniority allows them to call for a significant portion of natural flow in the basin up to their combined flow rate, meeting minimum flows during dry years and periods of low flow as feasible. Essentially, the Shoshone Water Rights act as a buffer against extreme hydrological events (such as droughts), contributing to more sustainable flows in upstream reaches. The increasing severity of debris flows associated with intense rainfalls and fire scars, and sediment flows after rain events, can be further mitigated by Shoshone flows. In winter the flows brought downstream by the Shoshone Water Rights also help reduce formation of anchor ice and provide habitat during seasonally low flow periods.

Riparian and Wetland Ecosystems: The riparian areas and wetlands along the Colorado River and upstream of the Shoshone Power Plant respond to fluctuations in river flow. Riparian and floodplain habitats provide essential ecological services but differ in location and function. Riparian habitats, located along riverbanks, feature plants like willows and cottonwoods. They stabilize streambanks, filter pollutants, and regulate water temperatures. These zones are crucial for juvenile fish, providing refuge shelter and abundant food sources, and serve as refuges during high-flow events, protecting fish from strong currents.

Without consistent water curtailment or replacement made in response to the Shoshone Water Rights, riparian vegetation may suffer from reduced water availability, leading to the degradation of wetland ecosystems that support many plants, animals, and migratory bird species.

3.1.2 Downstream Reaches

The Shoshone Water Rights are important for maintaining the ecological health of downstream areas, including important habitats such as wetlands and riparian zones. These habitats are vital for a wide range of species, including fish, amphibians, and waterfowl.

The area immediately downstream of the Shoshone Power Plant (Figure 1) supports a healthy sportfish population consisting of Brown Trout, Rainbow Trout, and Mountain Whitefish. Despite the challenges posed by invasive fish species, native species such as the Flannelmouth Sucker and Bluehead Sucker are frequently found in the Colorado River, particularly in and around Glenwood Canyon. Other native fish in this area include the Bluehead Sucker, Roundtail Chub, Sculpin, and Dace. The Shoshone Power Plant return flows help maintain riffle, run, and pool

[1] https://www.upcowildandscenic.com/uploads/1/3/5/3/135388668/amended_and_restated_sg_plan_july_2024.pdf

habitats. The resilience of the aquatic ecosystem is bolstered by the greater availability of riffle habitats, which enhances the productivity of macroinvertebrates and resident fish.

Water Quality Protection: Downstream water quality is significantly influenced by flow conditions. The Shoshone Water Rights help regulate the amount of water flowing through the system, preventing sudden drops in flow that could degrade water quality. For instance, low flows can increase water temperature and decrease dissolved oxygen levels, both of which are harmful to aquatic species. By maintaining reliable flows, the Shoshone Water Rights support good water quality, particularly temperature, for both aquatic life and human use.

Recreation and Tourism: The Colorado River downstream of the Shoshone Power Plant, particularly through Glenwood Canyon, is a popular recreational area for activities such as rafting, kayaking, fishing, and wildlife watching. Maintaining a reliable flow helps preserve these recreational opportunities by ensuring consistent river conditions, making the river more useable for river enthusiasts. Additionally, the recreation industry is vital to the local economy, and the Shoshone Water Rights contribute directly to the sustainability of this sector.

3.1.3 Shoshone Water Rights and Federally Listed Fish Species

The Shoshone Water Rights are important not only for the local fish community but also may have downstream benefits for four federally listed fish species under the Endangered Species Act (ESA): Bonytail, Colorado Pikeminnow, Humpback Chub, and Razorback Sucker. A consistent Shoshone Call supports the availability of water that may be used to support important habitats in the "15-Mile Reach" of the Colorado River, which extends from the Town of Palisade to the confluence with the Gunnison River in Grand Junction. This area is particularly susceptible to very low water flows because significant water withdrawals occur just upstream of Palisade for agricultural and other purposes. These ESA species are highly sensitive to changes in water flow, temperature, and habitat conditions.

Federally Listed Fish Species in the Colorado River Basin

The Colorado River and its tributaries are home to several ESA-listed fish species that have suffered significant declines due to habitat degradation, water diversions, and invasive species. The four Colorado River endangered fish species are:

- Colorado River Pikeminnow (*Ptychocheilus lucius*) – a large predatory fish historically abundant in the Colorado River but now listed as endangered.
- Bonytail *(Gila elegans)* – a species of riverine fish endemic to the Colorado River system, listed as endangered.
- Razorback Sucker (*Xyrauchen texanus*) – another Endangered species (currently proposed for downlisting to Threatened) that once thrived in the Colorado River but is now restricted to isolated populations.
- Humpback Chub (*Gila cypha*) – a species of riverine fish endemic to the Colorado River system, listed as threatened.

Critical habitat for the four endangered fishes in Colorado River is designated downstream of Glenwood Canyon beginning near Rifle, Colorado, and extends into the lower Colorado River basin. Colorado Pikeminnow and Razorback Sucker Critical Habitat starts at the Highway 13 bridge and includes the 15-Mile Reach identified as crucial to their recovery by the Upper Colorado River Recovery Program. The upstream extent of Bonytail and Humpback Chub Critical Habitat begins below the 15-Mile Reach, approximately 5 miles upstream of the Utah border.

The Colorado River's endangered fish species are highly dependent on specific flow regimes, water temperatures, and habitat conditions that are often disrupted by human activities, including damming, diversion, and water withdrawals. The U.S. Fish and Wildlife Service (USFWS) and other regulatory agencies have developed recovery plans for ESA-listed species in the Colorado River basin. These plans outline specific flow regimes and habitat conditions necessary for the survival and recovery of species.

3.2 SHOSHONE REACH BENEFITS

Permanently protecting the Shoshone Water Rights by adding an instream flow use is a future benefit that would preserve and improve aquatic habitat supporting fish populations, maintain stream health, and ensure ecological integrity within the Shoshone Reach. This section of the river supports a diverse array of species, including Rainbow Trout, Brown Trout, Mountain Whitefish, and Flannelmouth Suckers, and a robust population of macroinvertebrates. The survival of these species relies on adequate water flow conditions, which influence critical factors such as habitat availability, water temperature, oxygen levels, sedimentation, and food resources.

3.2.1 Fishery and Aquatic Habitat Conditions

The Shoshone Reach of the Colorado River plays a role in sustaining aquatic ecosystems, particularly for fish populations that rely on its diverse habitat throughout the year. When the Shoshone Reach is dewatered during plant operations, these valuable functions are impacted.

This section of the river provides important refugia and habitat complexity, ensuring fish have access to a variety of depth zones and structural features. The rough and diverse streambed—composed of boulders, cobbles, and gravels—provides interstitial habitats with numerous small pockets and spaces that fish can utilize for shelter and feeding. These microhabitats remain available even at high flows, providing refuge offering stability during fluctuating conditions.

Fish access the Shoshone Reach when feasible, utilizing available habitat for multiple life-cycle processes, including spawning, rearing, migration, foraging, and refuge. Even during periods of low flow, this reach remains viable for fish populations as it is sustained by spring and small tributary flows that allow downstream connectivity and fragmented connectivity within the reach. Lower flows prevent upstream fish passage in cascade and rapid sections where large bed drops and boulder pour-overs are barriers to fish that either cannot make the extensive jump or cannot swim through the fast laminar flows.

During low flow conditions, the channel functions more like a small stream and currently provides some spawning opportunities to fall spawners (e.g., Brown Trout and Mountain Whitefish) that would otherwise be washed out in higher native flows. The shallower stream-like habitat also offers refuge for juvenile fishes from larger predatory trout. Habitat for macroinvertebrates in the lesser stream channel supports an abundance of EPT Taxa (Ephemoroptera Plecoptera and Tricoptera Taxa) that indicate good water quality functions despite the reduced amount of available wetted habitat. Wetted areas retained during low flows offer connectivity downstream to other parts of the river and sustain juvenile fish that depend on its habitat (CPW personal communication, 2024).

The Shoshone Reach features both high-gradient and low-gradient areas, allowing fish to move between different habitat types based on their needs. This natural variation supports movement between the foraging, resting, and spawning areas that fish need to complete their life cycle.

The Shoshone Reach, when sufficient flow is available, provides important ecological benefits that support fish populations, enhance habitat connectivity, and sustain wildlife. Adding an instream flow use to the Shoshone Water Rights establishes a legal framework that will noticeably preserve and improve the Shoshone Reach, safeguarding long-term ecological balance, fish passage, and habitat resilience across seasons.

3.2.2 Macroinvertebrates

Aquatic macroinvertebrates play a crucial role in maintaining the health and balance of both aquatic and terrestrial ecosystems. Macroinvertebrates, particularly aquatic insects, are essential components of the Colorado River aquatic food webs, serving as primary consumers that feed on organic matter and algae and as prey for fish, amphibians, and birds. By breaking down organic material, they facilitate nutrient cycling, contributing to the decomposition process and improving water quality. Macroinvertebrates also serve as indicators of ecosystem health, as their presence and diversity reflect water quality and habitat conditions. Beyond the water, they are a vital food source for terrestrial insects, bats, and birds, creating a bridge between aquatic and terrestrial ecosystems. For example, emergent aquatic insects like mayflies and caddisflies provide essential energy and nutrients to riparian predators such as birds, bats, and spiders. This can be particularly true in river reaches with confined or limited riparian areas, like that exhibited in the Shoshone Reach. This interconnectedness underscores aquatic macroinvertebrate ecological significance, highlighting the need for their conservation to sustain biodiversity and ecosystem functions across landscapes.

The availability and quality of streamflows play a pivotal role in shaping aquatic ecosystems, directly influencing macroinvertebrate abundance and composition. Macroinvertebrates rely on specific habitat conditions, such as substrate composition, flow velocity, and water quality, to thrive. Adequate flow ensures that these conditions are met, creating diverse and stable habitats that support a wide variety of macroinvertebrate species. These organisms, in turn, serve as a critical food source for fish, forming a foundational link in aquatic food webs. Conversely, insufficient flow can degrade habitat quality, leading to higher water temperatures, lower dissolved oxygen levels, and increased sedimentation—all of which can stress or eliminate sensitive macroinvertebrate species. Such changes not only reduce the diversity and abundance of macroinvertebrates but also negatively affect fish populations that depend on them.

The interconnectedness between flow, habitat, water quality, and macroinvertebrates underscores the cascading effects that flow alterations can have on river ecosystems. When flow levels are reduced, the resulting environmental changes can disrupt the balance needed for a healthy ecosystem. Higher temperatures and lower oxygen levels can create inhospitable conditions for both fish and macroinvertebrates, while excessive sedimentation can smother benthic habitats critical for macroinvertebrate survival. On the other hand, maintaining adequate flow supports optimal conditions, including stable temperatures, high oxygen levels, and balanced sediment transport. These factors promote the health of macroinvertebrate communities, promoting a robust food supply for fish and fostering a resilient aquatic ecosystem. Protecting and restoring natural flow regimes is central to sustaining the intricate relationships that underpin ecosystem resilience and biodiversity.

4.0 INSTREAM FLOW ASSESSMENT OF THE SHOSHONE REACH

4.1 SHOSHONE REACH HYDROLOGY

The hydrologic time series data for the Shoshone Reach, derived from the StateMod modeling tool, were used to assess various flow scenarios. StateMod utilizes USGS flow records along with diversion records from the State of Colorado. This assessment incorporated a new StateMod daily model, the Upper Colorado River Basin Model (2024 UCRM), with modeling results evaluated at the Dotsero Gage (water years 1988-2003) as performed and documented by Hydros (Hydros, 2024). Because of the importance of Shoshone Reach flows for fish habitat in dry years, the StateMod model outputs were focused on dry years for which the record was complete during late summer and early fall (calendar years 1989, 1990, 2001 and 2002) consistent with overlapping dry years utilized by Hydros.

Flows at the Dotsero Gage may exceed the Shoshone Water Rights call for 1,408 cfs due to the administrative practice of shepherding by state water officials in Colorado, or due to snowmelt runoff. Bypassed flows, also known as shepherded releases, refer to water that is released from upstream reservoirs for delivery to downstream users beyond the natural levels expected at those locations. For example, these releases may benefit irrigators or provide environmental flows to the 15-Mile Reach in the Grand Valley.

The Dotsero Gage (USGS 09070500) serves as an administrative point used by the Colorado Division of Water Resources (DWR) to measure and administer streamflow for water rights, including for the Shoshone Water Rights. DWR accounts for two types of measured flow at the Dotsero Gage: (1) the amount of undepleted natural flow; and (2) the amount of shepherded bypassed flow. “Undepleted natural flow” refers to the volume of water that can be diverted under the Shoshone Water Rights when those rights are in priority, excluding any releases from upstream reservoirs that are shepherded for downstream use below the Shoshone Reach.

4.1.1 Shoshone Reach Flow Scenarios

- For this assessment, the River District evaluated and provided three flow scenarios for the Shoshone Reach (Hydros, 2024). Recent disruptions to the traditional flow regime—caused by wildfires, debris flows, and power plant maintenance—indicate that the most representative period of record is from the beginning of the 2024 UCRM model period Water Year 1988 (beginning October 1, 1987) through Water Year 2003. The analysis focused on consecutive months with lower water flows and higher temperatures that stress fish and affect habitat quality, specifically from August to October. This late summer to early fall period is critical for the relationship between water flow, temperature, and fish habitat. During this time, unfavorable habitat conditions for fish have resulted in voluntary fishing closures in the Shoshone Reach (CPW personal communication, 2025).
- Each of the time-series scenarios is an output from StateMod using the daily timeseries in the 2024 UCRM, a water rights administration model developed by the State of Colorado. The three scenarios, illustrated in Figure 3, are as follows:
  - **Scenario 1 (Baseline)**: Represents flows in the Shoshone Reach under existing conditions (Figure 3). This scenario is modeled as the flow at the Dotsero Gage minus the Shoshone Power Plant’s diversions, which is defined as the “Baseline” scenario in the 2024 UCRM and by Hydros (Hydros, 2024). The Shoshone Reach operates like an intermittent stream channel with high flows during runoff and little to no flow in seasonally low water periods, when the entire river flow is often diverted for hydropower production

at the Shoshone Power Plant and the Shoshone Reach flows like a small stream supplied by intervening small springs and tributary inputs.

- **Scenario 2 (Future with Permanency):** Represents a future condition with additional Colorado River build-out demand (Hydros, 2024) in which the Shoshone Power Plant no longer operates, and the Shoshone Water Rights (as defined by the Shoshone Baseline demands) are permanently protected as an instream flow water right (Figures 3). This scenario assumes all flows remain in the Shoshone Reach, corresponding to the Baseline Future model output at the Dotsero Gage (Hydros, 2024).
- **Scenario 3 (Future without Permanency):** Represents a future condition where the Shoshone Power Plant no longer operates, and the Shoshone Water Rights are no longer maintained or able to call (Figures 3) (Hydros, 2024).

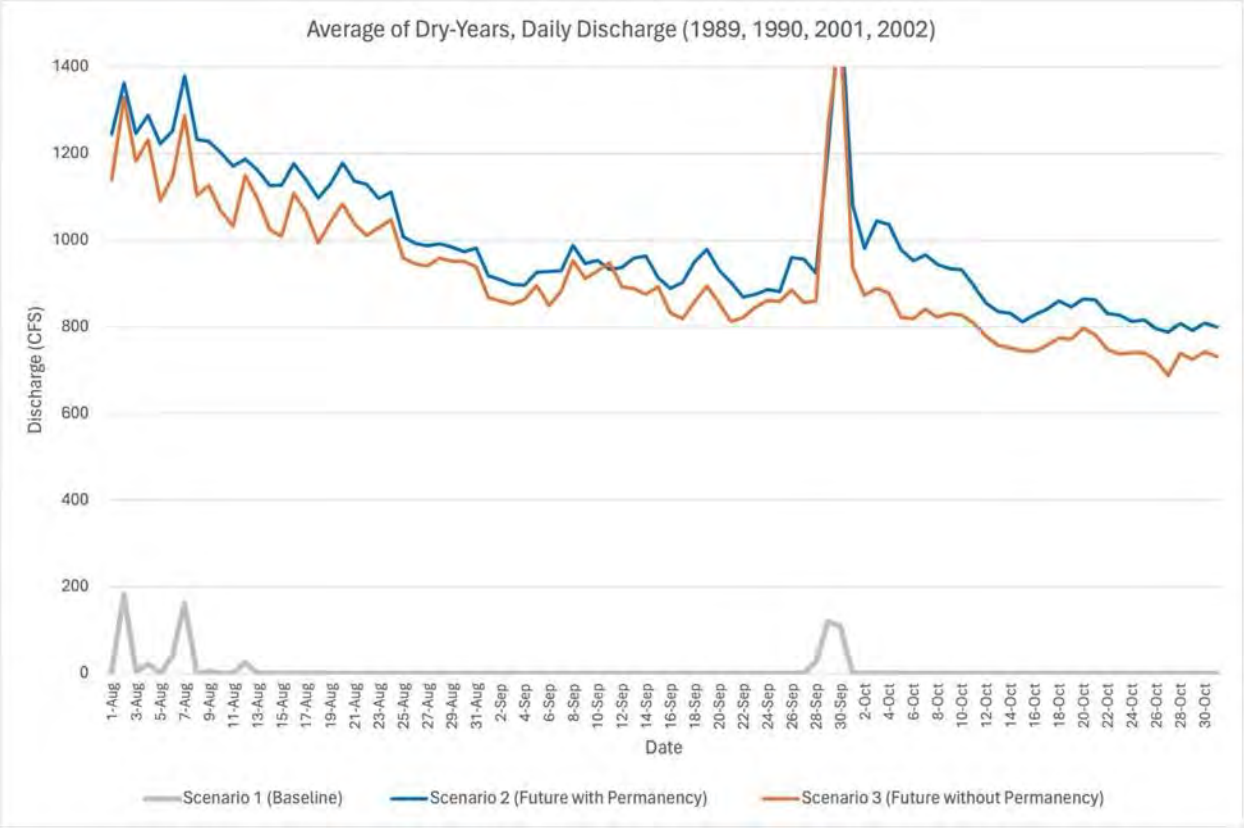

Figure 3: Shoshone Reach Mean Daily Discharge during low flow years 1989, 1990, 2001, and 2002, for each of the three Scenarios.[2]

The analysis indicates that both Scenario 2 (Future with Permanency) and Scenario 3 (Future without Permanency) will result in increased flows within the Shoshone Reach under all conditions, effectively eliminating days with flows below 700 cfs. Scenario 1 would have the most days/year (most frequency) of modeled flows of 250 cfs or less; Scenario 3 would have the most days/year (most frequency) of flows at 700 cfs and 1,020 cfs; Scenario 2 would have the most

[2] Note that the isolated spike in flows observed near the end of September in Figure 3 is attributable to modeled reservoir release operations at the end of the water year that resulted in the 2024 UCRM. These processes, operations, and trends have not occurred historically in September for all years and are unlikely to occur in the future as presented in Figure 3.

days/year (most frequency) of flows at 1,250 cfs, 1,400 cfs, 1,500 cfs, and 1,750 cfs. Differences in frequency of predicted discharges above 2,000 cfs between Scenarios 2 and 3 are nominal, but more frequent than Scenario 1. This informs the interpretation of the hydraulic habitat modeling; the Shoshone Reach is more likely to have flows between 1,250 cfs and 1,750 cfs and less likely to have flows between 700 cfs and 1,250 cfs with Future with Permanency (Scenario 2) than the Future without Permanency.

The analysis of median monthly flows for the entire period of record highlights a significant advantage of Scenario 2 (Future with Permanency), particularly during late-summer months (August–October) when ambient temperatures are still high, demand on storage water is at or near its peak, and cold-water species—primarily Brown Trout and Mountain Whitefish—are spawning (Figure 3).

In Scenario 2, late-summer discharge shows notable increases compared to Scenario 3, with median flow differences of:

- +144 cfs (+11.7%) in August
- +221 cfs (+20%) in September
- +26.9 cfs (+2.8%) in October

These increases provide up to 221 cfs more flow during this critical period, supporting spawning habitat, and aquatic ecosystem health.

The predicted frequency the Shoshone Reach will experience each flow informs the interpretation of the habitat suitability results and when reaches upstream and downstream of the Shoshone Reach will have changes in flow associated with each scenario. The modeled flow scenarios demonstrate that fish and other aquatic biota and other resources (such as recreation), would benefit from higher flows during seasons where they are most in need of those flows (Figure 3).

4.2 Evaluation of Instream Flows

This section documents the evaluation of instream flows using the IFIM process. The IFIM was used to explore the relationship between various flow scenarios and the hydraulic suitability of flows for focal fish species within the Shoshone Reach of the Colorado River. The study area spans from the point of diversion for the Shoshone Water Rights at the Shoshone Diversion Dam to the outfall of the Shoshone Power Plant. The objectives of this evaluation were to assess the current state of the aquatic habitat to predict expected changes due to potential hydrologic alterations resulting from the proposed change of use of the Shoshone Water Rights. The proposed hydrologic change would involve dedicating the full 1,408 cfs of flow, when available in priority to an alternate use for instream flow purposes, meaning that the otherwise diverted water would remain in the river to support aquatic habitat when the Shoshone Power Plant is not operating.

IFIM is a widely recognized method for assessing the relationship between streamflow and habitat quality for aquatic species. Developed by Bovee (1982), the IFIM uses habitat suitability curves and flow-habitat relationships to model how changes in streamflow affect the availability of suitable habitat for target species (Bovee, 1982; Stalnaker et al., 1995).

HHS is used to quantify the suitability of different habitats for various aquatic species under different flow conditions (Bovee, 1982). Habitat suitability curves were developed based on empirical data and expert judgment, relating the availability of habitat to streamflow parameters such as depth and velocity. The habitat suitability criteria for the fish species examined under this

IFIM were recommended by CPW and Dr. Miller (Miller 2024, Final Report), as habitat suitability curves from the published literature. No changes to the habitat suitability curves were made for this analysis (Appendix B).

Habitat availability was assessed by calculating the effect different flow levels have on the extent and quality of habitat within the study area. This is typically done using hydraulic models and habitat-suitability relationships to predict how different flows influence the quantity and quality of habitat. By simulating a wide range of flows, the evaluation examines how habitat availability for target species changes across different flow regimes (Poff et al., 1997; Bovee, 1982).

Study Sites

Site 1 is 1,854 ft. in length (River Restoration, 2023). The wetted area at 1,400 cfs is 6.1 acres (266,456 sq. ft.) and is representative of 14.4% of the total Shoshone Reach.

Site 2 is 1,830 ft. in length (River Restoration, 2025). The wetted area at 1,400 cfs is 5.9 acres (255,436 sq. ft.) and is representative of 14.2% of the total Shoshone Reach.

Combined, Sites 1 and 2 are representative of 28.6% of the Shoshone Reach (Figure 4).

4.2.1 Objectives

The primary objective was to evaluate the potential changes to aquatic hydraulic habitat (depth and velocity) resulting from incremental changes in flow. The analysis examines a range of flows, which include 50, 250, 700, 1,020, 1,250, 1,400, 1,500, 1,750, 2,000, 2,250, 2,500, and 3,000 cfs. The range of modeled flows allows quantification of how these flow changes influence aquatic species, and habitat availability. The range of flows were selected due to their likelihood of occurring in the reach based on the three scenarios provided (see section 2.6.1).

4.2.2 Discharge Flows Modeled

Currently, the Shoshone Water Rights divert up to 1,408 cfs from the Colorado River for power generation at the Shoshone Power Plant. The proposed change of the Shoshone Water Rights would allow the CWCB to exercise the Shoshone Water Rights, when not being used for hydropower generation, in a manner that would cause the decreed amount of water available to the water rights to remain in the Shoshone Reach to support aquatic ecosystems instead (CWCB, 2021). In addition to evaluating the effect of the proposed new use of the Shoshone Water Rights for instream flow purposes on flow conditions within the Shoshone Reach, the evaluation also considers the potential effects of a broader range of flow conditions, from 50 cfs to 3,000 cfs, to provide a more comprehensive understanding of how the flow changes may affect the Shoshone Reach’s aquatic habitat.

The three flow scenarios (1-Baseline, 2-Future with Permanency, 3-Future without Permanency) were analyzed in flow increments to explore the effects of both reduced and increased flows on habitat availability. Flow levels from 50 cfs to 3,000 cfs represent potential hydrologic conditions under current management practices and the proposed instream flow use.

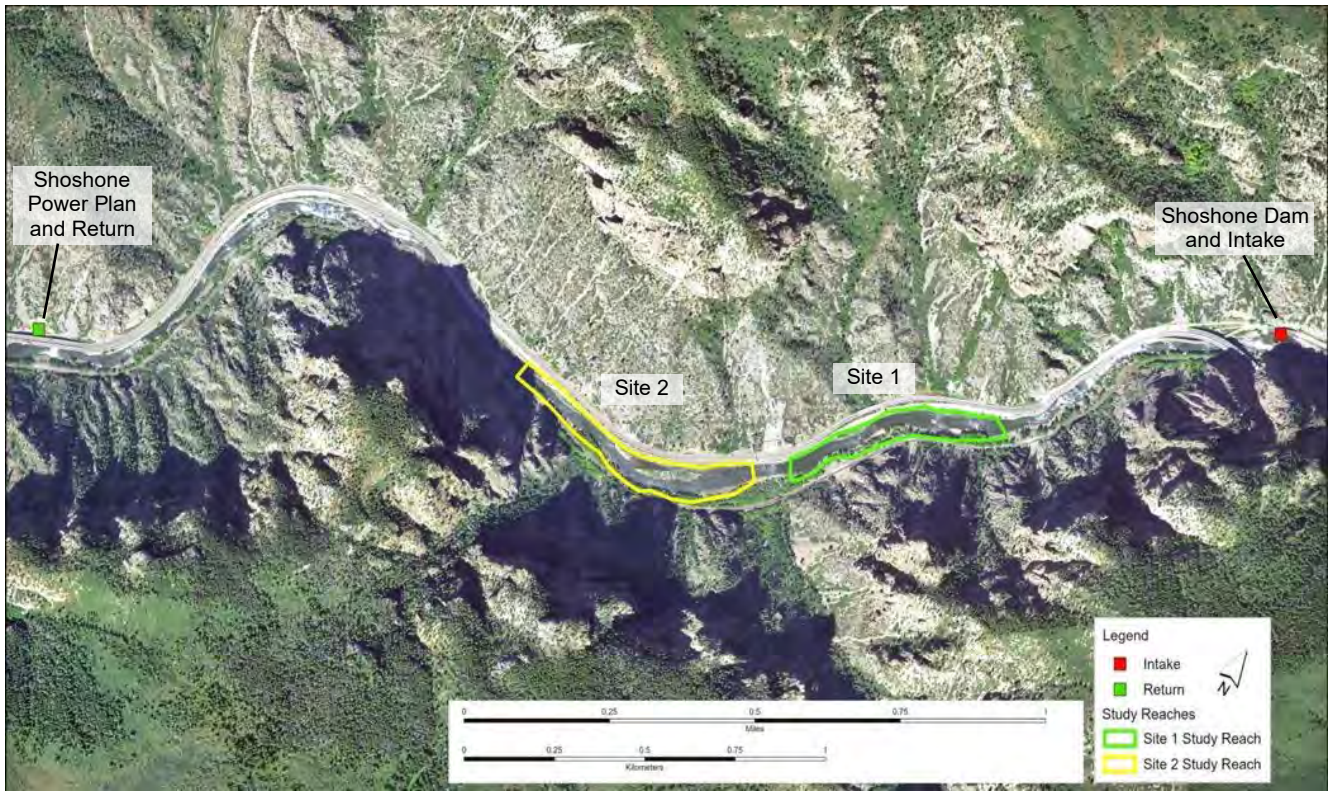

Figure 4: Shoshone Reach - Sites 1 and 2

4.3 METHODS

A two-dimensional habitat suitability model was created for two sites within the Shoshone Reach of the Colorado River (Figure 4). One suitability model was created for the two sites; meaning the same Hydraulic Habitat Suitability (HHS) criteria (velocity, and depth suitability curves) and equation were used for both sites. The two sites were assessed independently from one another. The HHS models were not combined into one continuous reach.

The following sections describe the development and application techniques used to create the two-dimensional model. The model was employed to derive the extent and quality, or suitability, of fish habitat within the two sites over a range of flows. Weighted Usable Area (WUA) is the measure of suitable habitat per species per flow per site and is calculated by multiplying an areas (pixel or polygon) suitability score by that areal extent to determine the actual measure of habitat available to each species at each flow. The extent and quality of suitable habitat is derived for adult Brown and Rainbow Trout, adult Flannelmouth Sucker, and adult Mountain Whitefish. The two-dimensional model examines depth and velocity to identify habitat suitability for each species. Environmental Systems Research Institute's (ESRI) ArcGIS Professional (ArcPro) was used to create and run the two-dimensional model. ArcPro is a Geographic Information System (GIS) platform. Accordingly, all data were converted (e.g., depth, velocity, suitability curves) to GIS consumable data and analyzed in ArcPro. Only the HHS model was run in ArcPro.

The topography (digital elevation model [DEM]) and hydraulic modelling was performed by River Restoration. These reports can be found in Appendix D which provide an in-depth description of the topographic data collection, topographic grid creation and the hydraulic modelling (Appendix D). The results of this work included depth and velocity grids (GIS data) for each modeled flow (e.g., 50, 250, 700, 1,020, 1,250, 1,400, 1,500, 1,750, 2,000, 2,250, 2,500, 3,000 cfs). These datasets were employed to derive the HHS for each species per flow.

4.3.1 Two-Dimensional Habitat Modeling—General Approach

There is considerable research on two-dimensional habitat suitability modeling for fish species. The methods used, computations, and the interpretation of results have been studied and deliberated (Austin 2002, Jowett and Davey 2011, Payne 2020). This research has led to a simple conclusion: that the methods employed to obtain results, and the interpretation of those results, should be dictated by the goals of the project (Austin 2002). The goal of this project, and the two-dimensional model used for the assessment, is to examine the impact that incremental flow changes would have on the extent and quality of habitat for four adult fish species (e.g., Brown and Rainbow Trout, Flannelmouth Sucker and Mountain Whitefish). This assessment evaluates a high gradient, confined canyon reach of river that does not provide optimal habitat for all life stages and species of fish. Therefore, the goal of this assessment is expressly to look at the extent and quality of each adult fish species' habitat, and how that habitat is affected by depth and velocity changes over a range of flows. Furthermore, this assessment is not intended to evaluate permanency of the Shoshone Water Right, rather it is to evaluate HHS benefits of the water right should it be converted to an instream flow beneficial use. Therefore, when the Shoshone Power Plant is not diverting, the flows can be put to beneficial use for the environment.

An additive model was chosen to derive HHS in the Shoshone Reach. The equation for habitat suitability for each species in the Shoshone Reach is:

$$\textit{Fish Species HHS per flow} = \textit{Depth HHS} + \textit{Velocity HHS}$$

Additive models resolve some of the criticisms that have been made of conventional habitat suitability criteria and habitat suitability modeling (Jowett and Davey, 2007). The main rationale for employing an additive model rather than a computation including multiplication is to address the depth-averaged velocity issue in high gradient and deeper rivers, such as the Colorado River Shoshone Reach. Depth-averaged velocity output from hydraulic models, which gives one velocity value for the entire water column, often does not account for lower and likely suitable velocities that can occur along the streambed and adjacent to roughness elements that create a hydraulic shadow. In large rivers with boulder substrates, such as the Colorado River through the Shoshone Reach, suitable velocities could be found along the bed in locations where the depth-average velocity would be considered too high. In which case, using a traditional approach of multiplying the depth and velocity suitability to obtain a composite suitability may underestimate the true amount of suitable habitat.

The additive model improves, or overcomes, the depth-averaged velocity because it does not constrain suitable habitat predictions in deep, fast-flowing areas where few data were collected, and where velocity is not consistent throughout the water column (Jowett and Davey, 2007). Large bed material, such as what exists throughout the Shoshone Reach, provides velocity breaks for fish, and enable movement even at high flows, where velocities are extreme. Thus, velocity is not consistent in the water column, and depth-averaged velocities used in 2-D models may not be biologically informative.

Sampling deep and/or fast-flowing habitat types presents significant challenges. These habitat features are common in the Colorado River Shoshone Reach. Field researchers and biologists have reduced capture efficiency when sampling areas with deep and/or swift currents. Species suitability curves are largely based on where humans are able to observe fish species. This bias, resulting from the lack of observations in deep, fast-flowing waters, typically leads to a pronounced negative interaction between velocity and depth in rivers such as the Colorado River Shoshone Reach. The negative velocity-depth interaction means that high average velocity values (e.g., HHS_{vel} > 6.0 feet per second = 0) often exclude potential habitat because the velocity suitability score is zero (Jowett and Davey, 2007). In traditional HHS models, velocity suitability is multiplied by depth suitability (HHS = D*V) to determine an overall suitability metric. Anywhere that velocity suitability is zero is deemed as non-habitat. This velocity-depth interaction has been shown to be a poor predictor of species occurrence in deep fast flowing rivers (Jowett and Davey, 2007). Therefore, the simplified additive model was used for this assessment. Additive models provide a more biologically realistic results and have been shown to be a better predictor of species occurrence than multiplicative models (Jowett and Davey, 2007).

4.3.2 Habitat Suitability Curves

The Habitat Suitability Curves were recommended in the 2024 Miller Report with feedback provided by CPW, and based on local expertise and professional judgement:

> *Habitat data for the species of interest came from several sources and have been used in previous studies on the Colorado River (Miller and Swaim 2011). The data for adult trout was collected by direct observation at several locations in rivers in Colorado. The data was collected by personnel from the Colorado Division of Wildlife (now CPW) and US Fish and Wildlife Service in 1988 and 1989 (Colorado Division of Wildlife 1989). Those observations were used to develop habitat preference suitability indices for depth and velocity and corrected for habitat presence (Wilding 2012)*. (Miller 2024).

Additionally, the 2024 Miller Report provides that:

> *Criteria for Mountain Whitefish used for this analysis came from Bovee (1978). The criteria for adult Flannelmouth Sucker were updated in early 2024 from a combination of data from radio telemetry studies on the Colorado River near Grand Junction, existing data from a range of rivers and literature review of habitat and population studies (Miller 2024). Additional habitat criteria for Flannelmouth Sucker were incorporated into the final suitability criteria as documented by Miller (2024).*

The suitability curves for all species are shown in Appendix B. The numeric suitability curves (Excel files) for each fish species were imported into ArcPro and converted to a GIS table.

4.3.4 Application in Geographic Information System (GIS)

As mentioned above, the habitat suitability modeling used ESRI's ArcPro. Four species were modeled at two sites within the Shoshone Reach of Colorado River. Twelve flow rates were modeled. A total of 96 HHS scenarios were modelled to document the change in extent and quality of habitat for the four fish species in the Shoshone Reach.

Figure 5 below demonstrates the simplified process of taking raw depth and velocity grids, provided by the hydraulic modeling (River Restoration 2023, 2025, Appendix D), and then converted each into a suitable habitat layer for each species. The initial step in the process is to import the depth and velocity grids to ArcPro. The next step is to apply the suitable habitat criteria (HHS Table) to the raw depth and velocity grids using a tool called "Reclass by Table." This step

converts the depth and velocity grids to a suitable habitat layer, based on the suitability curves, with values ranging from 0 to 1. The next step is to add the depth and velocity grids (i.e., additive model) together to create an overall HHS score (additive model maximum = 2) for each species at each flow (Figures A1-A18, Appendix A). Habitat selection by fish often appears to have thresholds. For example, many fish species will use a wide range of depths once the depth has exceeded some critical minimum value (Bovee et al. 1998). For this assessment, the critical minimum HHS depth value for all species was identified as 0.5 feet (CPW Personnel Communication, 2025). Areas of each site where depths were less 0.5 feet were given an overall score of 0 regardless of velocity. HHS values ranged from 0 to 2. A score of zero indicates no habitat. Low HHS values (<0.2) indicate marginal habitat, whereas high or maximum HHS values (2.0) indicate optimal habitat.

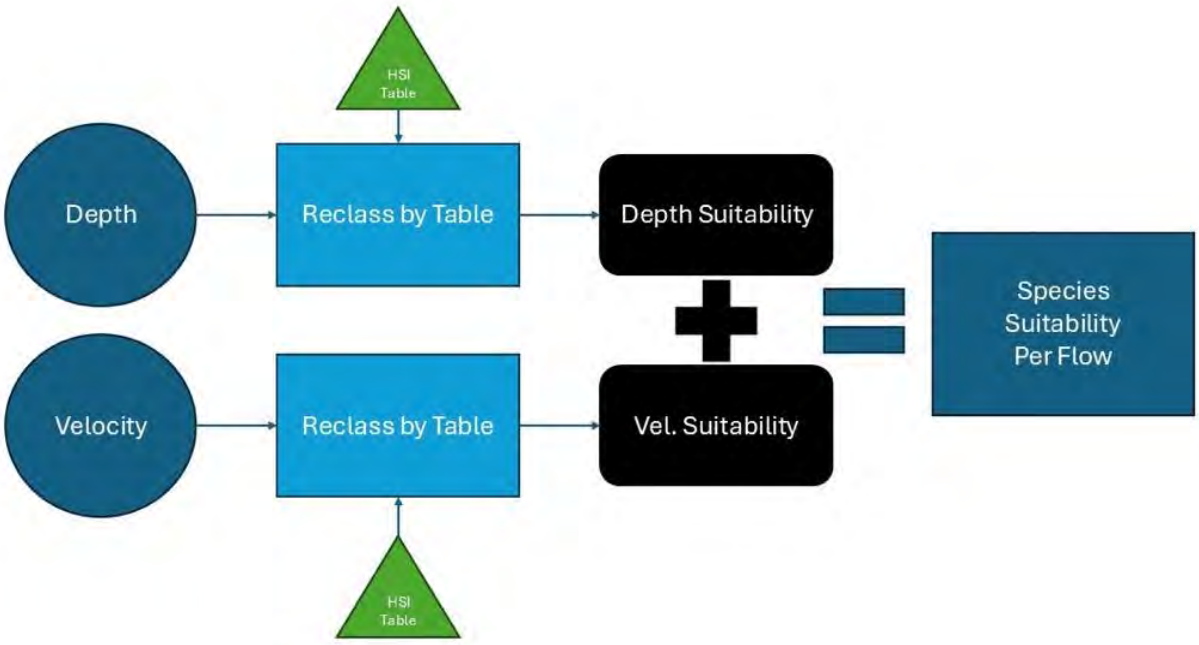

Figure 5. Simplified Process of Creating HHS Layers in ArcPro.

Results discussed below are expressed as Weighted Usable Area (WUA) per species per flow per site. WUA is derived by multiplying each modeled pixel's area by that pixel's HHS (WUA_{pixel} = Pixel * HHS). Effectively, if the additive model (depth HHS + velocity HHS) pixel sum is greater than zero, the pixel offers suitable habitat and the WUA is equal to the pixel area multiplied by the HHS. For the WUA calculation, additive HHS values were converted to a 0 to 1 scale by dividing the additive HHS by 2 (e.g., Additive HHS = 1.4, [1.4/2 = 0.7], WUA = 0.7 * Pixel Area). WUA is further calculated as a linear measurement, where overall WUA per species per flow is divided by the length of the study site to determine square feet of habitat per 1,000 ft of stream. Thus, the WUA figures per site and per species depict square feet of habitat per 1,000 ft of stream length.

4.4 RESULTS

The results presented in this assessment are organized by study site. For each site, results for wetted area per flow (depth >0.1ft) and HHS per species and per flow are presented and described. Minimum suitable depths were based on communication with CPW and set as 0.5 feet

for all species (CPW personnel communication, 2025). HHS results are presented as WUA per species, per flow, and per site.

The two study sites, when viewed together, present a mosaic of instream habitat characteristics that represent the overall Shoshone Reach. Site 1 is 1,854 feet in length (River Restoration 2023). Site 2 is 1,830 feet in length (River Restoration 2025). The combined study sites' total length is 3,684 feet. Together, the study sites comprise 28.6% of the total Shoshone Reach.

4.4.1 Site 1

Site 1 is located roughly ½ mile downstream of the Shoshone Diversion Dam (Figure 4). Site 1 is discernable by two large pools divided by a riffle in the center of the site. Site 1 is narrower (e.g., floodplain width) than Site 2, with a defined channel flowing through the middle of the site. There is limited off-channel areas at Site 1. The two pools within Site 1 provide significant habitat for all species modeled, dependant on discharge and depth.

Site 1 Wetted Area

Wetted area increases with flow at Site 1. Minimum wet area within Site 1 occurs at a discharge flow of 50 cfs, with over 118,000 sq. ft. of linear wetted area per 1,000 ft. of stream (Figure 6). Maximum hydraulic modeled wetted area occurs at the highest flow, 3,000 cfs, and includes over 152,000 sq. ft. of wetted area per 1,000 ft. of stream (Figure 6). Although the adult fish species modeled do not use the entire wetted area, based on HHS criteria, wetted area below the adult species minimum suitability criteria provides food base (e.g., macro-invertebrate habitat when inundated for sufficient duration for colonization) and habitat for non-modeled life stages (e.g., juvenile). Wetted area extent is an important indicator of the overall stream habitat available to modeled species, potential habitat for non-modeled life stages, and stream life-cycle dynamics.

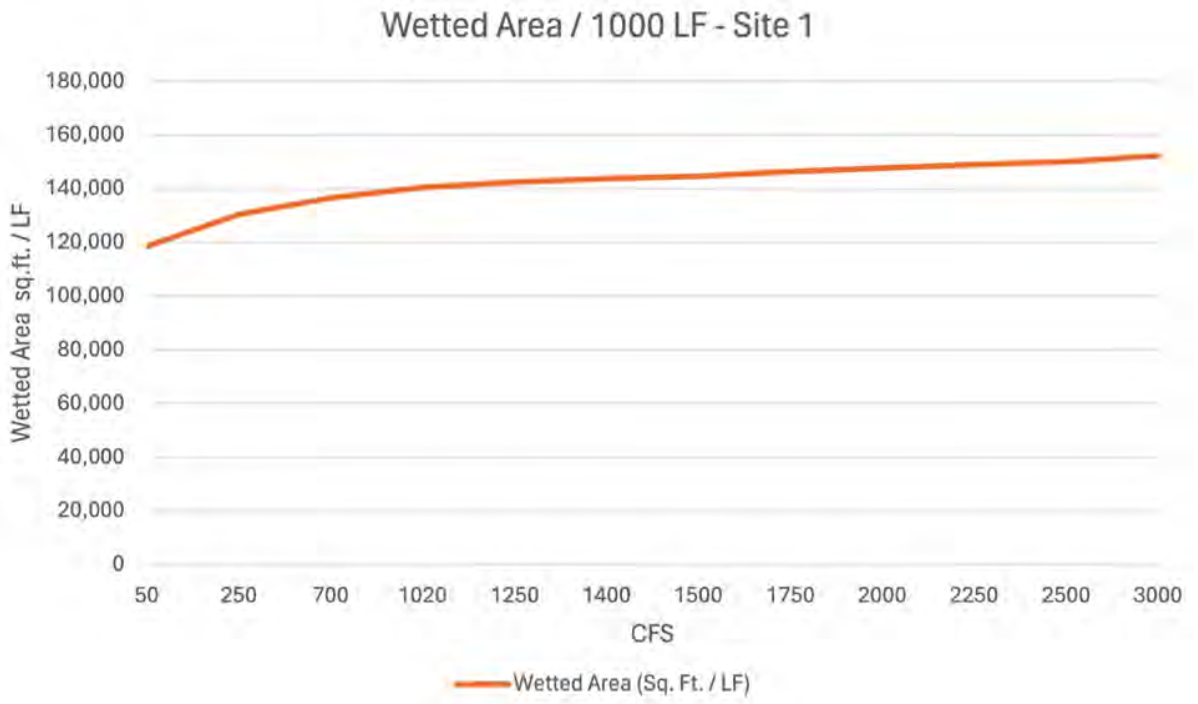

Figure 6. Site 1 Wetted Area Results, all Discharge (cfs) per 1,000 linear feet.

Site 1 WUA Results Per Species

The extent of suitable habitat per 1,000 feet of stream, per adult species modeled, defined as WUA, generally increases with flow at Site 1 (Figures 7, 8, 9, 10). Maximum WUA for Brown and Rainbow Trout occurs at 2,250 cfs (Figure 7 and Figure 8, respectively). As flow increases above 2,250 cfs the suitability of the habitat within the Shoshone Reach for trout species begins to plateau and slightly decline, thus slightly reducing the overall WUA. Adult Flannelmouth Sucker WUA increases from 50 cfs to 1,500 cfs (Figure 9). Above 1,500 cfs, habitat quality (HHS) begins to plateau and then decline as velocity and depth thresholds for the species reach maximum values. Mountain Whitefish maximum WUA occurs at 2,000 cfs at Site 1. Above 2,000 cfs, Mountain Whitefish habitat quality begins to plateau and then slightly decline, thus reducing the extent of WUA for the species (Figure 10). In summary, at Site 1, the extent of adult fish species suitable habitat generally increases with flow, even up to the higher discharges modeled for some species, while others experience a plateau and slight decline.

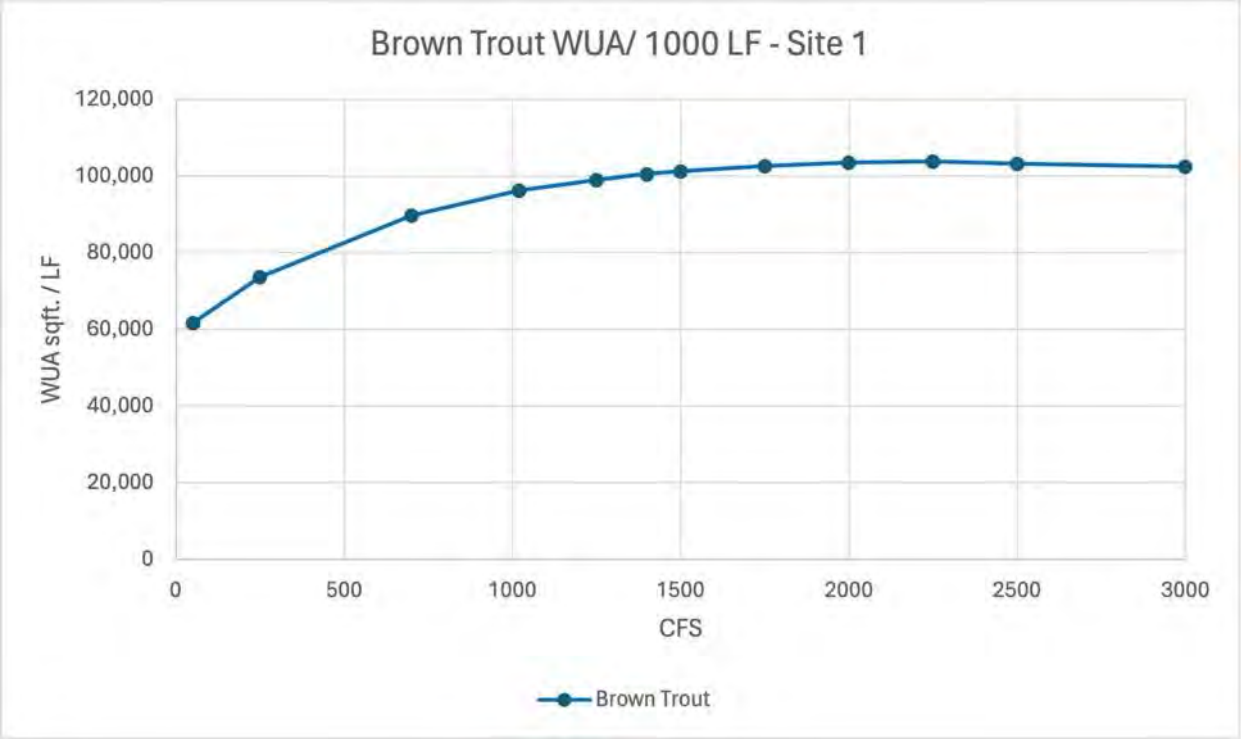

Figure 7. Weighted Usable Area per discharge flow (cfs) for Brown Trout at Site 1.

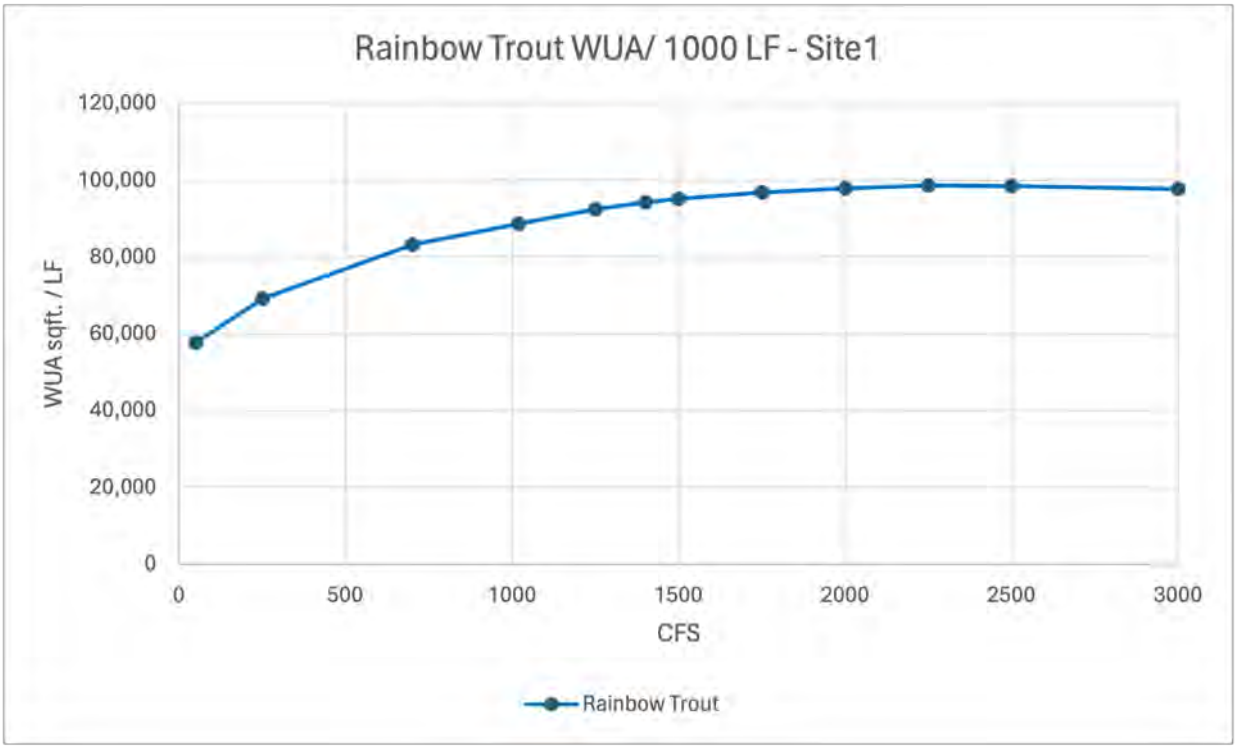

Figure 8. Weighted Usable Area per discharge flow (cfs) for Rainbow Trout at Site 1.

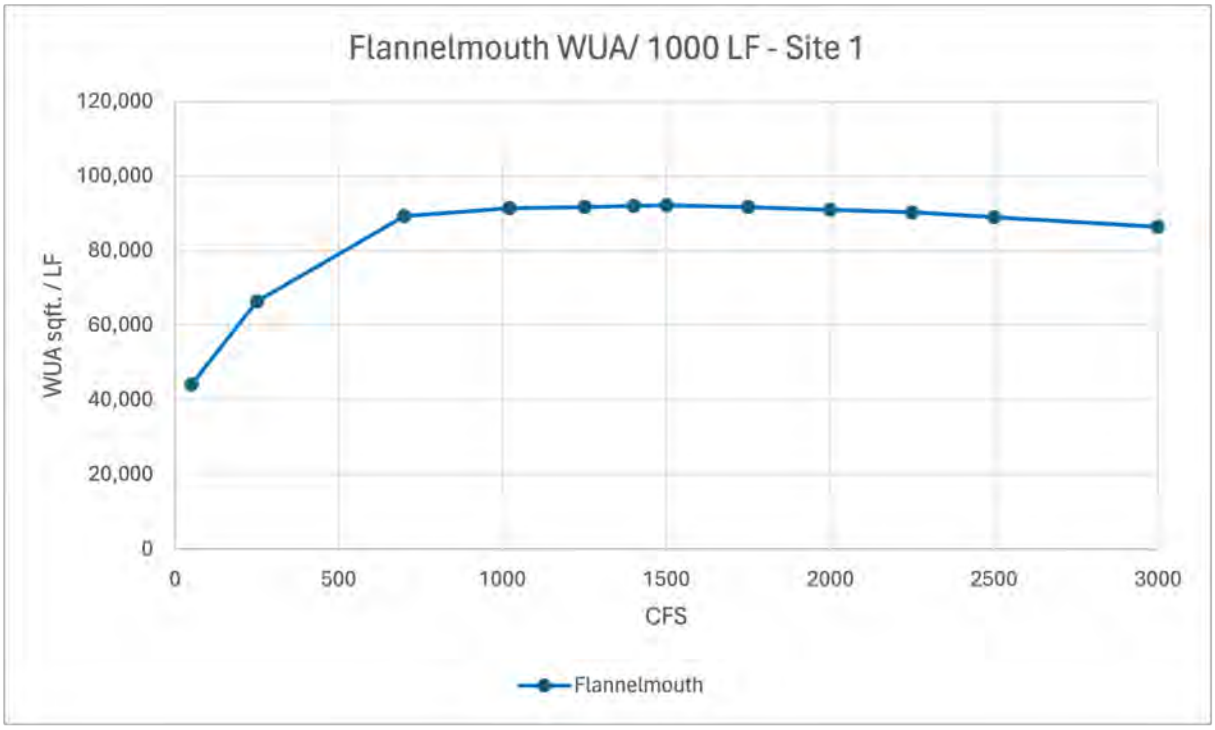

Figure 9. Weighted Usable Area per discharge flow (cfs) for Flannelmouth Sucker at Site 1.

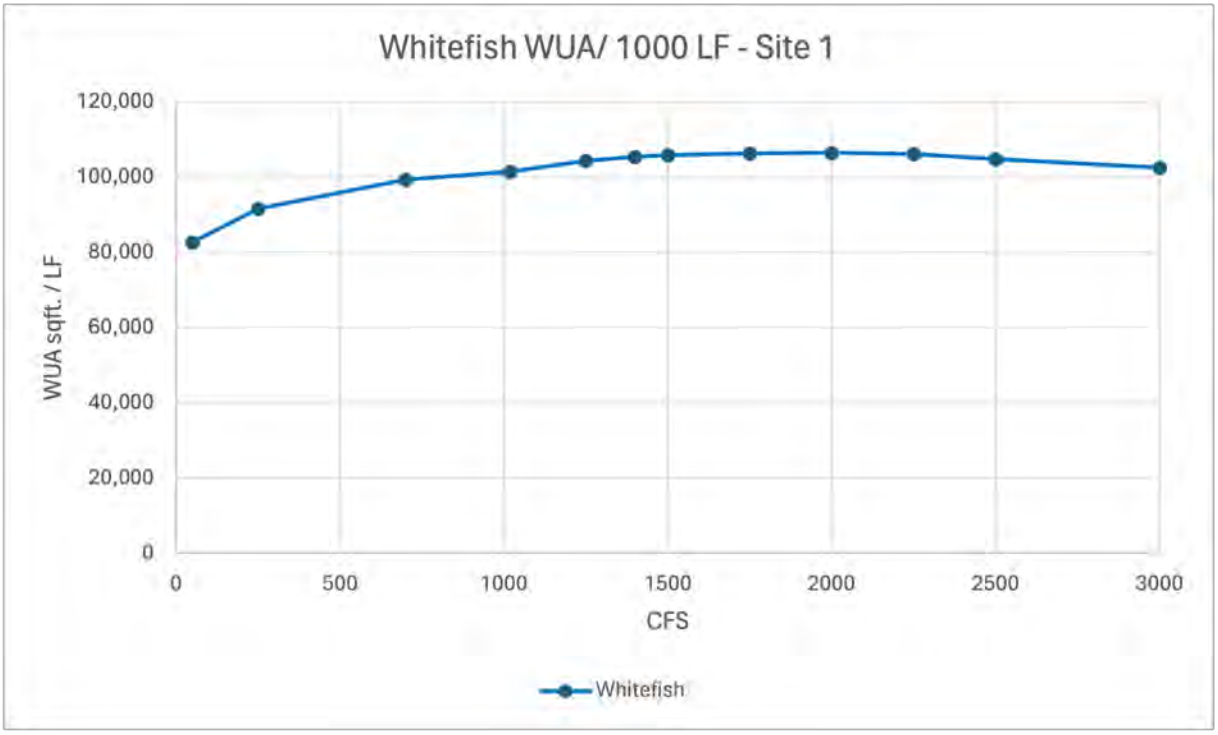

Figure 10. Weighted Usable Area per discharge flow (cfs) for Mountain Whitefish at Site 1.

4.4.2 Site 2

Site 2's floodplain is wider than Site 1's floodplain and provides a notable difference in overall riverine complexity. Site 2 includes two large islands that create a complex channel environment. Portions of the complex channel are wetted at different flows, creating a dynamic environment in which flow volume increases and previously dry areas (e.g., off-channel areas) become wetted and provide accessible habitat. This complexity offers different habitat availability for the four modeled species and demonstrates a diverse habitat (extent and quality) response to increased flows.

Site 2 Wetted Area

In Site 2, wetted area increases with increasing flow volume, like Site 1. However, the increase in wetted area is not as linear as at Site 1. For example, Site 2 wetted area increases significantly from 50 cfs to 250 cfs (Figure 11). Another significant wetted area increase occurs from 250 cfs to 700 cfs of discharge at Site 2 (Figure 11). Above 700 cfs, wetted area increases are similar to Site 1, with varying increases of generally less than 10,000 sq. ft. per 1,000 ft of stream occurring from 1,020 cfs to 3,000 cfs. The greatest wetted extent at Site 2 occurs at 3,000 cfs, with just over 160,000 sq ft of wetted area per 1,000 ft of stream (Figure 11). This is likely the result of high-flow channels being wetted.

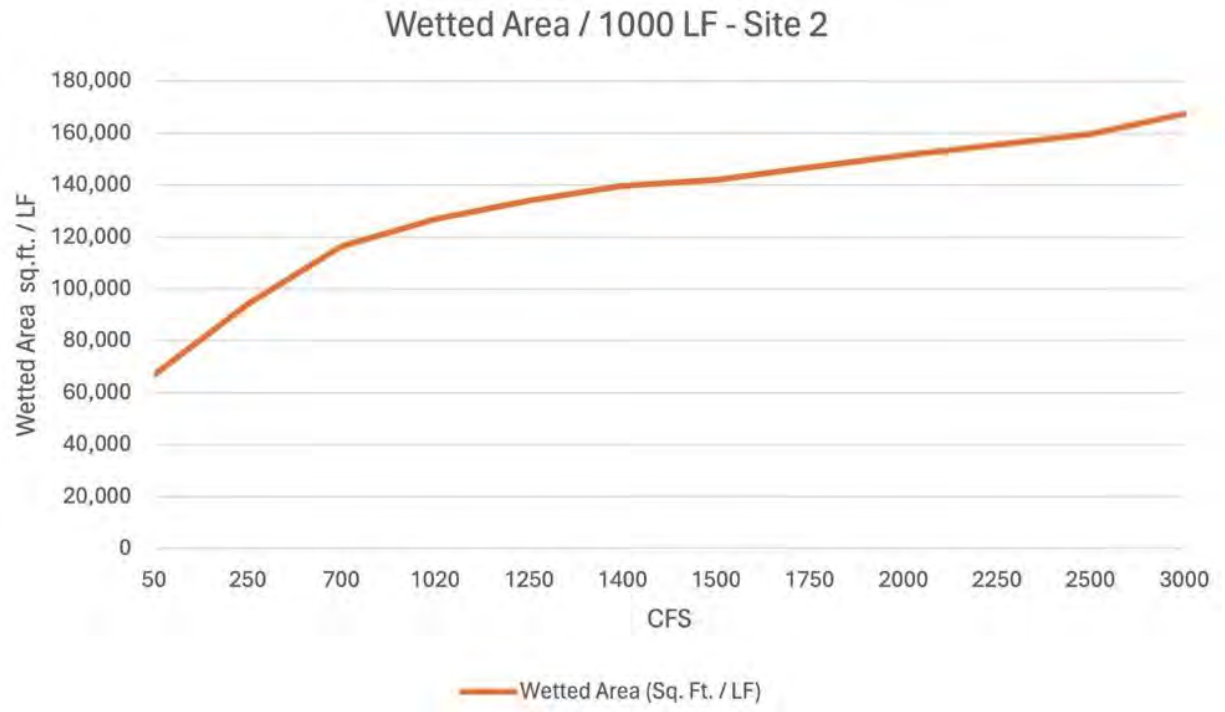

Figure 11. Site 2 Wetted Area Results, all Discharge (cfs) per 1,000 linear feet

Site 2 WUA Results Per Species

The extent of WUA per 1,000 feet of stream, per adult species modeled, increases with discharge flows at site 2 (Figures 12, 13, 14, 15). Noticeably, a large increase in WUA occurs for all species from 50 cfs to 700 cfs. Maximum WUA for Brown and Rainbow Trout occurs at 3,000 cfs (Figure 12 and Figure 13). There is a noticeable increase in WUA between 2,500 cfs and 3,000 cfs for Brown and Rainbow Trout at Site 2. While not modeled, this trend likely indicates that Trout species WUA would continue to increase at flows above 3,000 cfs (Figures 12 and 13).

Flannelmouth Sucker WUA at Site 2 increases up to 2,250 cfs, and plateaus as flows increase towards 3,000 cfs (Figure 14). Mountain Whitefish WUA over the range of flows modeled exhibits a similar curve as the trout species, with gains as flows increase (Figure 15). However, the slope of the Mountain Whitefish WUA curve, between 2,500 cfs and 3,000 cfs begins to plateau and levels off.

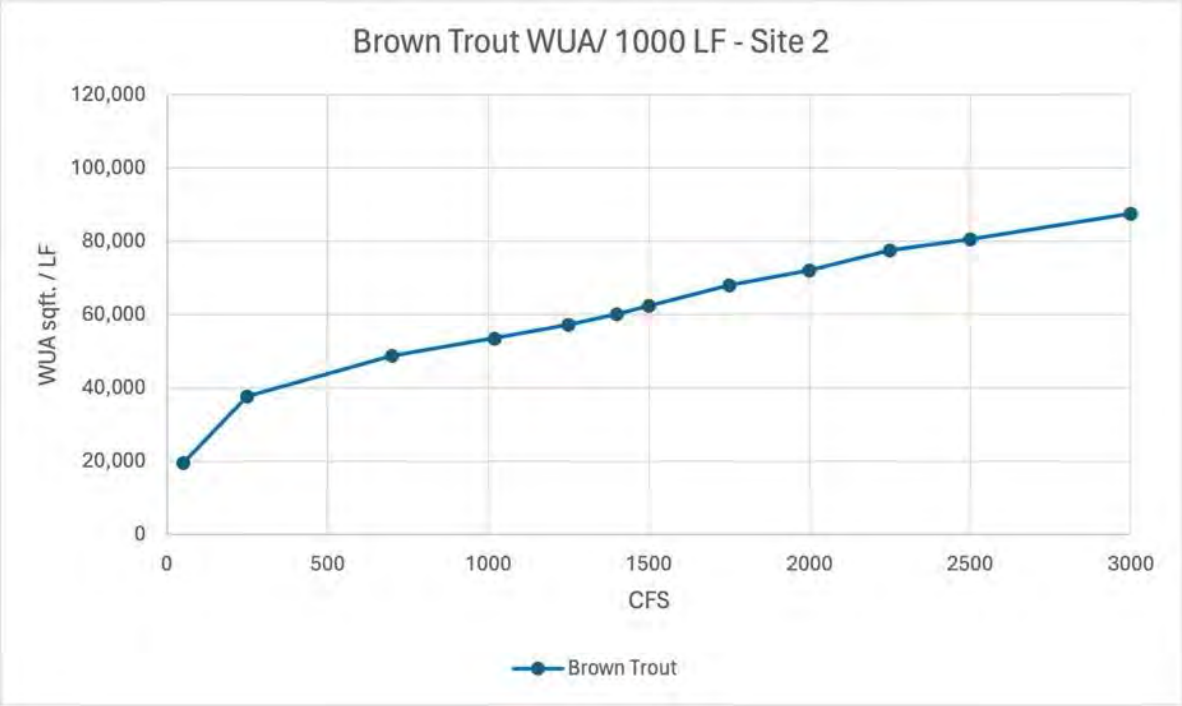

Figure 12. Weighted Usable Area per discharge flow (cfs) for Brown Trout at Site 2.

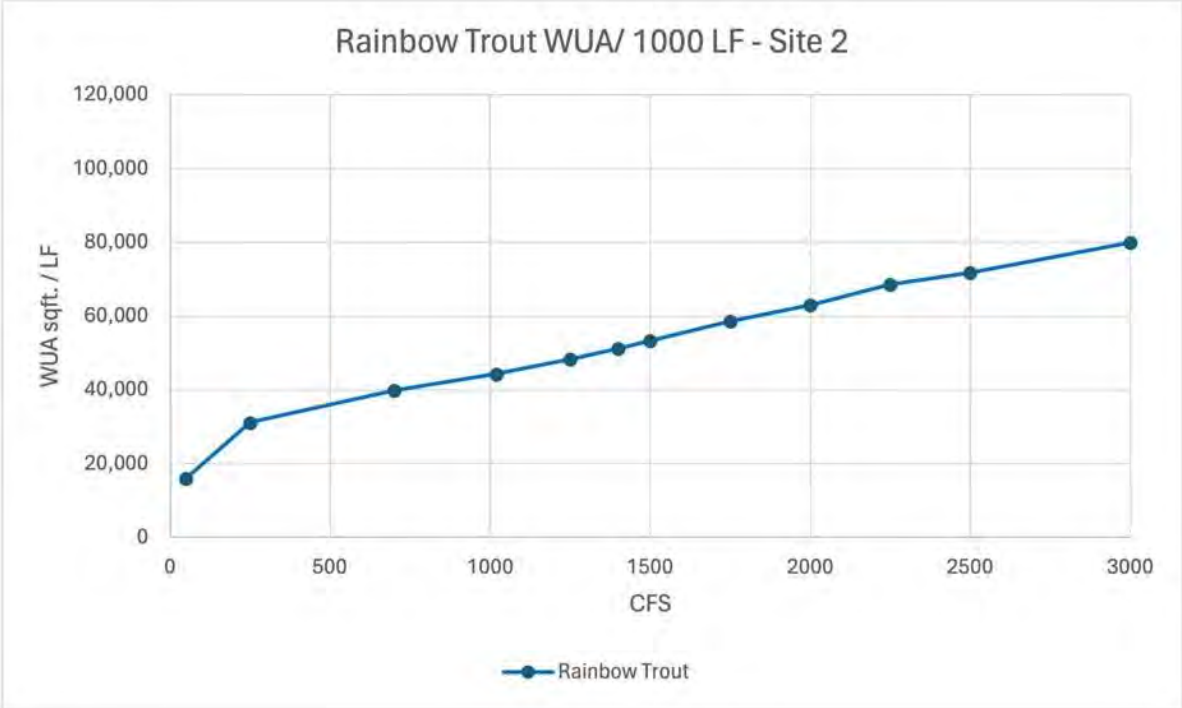

Figure 13. Weighted Usable Area per discharge flow (cfs) for Rainbow Trout at Site 2.

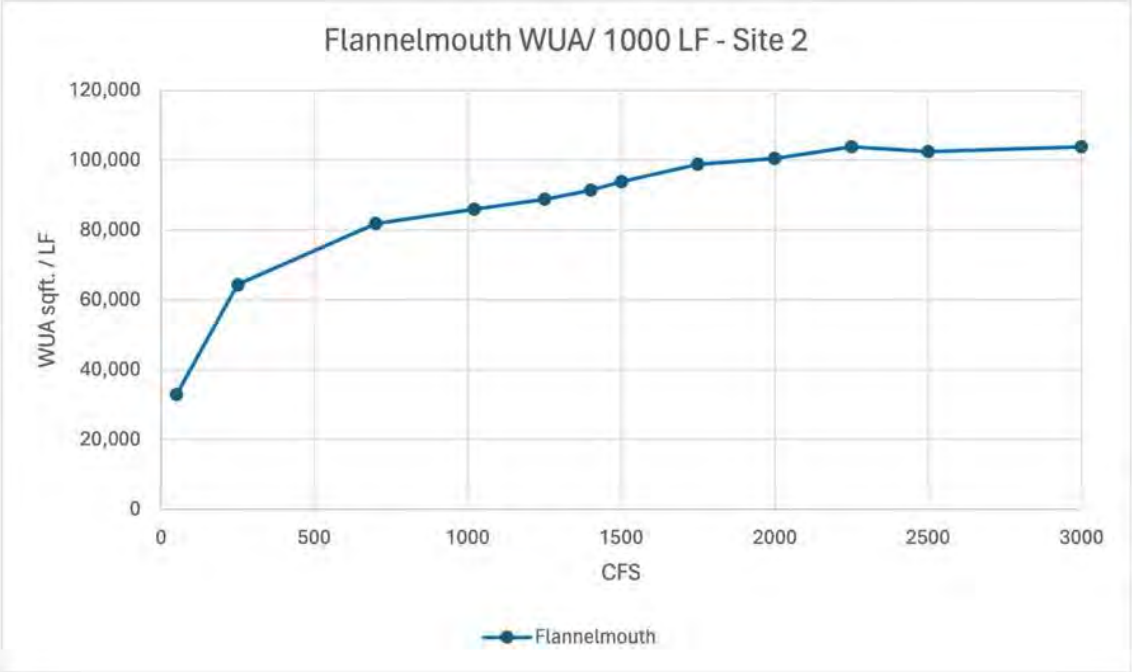

Figure 14. Weighted Usable Area per discharge flow (cfs) for Flannelmouth Sucker at Site 1.

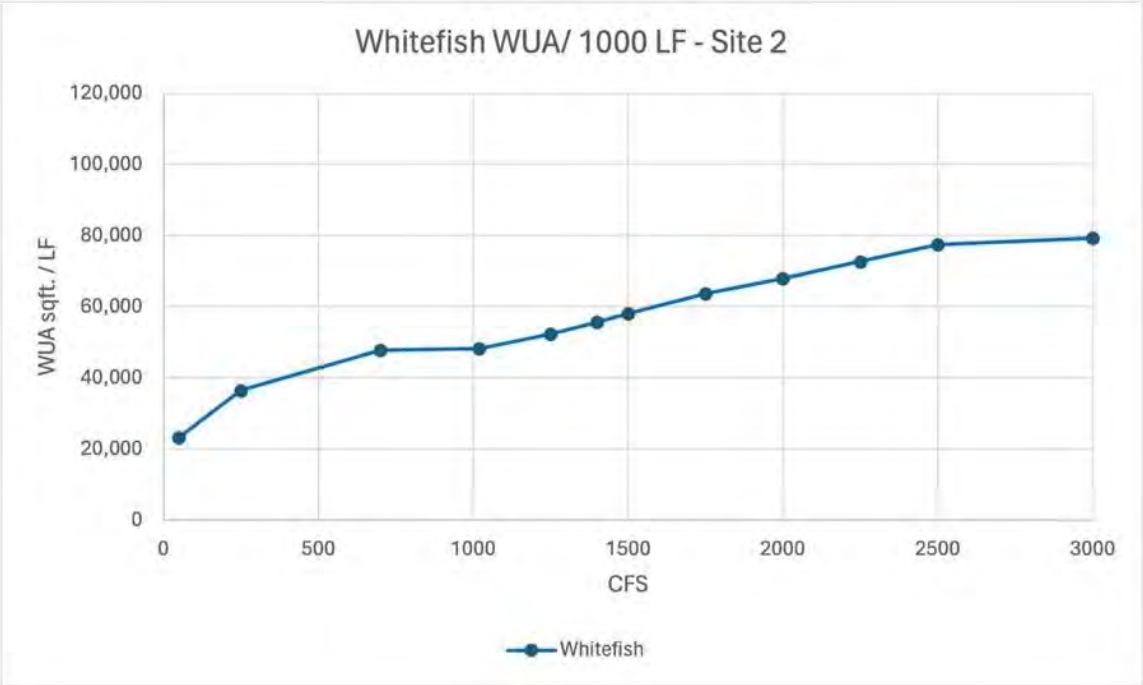

Figure 15. Weighted Usable Area per discharge flow (cfs) for Mountain Whitefish at Site 2.

Visual HHS Results Site 1 and Site 2

Appendix A includes visual layouts of results for each study site reach with flow model and WUA charts (Figures A1-A18, Appendix A).

5.0 DISCUSSION AND CONCLUSION

5.1 DISCUSSION

Hydraulic Habitat Suitability and Wetted Area

The hydraulic suitability results from the expanded IFIM analysis provide useful insights into how varying flow regimes influence habitat quality and availability within the Shoshone Reach of the Colorado River. At Site 1, WUA generally increases with flow, peaking at approximately 2,000 cfs, dependent on species. Beyond this range, suitability scores plateau and slightly decline at maximum discharge flows, primarily due to reductions in velocity suitability. Despite this plateau or slight decline in suitability scores at the highest discharge flows, the wetted area continues to increase, providing additional habitat that helps offset minor reductions in overall hydraulic habitat suitability that is observed beyond and at the higher range of discharge flows. Additionally, the two large pools at Site 1 provide quality habitat for all fish species.

In comparison, WUA at Site 2 continues to improve as flows increase through higher discharge flow scenarios up to the highest modeled flow of 3,000 cfs. This outcome is likely due to the greater habitat complexity at Site 2, which provides a diverse array of hydraulic conditions and microhabitats throughout all flows. For example, wetted area at Site 2 almost doubles from 50 to 700 cfs and continues to increase steadily up to the highest flow modeled. Features such as large boulders, cobble substrates, an island complex, and deep pools contribute to a wider range of depth and velocity conditions, as compared to Site 1, that remain suitable for fish across a broader range of flows. These instream structural attributes not only enhance habitat suitability but also provide critical velocity refuges and feeding zones during high flows in high gradient reaches, further supporting both the modeled and other aquatic species. For example, Brown and Rainbow trout WUA continues to increase at the highest modeled flows (e.g., 2,500 and 3,000 cfs), while Mountain Whitefish and Flannelmouth Sucker WUA plateaus at similar modeled discharges.

The geomorphic characteristics of Site 2 also play a significant role in shaping the hydraulic responses to increasing flows. Site 2's physical diversity promotes steady increase in WUA as flows increase, avoiding the leveling off and slight declines in velocity suitability observed at Site 1. This enhanced connectivity between habitats allows fish to exploit newly wetted areas that are unavailable under lower flow conditions. The expansion of wetted area at higher flows further supports primary (e.g., algae) and secondary (e.g., aquatic macroinvertebrate) production, both of which form the foundation of the river's food web.

The site-specific differences observed in the analysis illustrate the critical role of local channel morphology in shaping hydraulic conditions and habitat availability. These results highlight the ecological benefits of the Shoshone Reach's physical heterogeneity in supporting a range of flows for multiple species.

Although hydraulic suitability scores are a valuable tool for evaluating relative habitat quality, they likely underrepresent the ecological benefits of increased flows for fish and other aquatic species within high gradient, confined canyon reaches like the Shoshone Reach. The abundant velocity refuges created by large boulders and cobble substrates provide microhabitats that are not fully captured in the two-dimensional hydraulic model. These microhabitat pockets, located behind large boulders and cobble substrate, offer shelter for fish, particularly during high flows, reducing the energetic costs of maintaining instream position while also providing foraging opportunities along velocity seams. While the hydraulic model used in this assessment effectively quantifies depth and velocity relationships, it does not account for the influence of substrate and cover

features on microhabitat diversity, or geomorphic benefits of higher flows including flushing fine sediment, maintaining habitat diversity, and recruitment of wood and organics.

The HHS results emphasize the ecological benefits of higher flows within the Shoshone Reach. While flows in the range of 1,500 to 2,250 cfs maximize hydraulic habitat suitability for modeled species at Site 1, the continued increase in wetted area at higher flows supports expanded habitat availability and off-channel (not wetted at lower flows [e.g., under 700 cfs]) connectivity, particularly in reaches with greater habitat complexity, such as Site 2. Higher flow conditions, particularly at Site 2, benefit fish populations and broader aquatic ecosystems by enhancing habitat diversity (e.g., wetting off-channel areas with higher flows) and supporting critical ecological processes.

Microhabitat Features and Interstitial Space

Fish microhabitat use involves interactions of habitat features, behavior, and ecology. Trout benefit from large substrates like boulders and cobbles, which provide shelter, foraging opportunities, and refuge from strong currents. Trout prefer lower flow areas but utilize faster currents as needed. Riffles are essential for food production. Species like Brown and Rainbow Trout favor complex substrates in high-gradient streams for predator evasion and efficient feeding. They seek refuge in areas with slower water and adjust their positions based on flow conditions. The riverbed's stability during high flows can influence available trout refuges.

The influence of hydraulic conditions on habitat selection is significant. Studies have shown that adult Brown Trout can occupy microhabitats with relatively high stream velocities, although juveniles typically favor lower velocities (Raleigh et al., 1984 & 1986). Additionally, the availability of cover, such as woody debris and boulders, plays a critical role in habitat selection, providing both protection from predators and a reliable environment for feeding and growth (Ayllón et al., 2008). The interaction between flow regimes and habitat use is essential for understanding trout behavior in high-velocity rivers. Research indicates that trout from rivers with highly irregular flow patterns are more adaptable and willing to shift habitats compared to those in stable environments (Ayllón et al., 2013). This adaptability is vital for their resilience in fluctuating habitats, allowing them to exploit spatially distinct refugia during periods of high flow (Ayllón et al., 2013). The presence of these substrates can significantly influence the distribution and abundance of trout populations. For example, studies have shown that juvenile trout often seek shelter in boulder-sheltered positions, while older individuals may prefer visually isolated areas along river margins (Ayllón et al., 2008; Ayllón et al., 2010). This behavior is particularly pronounced in high-velocity environments, where the risk of displacement is greater, and the availability of refuge is critical for survival.

The instream microhabitat use by trout in high-velocity rivers is shaped by a multitude of factors, including physical habitat characteristics, hydraulic conditions, behavioral adaptations, and ecological interactions. The presence of interstitial spaces and large substrates plays a pivotal role in providing refuge and foraging opportunities.

Aquatic Invertebrates

A variety of macroinvertebrate species inhabit the Glenwood Canyon. These and other aquatic invertebrates provide important high value food sources for resident fish, birds, and bats and are an important component of the riverscape food web. Flow management is a critical determinant of macroinvertebrate community health. Research shows that reductions in instream flow can lead to increased sedimentation, elevated water temperatures, and lower dissolved oxygen levels, all of which can stress or exclude sensitive taxa like EPT (Poff et al., 1997; Biaou et al., 2024). Conversely, restoring and maintaining adequate instream flows and natural hydrograph

characteristics can enhance habitat conditions, water quality, and promote macroinvertebrate production. Scenario 2, Future with Permanency, would provide reliable flows that support a healthy macroinvertebrate community within the Shoshone Reach. Reliable annual flow would not only enhance the Shoshone Reach's overall ecological value, but potentially support a fishery on par with other world-renowned fisheries. Reliable annual flow volumes, like those proposed in Scenario 2, Future with Permanency, would promote resilient macroinvertebrate communities, supporting a thriving aquatic food web, and improve the Shoshone Reach capacity to function as a healthy fishery.

Fishery

Fish access the Shoshone Reach for seasonal movements, foraging, reproduction, and refuge. Its complex streambed creates microhabitats that provide shelter and feeding opportunities. The reach features both high-gradient and low-gradient areas, allowing fish to move between different velocity zones, enhancing passage and supporting various species.

In flow Scenario 2 (Future with Permanency), the habitat suitability in the Shoshone Reach is higher more often compared to Scenario 1 (Baseline) and Scenario 3 (Future without Permanency). This is because the water flows in this reach would more frequently fall within a higher HHS range for longer durations particularly in the later summer to fall period. The reliable annual flows provided under Scenario 2 (Future with Permanency) would also alleviate the stresses associated with habitat fragmentation that occurs at low flows and when water is diverted to support hydropower operations. Habitat fragmentation occurs when flow is insufficient to provide the depth required for fish species to be able to migrate between habitats. Habitat fragmentation is a common occurrence under existing conditions and can lead to fish kills (personal communication CPW, 2025). If fish get stranded in pools and air temperature and stream temperatures are elevated fish become stressed. This condition has led to CPW calling for salvage operations in the Shoshone Reach (personal communication CPW, 2025). Under Scenario 2 (Future with Permanency) salvage operations in the Shoshone Reach would be unlikely.

Summer Stream Temperatures & Winter Habitat

Preserving and improving the natural environment in the Shoshone Reach by providing reliable instream flow is likely to help regulate water temperatures, particularly during the summer months and early fall when ambient air temperatures are high, and warm spring inputs have the potential to elevate water temperatures. This reach of the Colorado River is listed as impaired for temperature under Section 303(d) of the Clean Water Act, suggesting that elevated temperatures may be affecting aquatic life. Higher flows can help buffer temperature fluctuations by increasing thermal mass and promoting greater mixing, potentially reducing the likelihood of localized thermal spikes. Additionally, increased flow volumes are likely to mitigate the influence of warm groundwater or thermal hot spring inputs by dispersing heat more effectively throughout the water column. Temperature regulation is particularly important for cold-water species such as Mountain Whitefish, Rainbow Trout, and Brown Trout, which are sensitive to thermal stress. Sustaining higher flows through the Shoshone Reach provides important thermal refugia for fish and other aquatic organisms, supporting overall ecosystem health and resilience in the face of warming trends and increasing climatic variability. Based on the three flow scenarios, Scenario 2 (Future with Permanency) would result in increased flows during these critical months compared to Scenarios 1 or 3. Critical flow periods in the Shoshone Reach are late summer (August) through fall (October), when stream flow is often low and ambient air temperatures and solar input is high.

Instream flows during the winter months could improve habitat conditions by increasing wetted area and enhancing holding and foraging opportunities for fish. At unnaturally low winter flows

when most, if not all, of the river flow is diverted through the penstocks, habitat availability can become significantly constrained, limiting the space available for fish to occupy and potentially increasing competition for resources. Additional flow would provide greater access to deep pools, velocity refuges, and complex habitat features, which are critical for fish survival during winter when metabolic rates are lower, and energy conservation is essential. By maintaining even modest instream flows (greater than 1,020cfs), the Shoshone Reach may support habitat complexity and improve overwinter survival rates, contributing to overall fish population stability and resilience.

5.2 CONCLUSION

The instream flow use of the Shoshone Water Rights will preserve and improve flow conditions through the Shoshone Reach and would provide direct ecological benefits by increasing aquatic habitat, fostering connectivity, and supporting primary and secondary production. The proposed instream flow uses within this reach would help regulate stream temperatures, maintain habitat complexity, and enhance the availability of critical refuges for fish, particularly during seasonal low-flow periods.

The assessment's key conclusion, which is the Shoshone Water Rights applied as an instream use would preserve and improve the ecological condition of the Shoshone Reach, is backed by habitat modeling results from two sites in the Shoshone Reach. HHS scores, WUA, and wetted area increase with flow. The complexity of the habitat—featuring boulders, cobble substrates, islands, and deeper pools—creates diverse conditions that support fish habitat for all species at various flow levels, providing critical refuges and feeding zones. The trends of the two sites differ in overall habitat suitability due to their physical diversity. However, both sites provide suitable habitat for all species upwards of 1,500 cfs and above, underscoring the ecological benefits of permanent instream flows in the Shoshone Reach. The velocity refuges formed by boulders and cobble, which are often underrepresented in habitat suitability curves, provides essential microhabitats for several the fish species modeled. Indeed, higher flows enhance availability of wetted area and habitat connectivity (Site 2 specifically), benefiting fish populations and aquatic ecosystems overall.

Although HHS scores are useful in characterizing immediate and direct benefits to fish, they do not evaluate the ecological advantages of increased flows to habitat maintenance and water quality. The reliable annual flows provided by the Shoshone Water Rights, applied to instream use, would provide channel forming and water quality (primarily temperature) benefits that are not being realized under current conditions.

Under the proposed permanent instream flow scenario (Scenario 2, Future with Permanency) with preservation of the Shoshone Water Rights, HHS for fish in the Shoshone Reach would be higher more frequently (and therefore a greater WUA sq. ft./1,000 LF). Flow levels would more often remain within a high suitability range for extended periods and would provide greater flow during the critical late summer and early fall seasons when temperatures and other stressors are at their peak. The assessment's findings indicate that the use of the Shoshone Water Rights for instream flow would preserve and improve the natural environment of the Shoshone Reach up to the highest evaluated discharge of 3,000 cfs. This is demonstrated by Scenario 2 (Future with Permanency) as it would provide the most habitat on an average annual basis when compared to Scenario 1 (Baseline) or Scenario 3 (Future without Permanency). Further, Scenario 2 (Future with Permanency) would provide added habitat during critical late summer and early fall time periods when fish are more likely to be stressed by low flows and elevated temperatures.

The two study sites cover a mosaic of instream habitat characteristics that represent the overall Shoshone Reach. The diverse geomorphic features of both locations create a variety of flow conditions, which enhance habitat complexity, an essential factor for fish survival. The hydraulic connectivity between the sites enables fish to access newly wetted areas and different habitats under varying flow conditions.

At the same time, the Shoshone Water Rights provide benefits that extend beyond their immediate area. The Shoshone Water Rights would preserve flows necessary to support upstream and downstream ecosystems and will improve conditions dramatically within the Shoshone Reach. The Shoshone Water Rights strengthen regional economies by supporting outdoor recreation and tourism, while also playing a role in securing downstream water deliveries. As competition for water resources in the Colorado River Basin continues to intensify, the preservation of the Shoshone Reach Water Rights is a key strategy for balancing environmental and economic needs across the region while also maintaining the ecological integrity of the Shoshone Reach itself.

These water rights, if made permanent through the introduction of an alternate use for instream flow purposes, would preserve and improve the Shoshone Reach's natural environment. Without them, the river could experience rising temperatures, habitat degradation, and declining fish populations. The Shoshone Water Rights are an important factor for the survival and resilience of fish populations, the integrity of aquatic and terrestrial (i.e., riparian) habitats, and the long-term health of the Colorado River. A vital component of all aquatic systems is a connection to requisite resources throughout the year that supports all life-stages and strategy needs (food, clean water, velocity break, feeding zones, spawning habitat, etc.). The Shoshone Water Rights employed for in-stream use would provide a reliable and ecologically meaningful year-round flow that would support all aquatic species in the Shoshone Reach.

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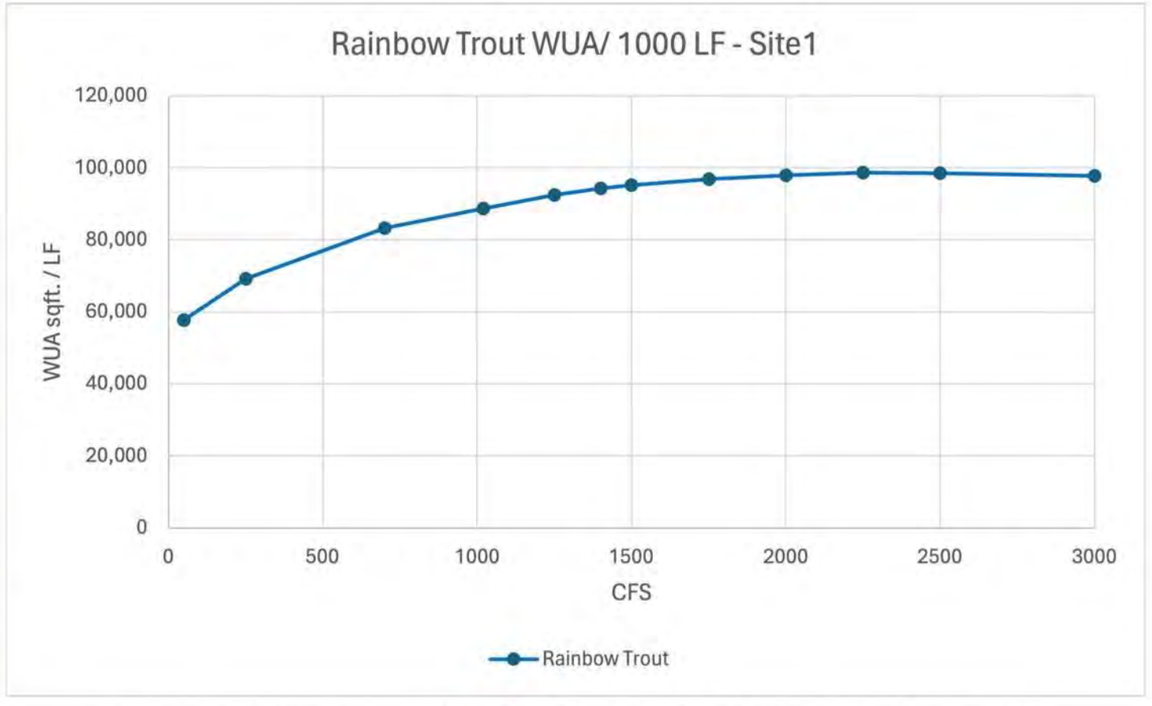
APPENDIX A - Hydraulic Habitat Suitability Results, Maps and Weighted Useable Area Graph

Study Site 1 Habitat Suitablity

Adult Rainbow Trout



Graph of Weighted Useable Area (WUA Sq. Ft. / LF.) for Adult Rainbow Trout at Site 1 per Discharge (cfs).

Figure A-1: Study Site 1 - Hydraulic Habitat Suitability and WUA Adult Rainbow Trout

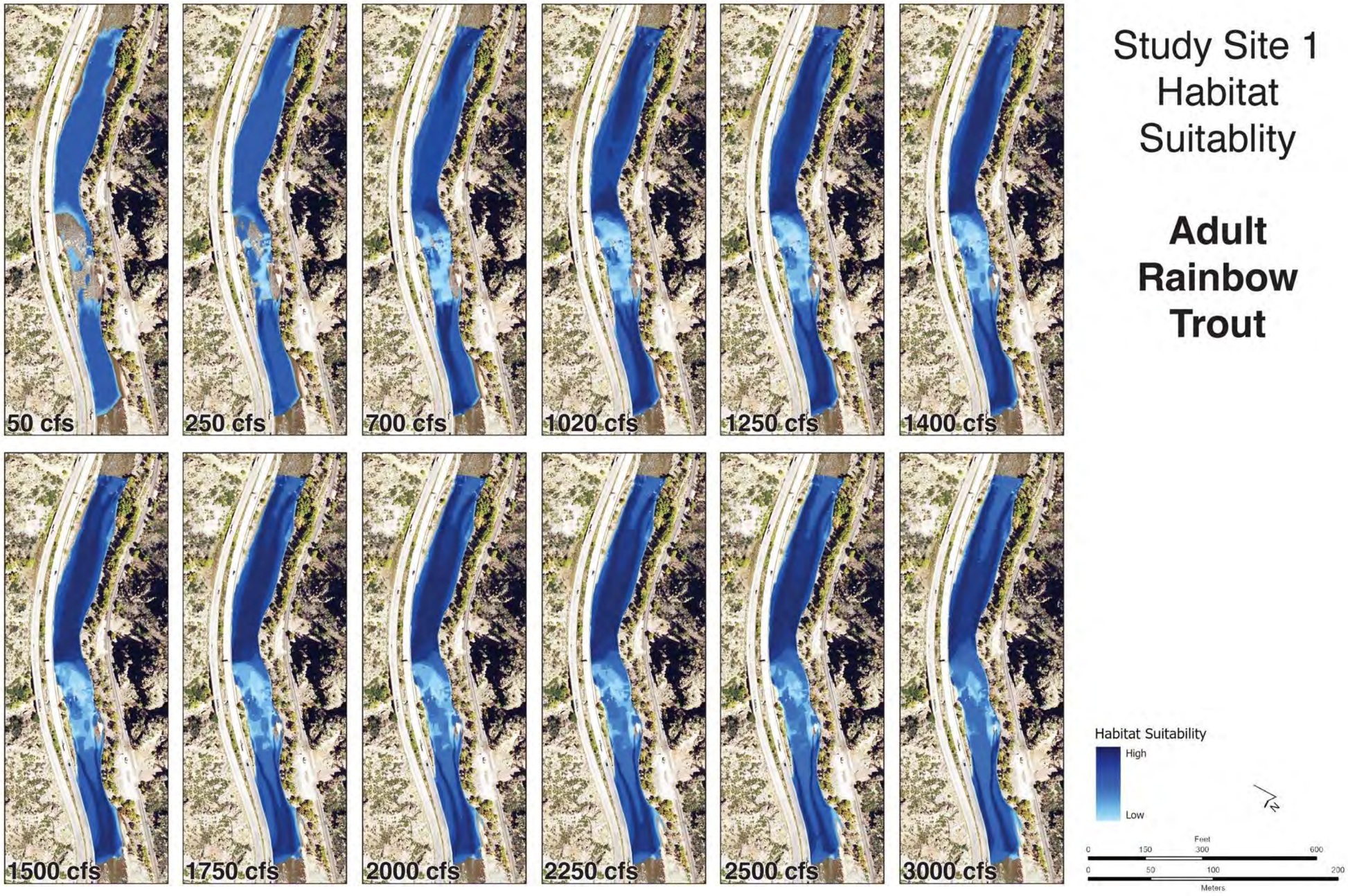
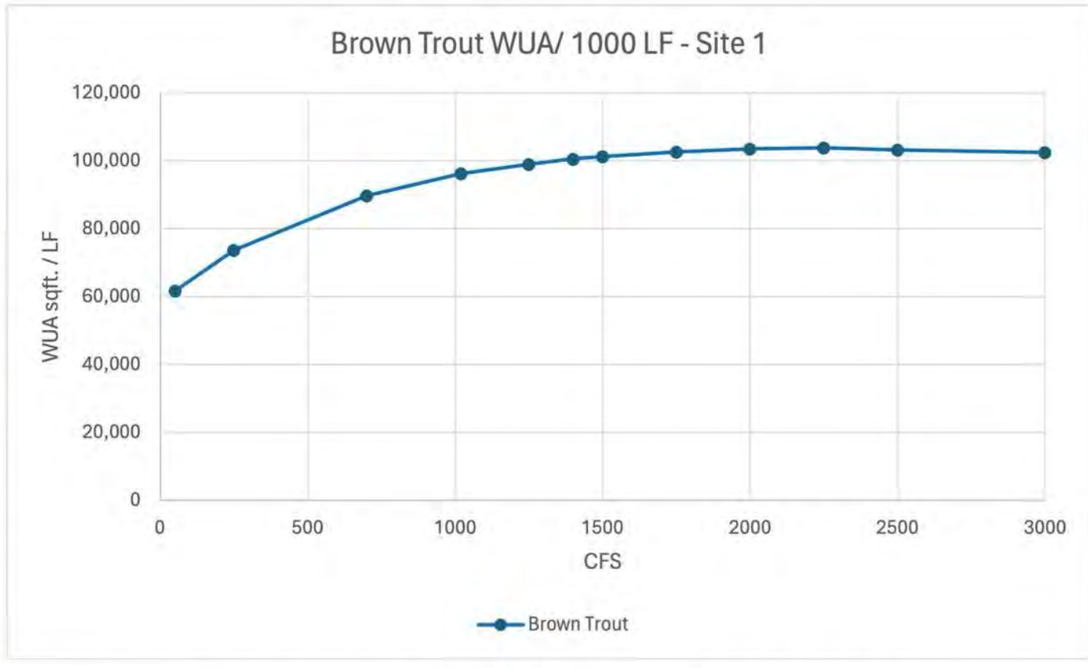


Figure A-2: Study Site 1 - Adult Rainbow Trout HHS Maps per Flow (cfs)

Study Site 1 Habitat Suitablity

Adult Brown Trout



Graph of Weighted Useable Area (WUA Sq. Ft. / LF.) for Adult Brown Trout at Site 1 per Discharge (cfs).

Figure A-3: Study Site 1 - Hydraulic Habitat Suitability and WUA Adult Brown Trout

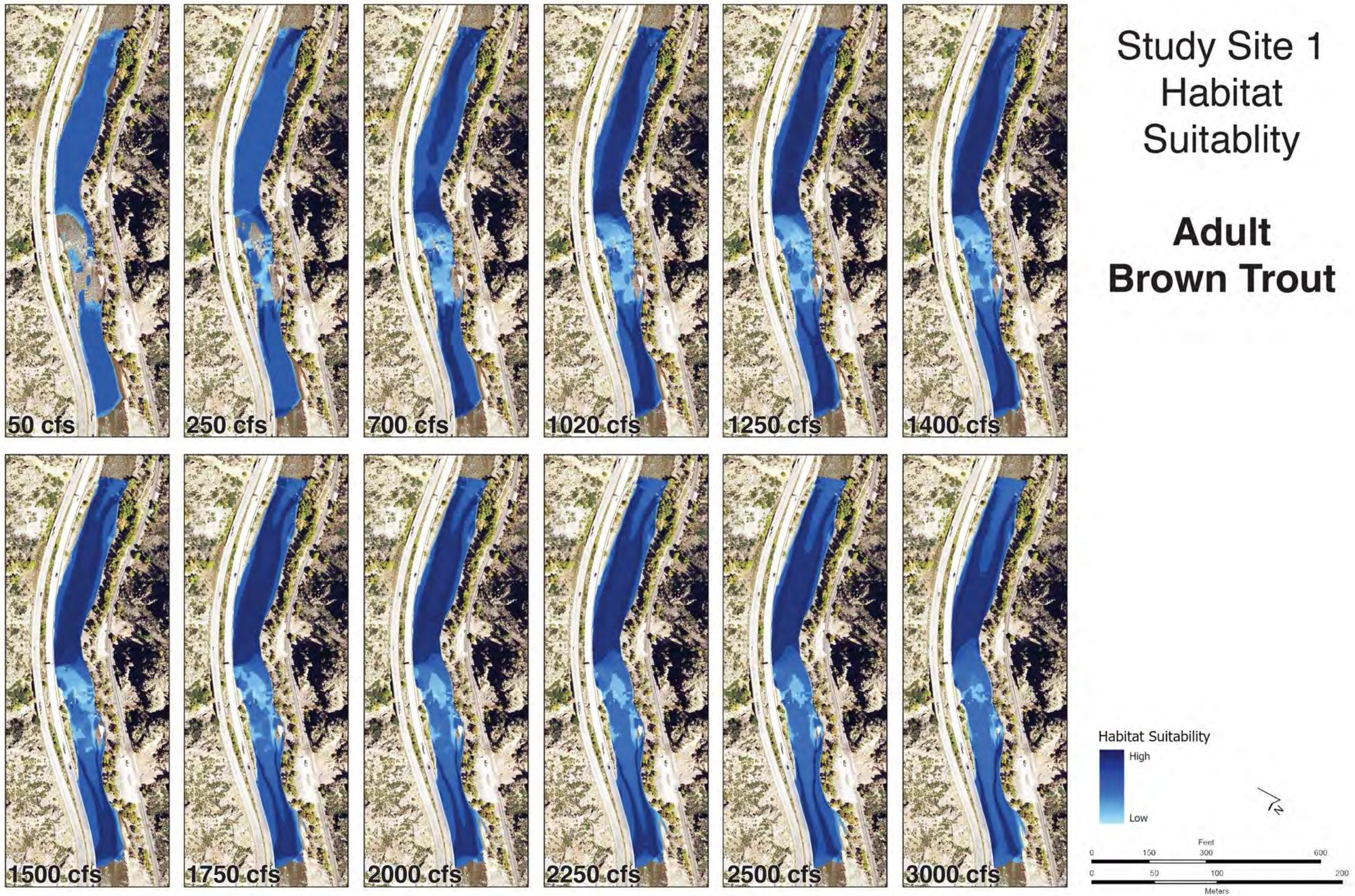
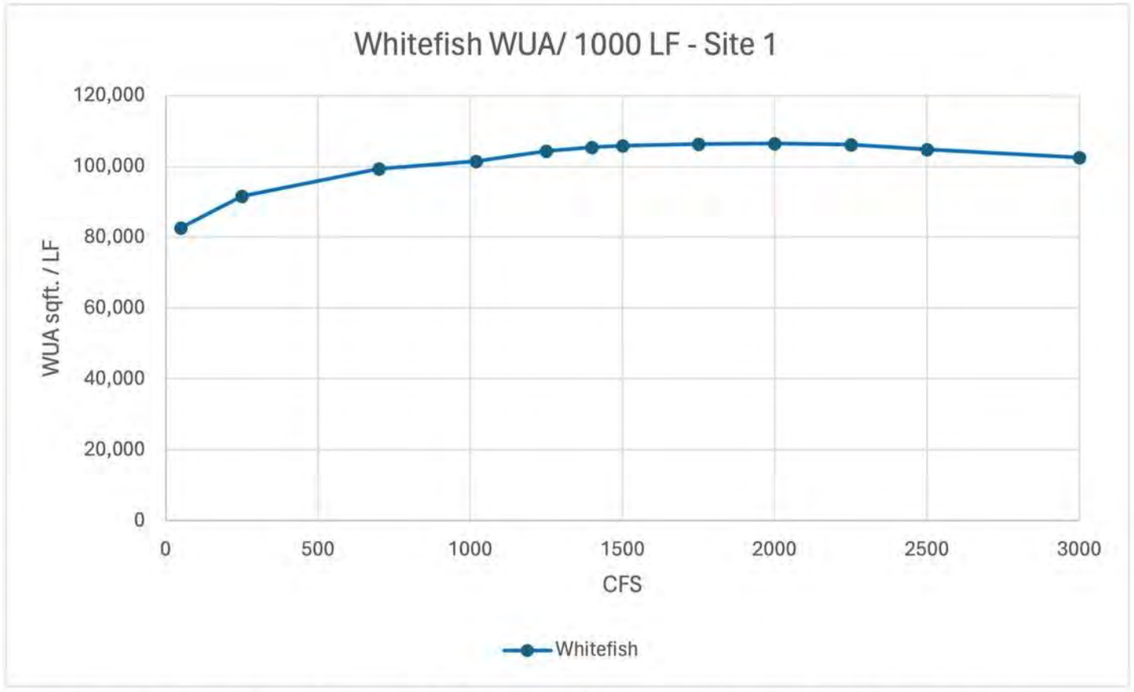


Figure A-4: Study Site 1 - Adult Brown Trout HHS Maps per Flow (cfs)

Study Site 1 Habitat Suitablity

Adult Mountain Whitefish



Graph of Weighted Useable Area (WUA Sq. Ft. / LF.) for Adult Mountain Whitefish at Site 1 per Discharge (cfs).

Figure A-5: Study Site 1 - Hydraulic Habitat Suitability and WUA Adult Mountain Whitefish

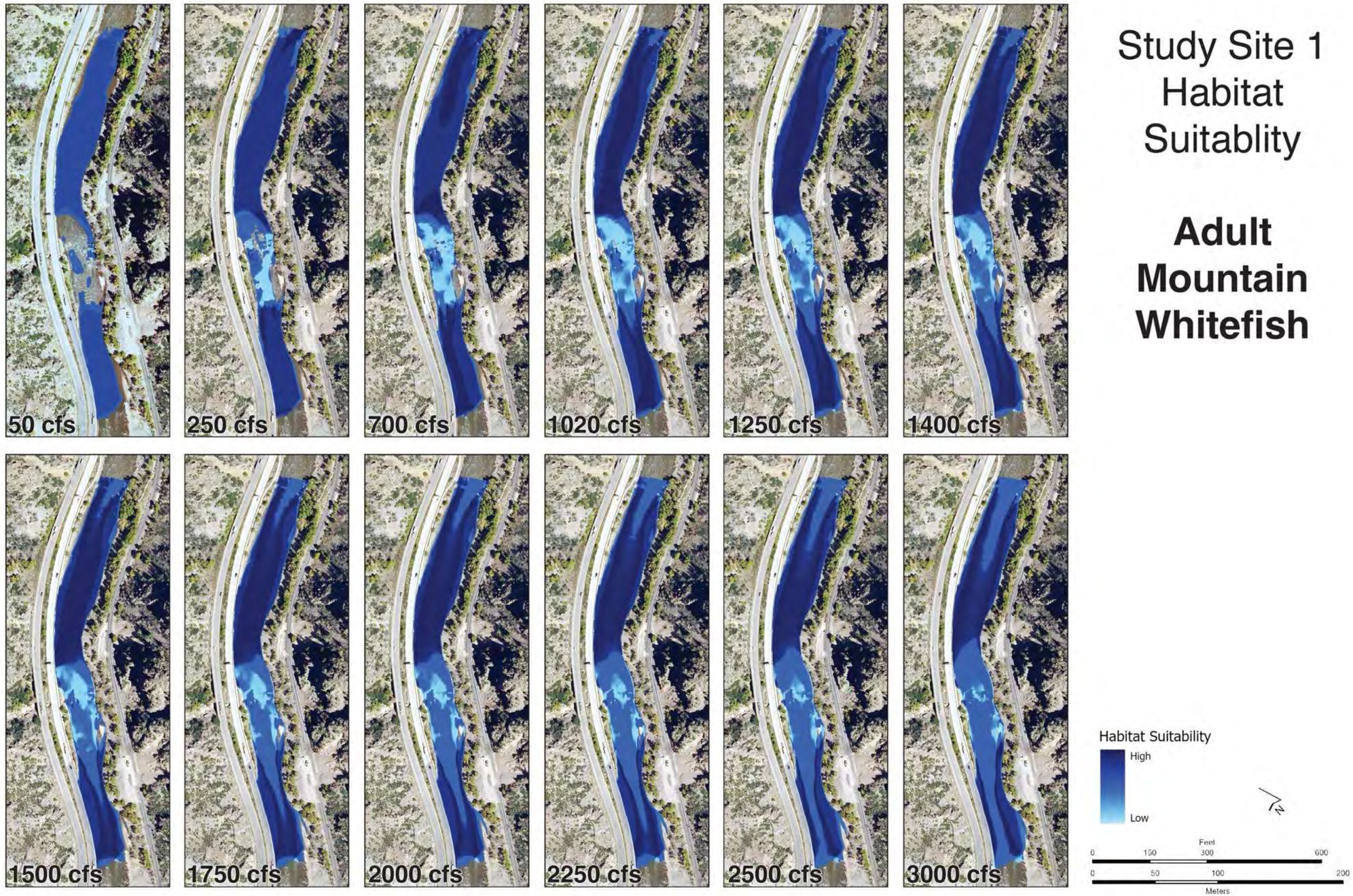
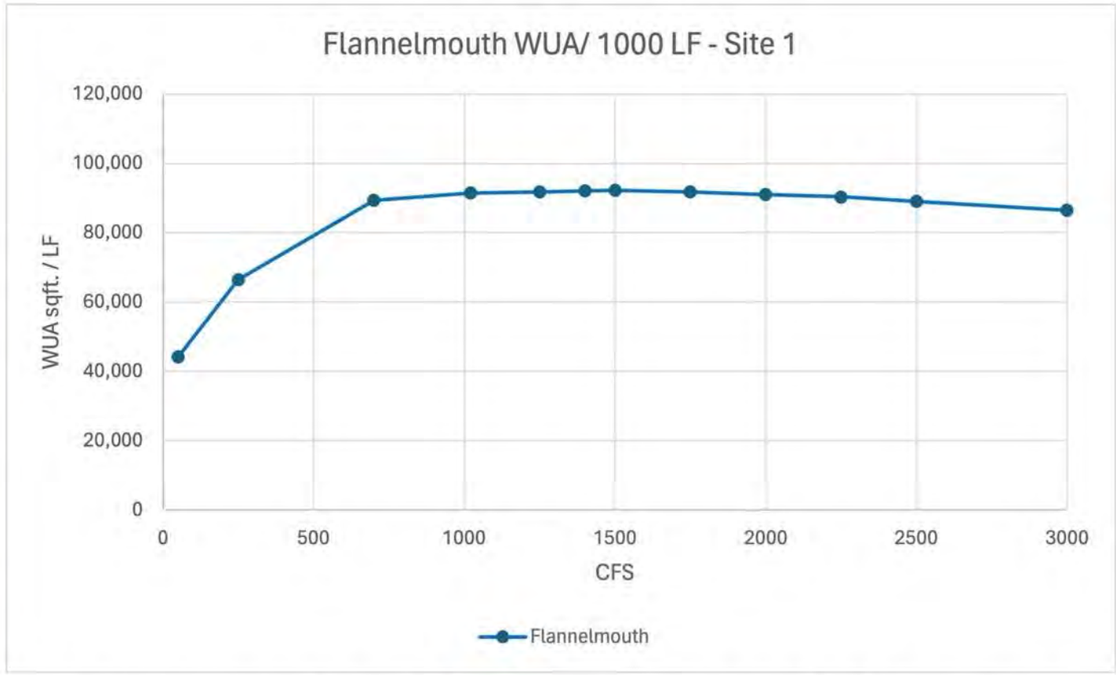


Figure A-6: Study Site 1 - Adult Mountain Whitefish HHS Maps per Flow (cfs)

Study Site 1 Habitat Suitablity

Adult Flannelmouth Sucker



Graph of Weighted Useable Area (WUA Sq. Ft. / LF.) for Adult Flannelmouth Sucker at Site 1 per Discharge (cfs).

Figure A-7: Study Site 1 - Hydraulic Habitat Suitability and WUA Adult Flannelmouth Sucker

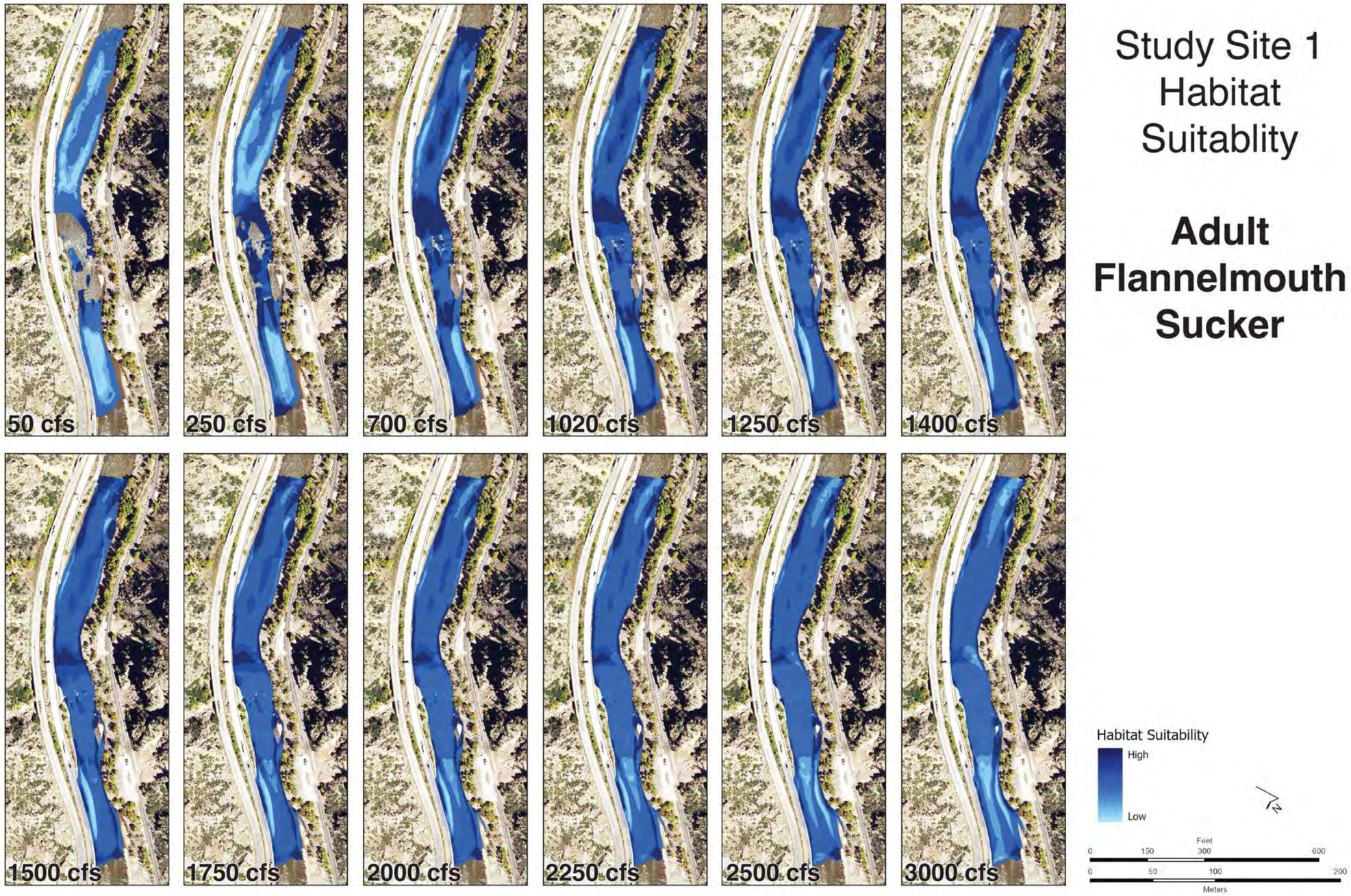
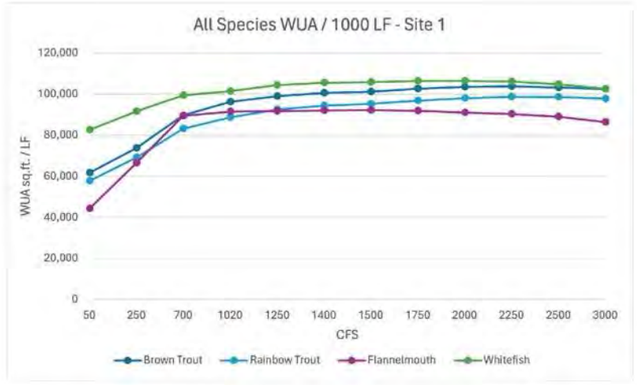
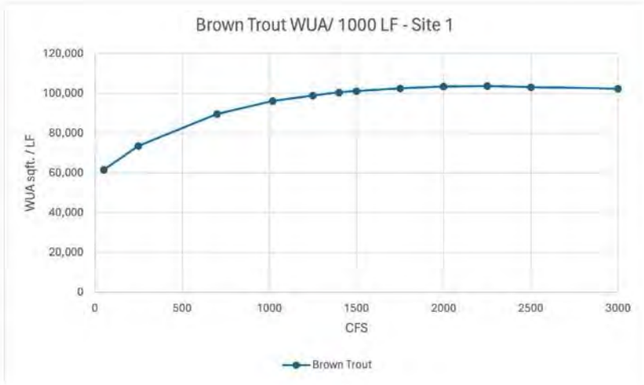
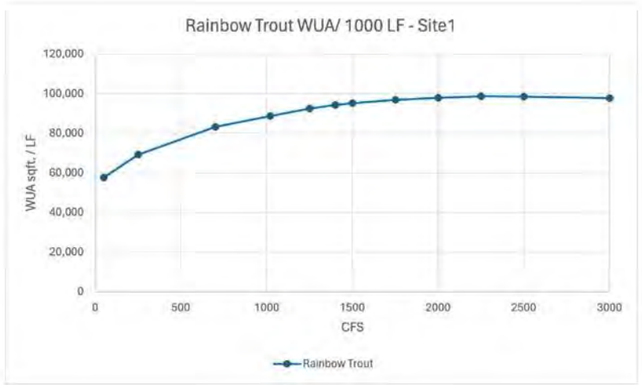


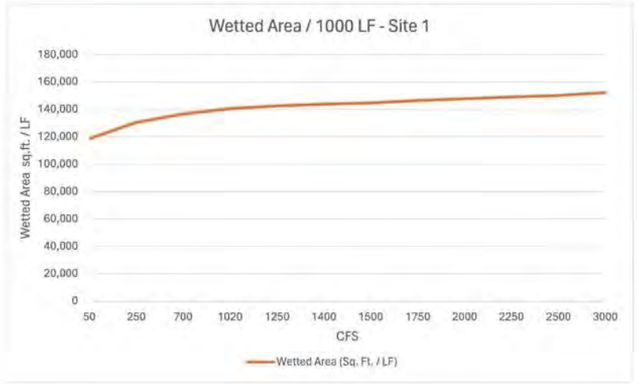
Figure A-8: Study Site 1 - Adult Flannelmouth Sucker HHS Maps per Flow (cfs)

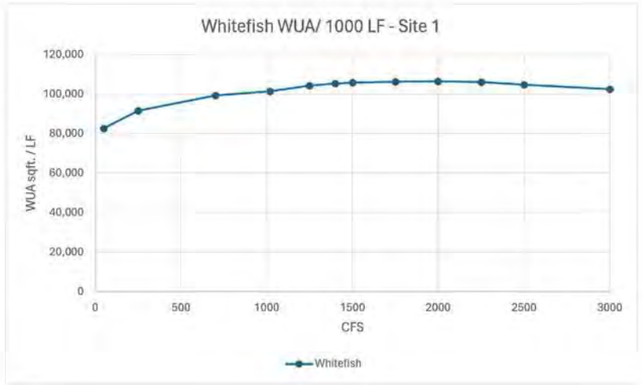
Study Site 1 Habitat Suitablity









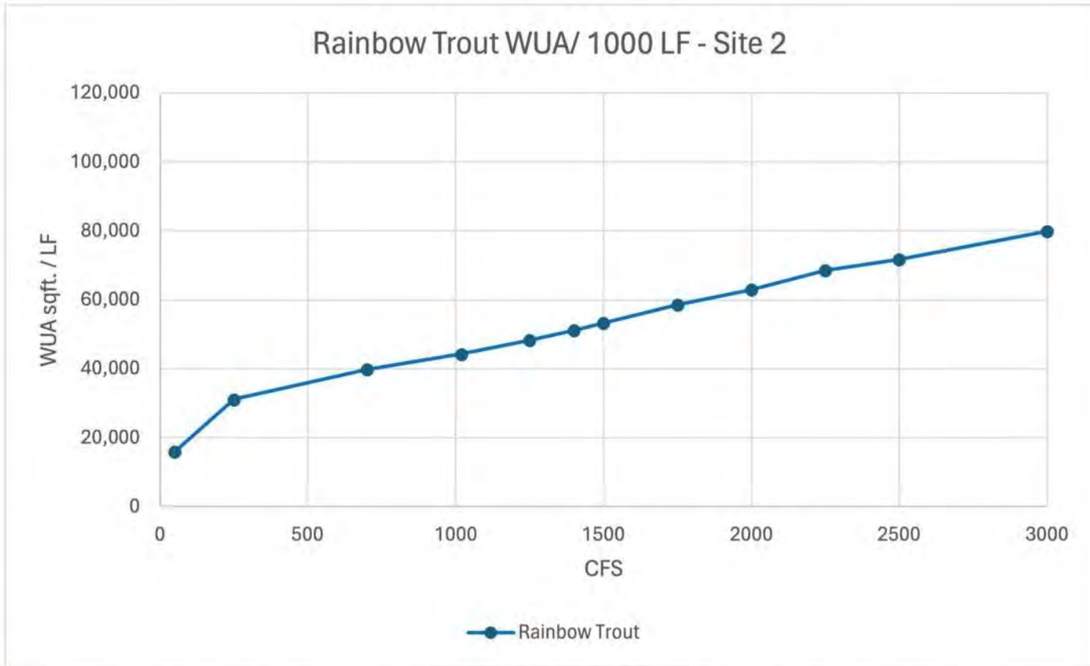


Graphs of Weighted Useable Area (WUA Sq. Ft. / LF.) for all species at Site 1 per Discharge (cfs).

Figure A-9: Study Site 1 - WUA All Species

Study Site 2 Habitat Suitablity

Adult Rainbow Trout



Graph of Weighted Useable Area (WUA Sq. Ft. / LF.) for Adult Rainbow Trout at Site 2 per Discharge (cfs).

Figure A-10: Study Site 2 - Hydraulic Habitat Suitability and WUA Adult Rainbow Trout

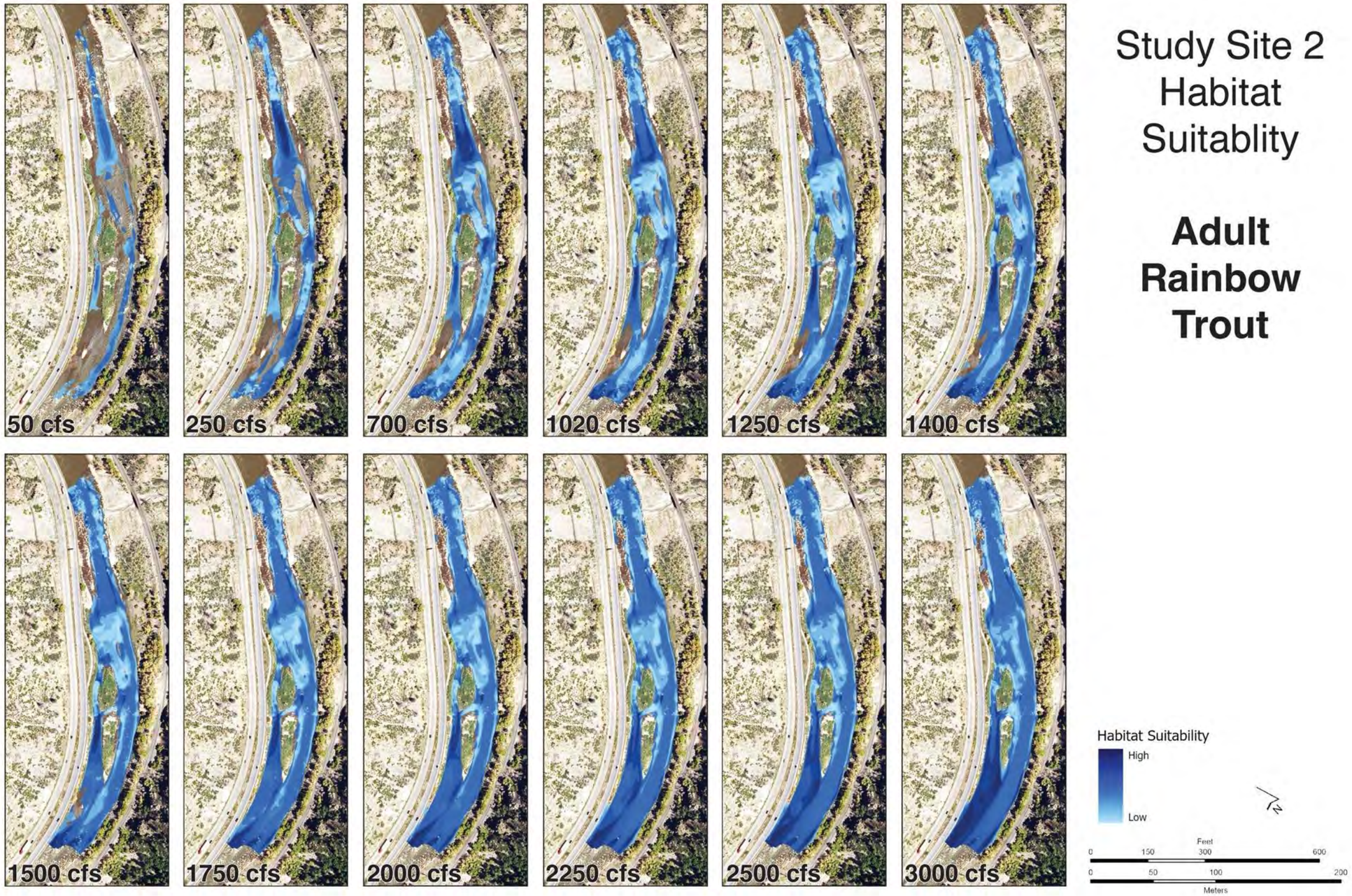
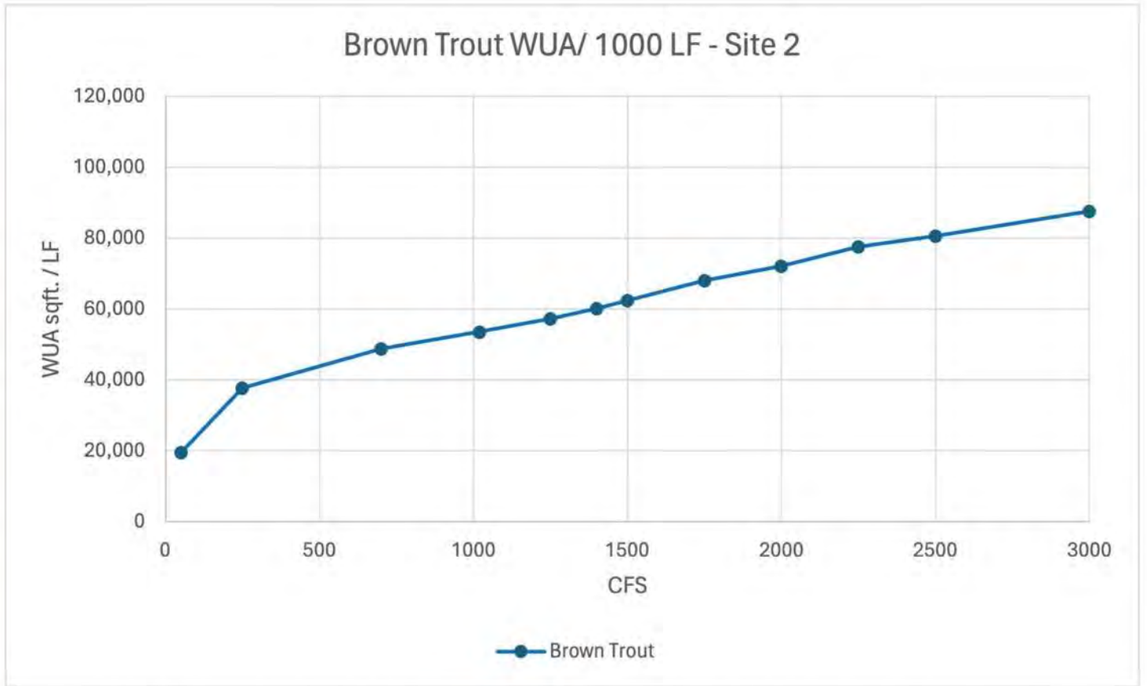


Figure A-11: Study Site 2 - Adult Rainbow Trout HHS Maps per Flow (cfs)

Study Site 2 Habitat Suitablity

Adult Brown Trout



Graph of Weighted Useable Area (WUA Sq. Ft. / LF.) for Adult Brown Trout at Site 2 per Discharge (cfs).

Figure A-12: Study Site 2 - Hydraulic Habitat Suitability and WUA Adult Brown Trout

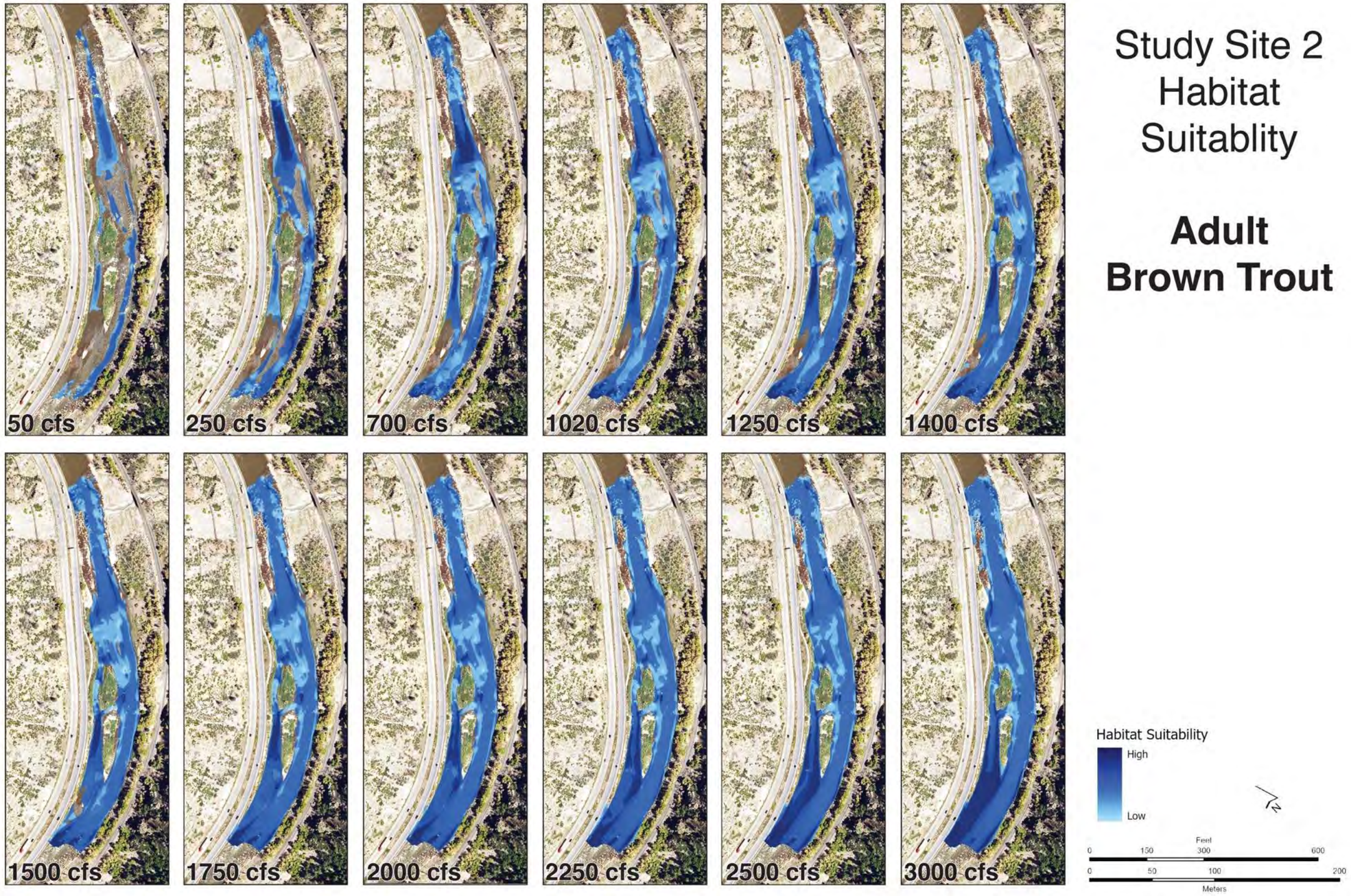
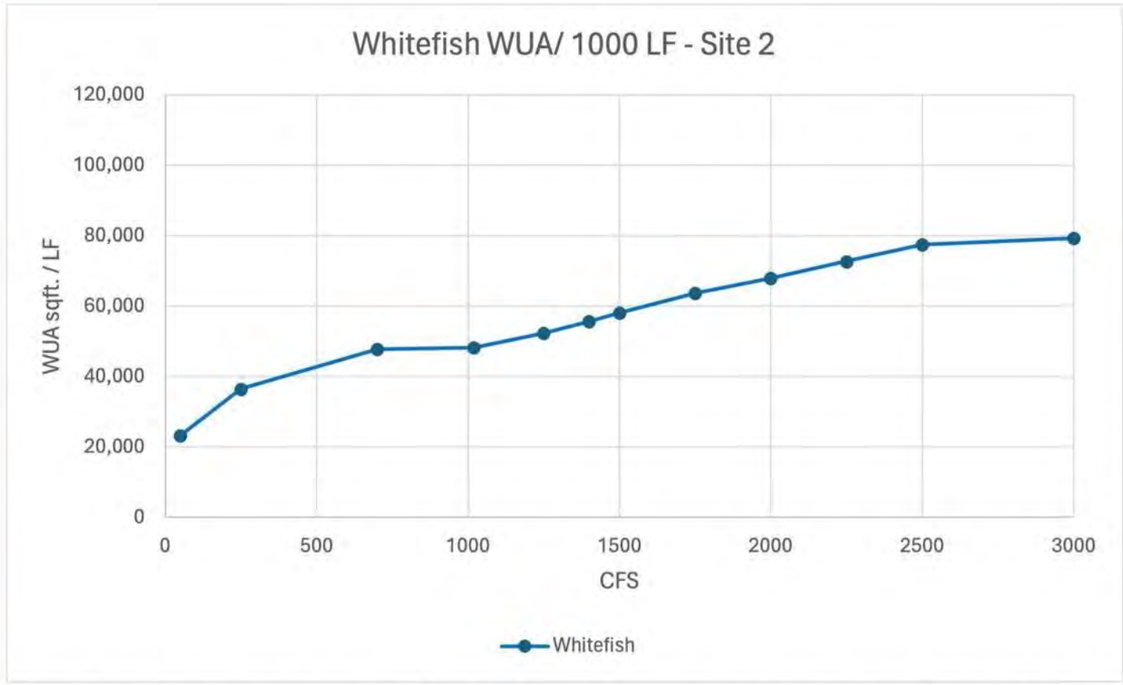


Figure A-13: Study Site 2 - Adult Brown Trout HHS Maps per Flow (cfs)

Study Site 2 Habitat Suitablity

Adult Mountain Whitefish



Graph of Weighted Useable Area (WUA Sq. Ft. / LF.) for Adult Mountain Whitefish at Site 2 per Discharge (cfs).

Figure A-14: Study Site 2 - Hydraulic Habitat Suitability and WUA Adult Mountain Whitefish

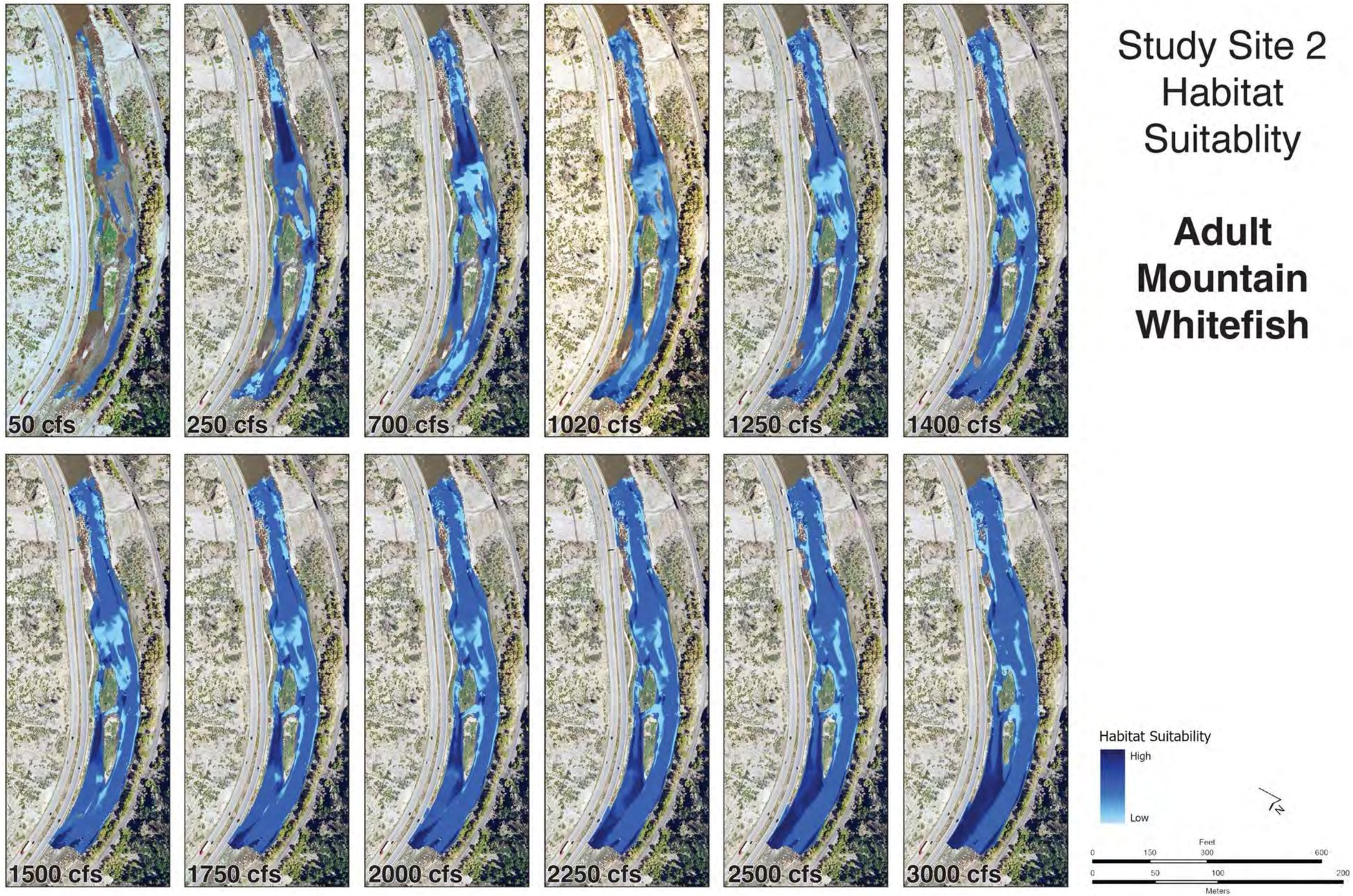
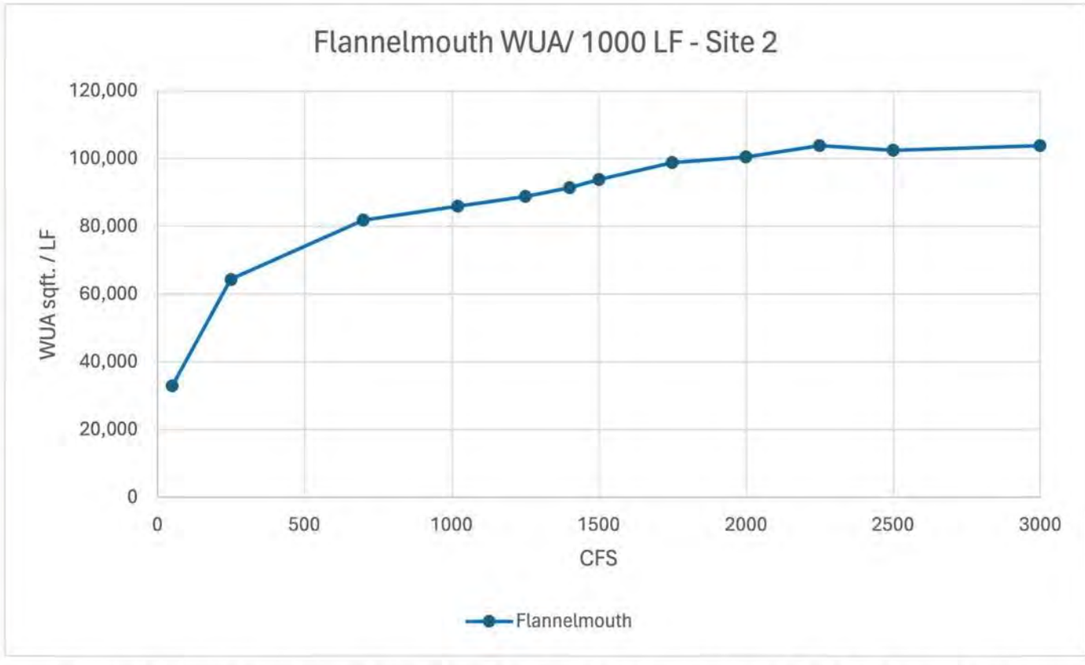


Figure A-15: Study Site 2 - Adult Mountain Whitefish HHS Maps per Flow (cfs)

Study Site 2 Habitat Suitablity

Adult Flannelmouth Sucker



Graph of Weighted Useable Area (WUA Sq. Ft. / LF.) for Adult Flannelmouth Sucker at Site 2 per Discharge (cfs).

Figure A-16: Study Site 2 - Hydraulic Habitat Suitability and WUA Adult Flannelmouth Sucker

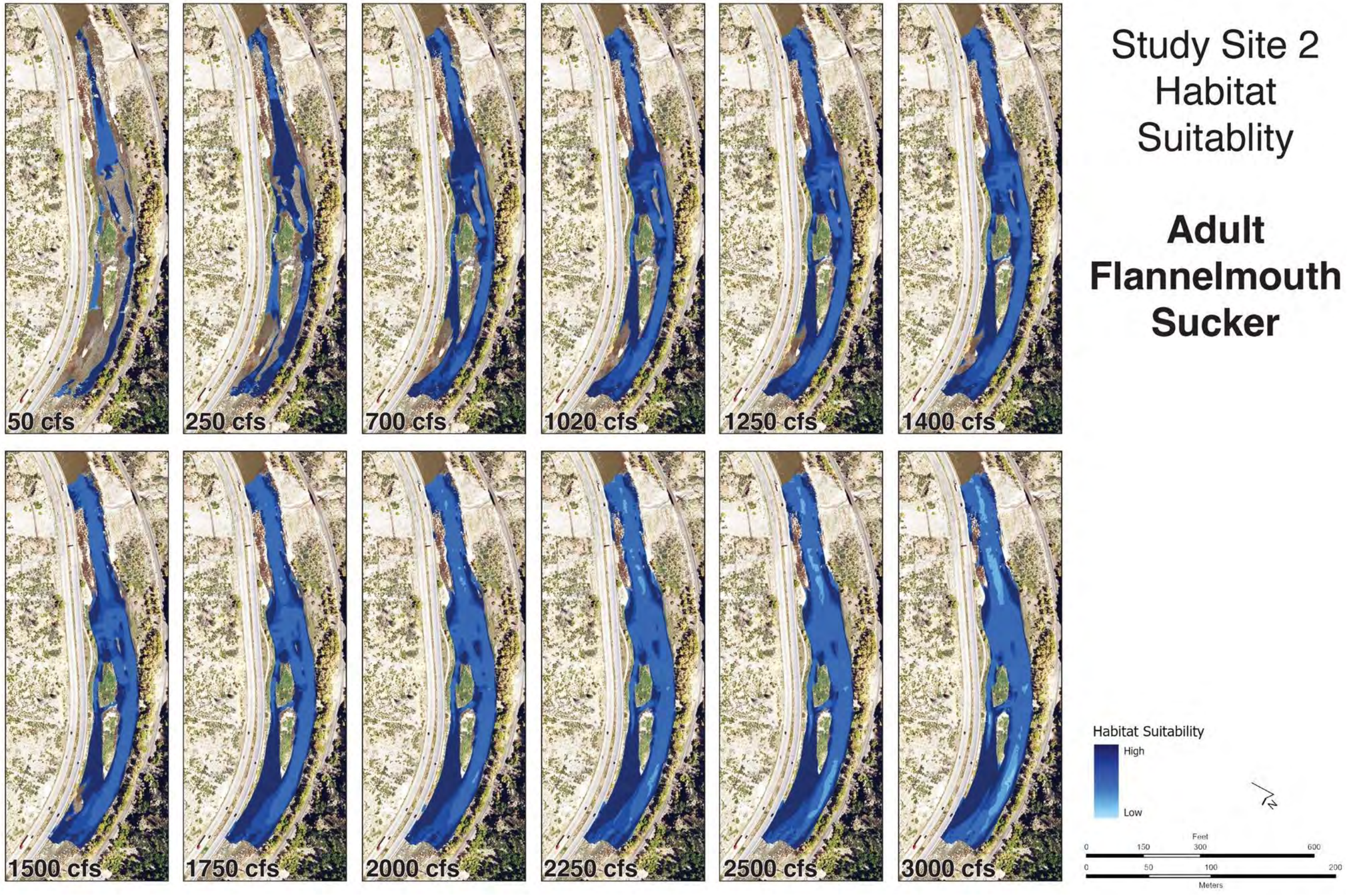
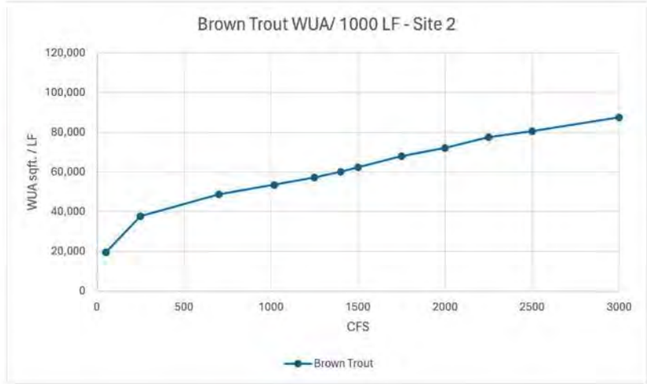
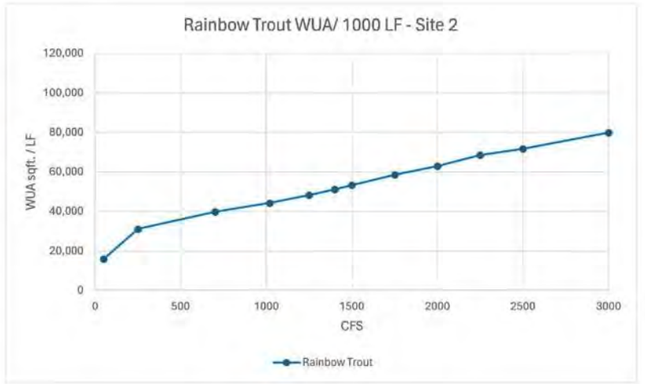
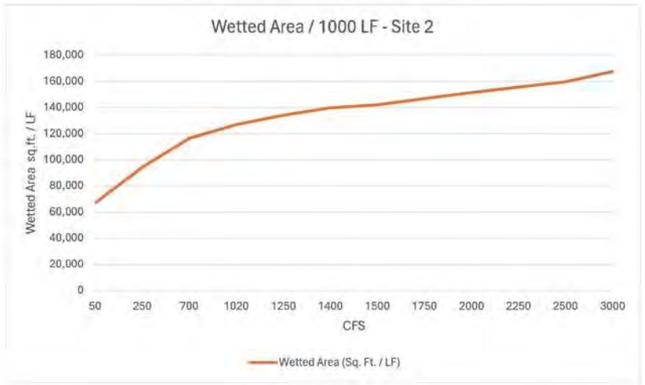


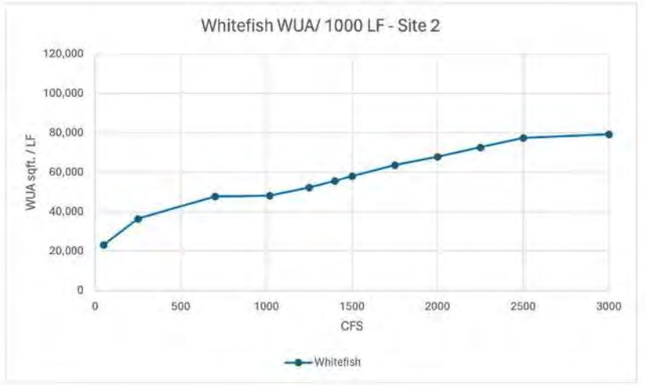
Figure A-17: Study Site 2 - Adult Flannelmouth Sucker HHS Maps per Flow (cfs)

Study Site 2 Habitat Suitablity





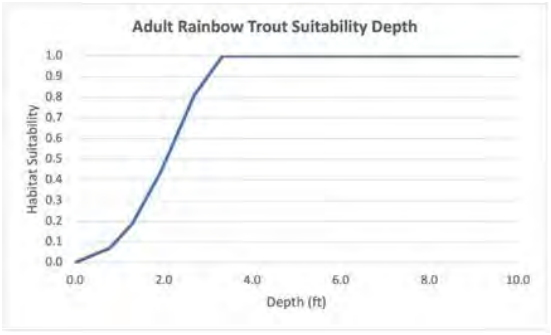




Graphs of Weighted Useable Area (WUA Sq. Ft. / LF.) for all species at Site 2 per Discharge (cfs).

Figure A-18: Study Site 2 - WUA All Species

APPENDIX B – SPECIES Suitability Curves



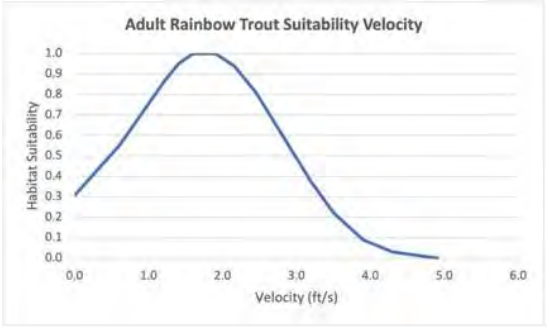
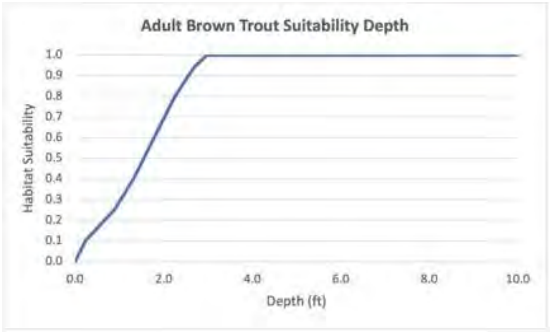


Figure B-1: Adult Rainbow Trout Suitability Curves (Depth and Velocity)



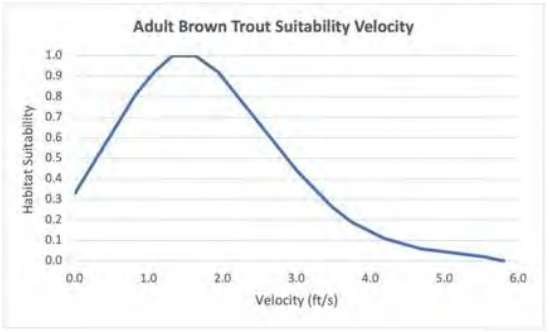
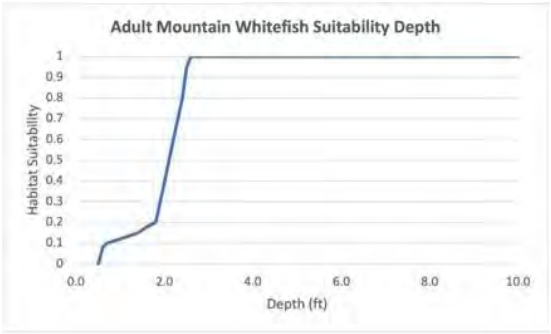


Figure B-2: Adult Brown Trout Suitability Curves (Depth and Velocity)



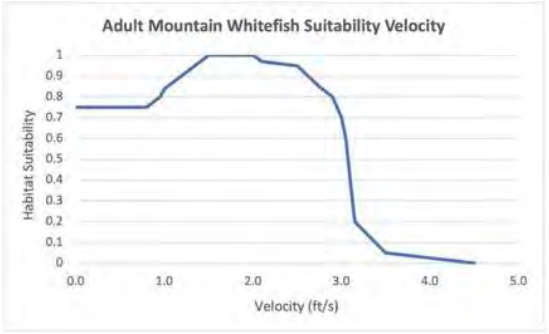
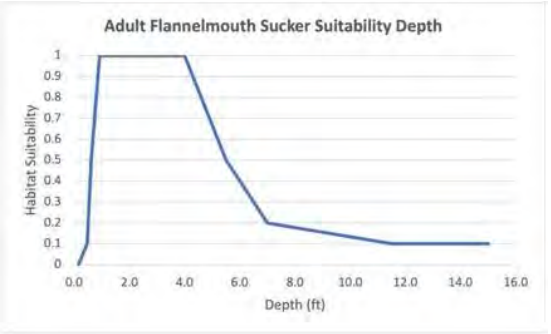


Figure B-3: Adult Mountain Whitefish Suitability Curves (Depth and Velocity)



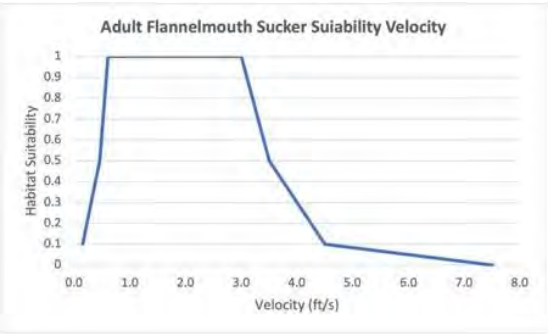


Figure B-4: Adult Flannelmouth Sucker Suitability Curves (Depth and Velocity)

APPENDIX C – HYDRAULIC MODELING AND HYDROGRAPHIC SURVEY REPORTS

Hydraulic Modeling Report – 2023. Prepared by Riverrestoration.org, December 2023.

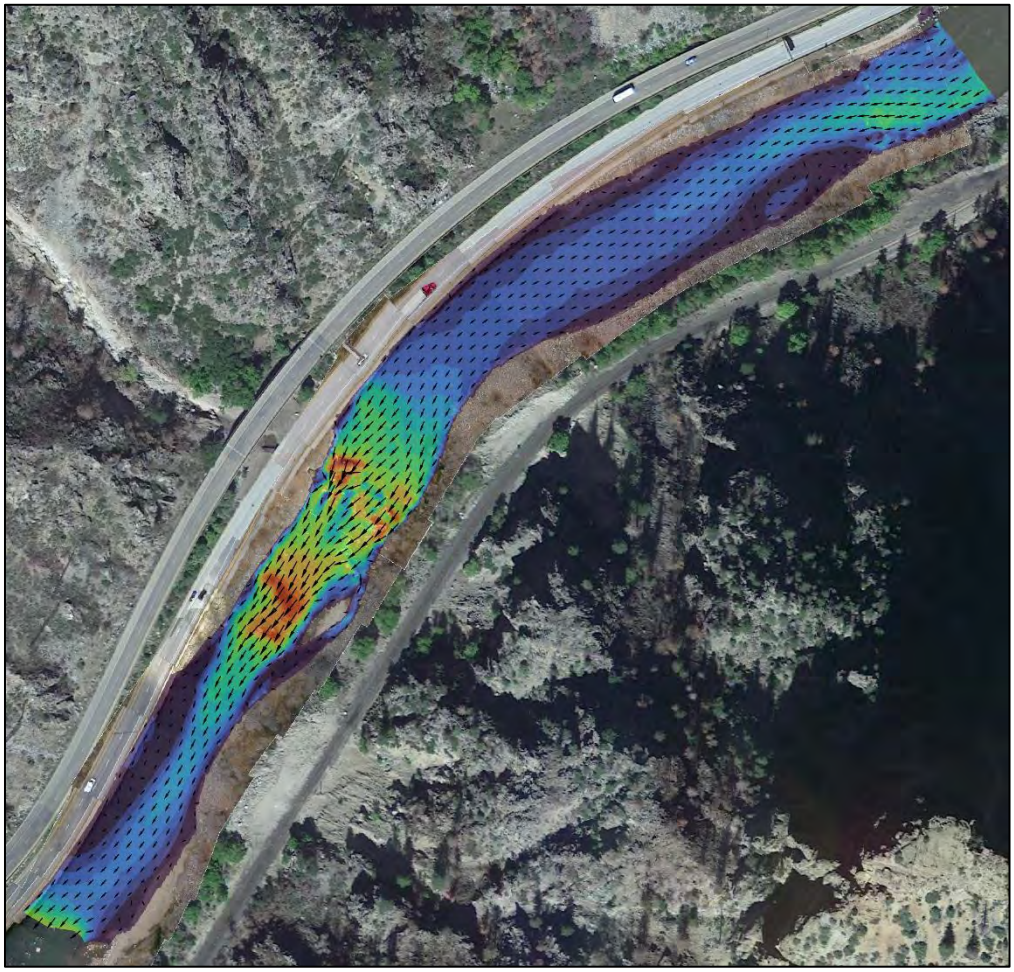
Hydrographic Survey Report – 2023. Prepared by Riverrestoration.org, January 2024.

Hydraulic Modeling Report – 2024. Prepared by Riverrestoration.org, January 2025.

Hydrographic Survey Report – 2024. Prepared by Riverrestoration.org, January 2025.

GLENWOOD CANYON AQUATIC HABITAT STUDY COLORADO RIVER, COLORADO

HYDRAULIC MODELING REPORT – 2023



PREPARED BY RIVERRESTORATION.ORG, DECEMBER 2023

Corresponding authors: Jason Carey, PE – Project Manager – jason.carey@riverrestoration.org
Russell Bair, PE – River Engineer; russell.bair@riverrestoration.org

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50cfs_results.xlsx
250cfs_results.xlsx
700cfs_results.xlsx
1020cfs_results.xlsx
1250cfs_results.xlsx
1400cfs_results.xlsx
3000cfs_results.xlsx

1. INTRODUCTION

A 2 dimensional (2D) hydrodynamic model was used to simulate a variety of low flow conditions for a study reach on the Colorado River in Glenwood Canyon. The model was based on a digital elevation model (DEM) developed from hydrographic survey data collected over an 1854 foot reach (Figure 1). The goal was to provide spatially discrete data and weighted values of water depth, velocity, shear stress, and a Froude value for use in a usable habitat analysis.

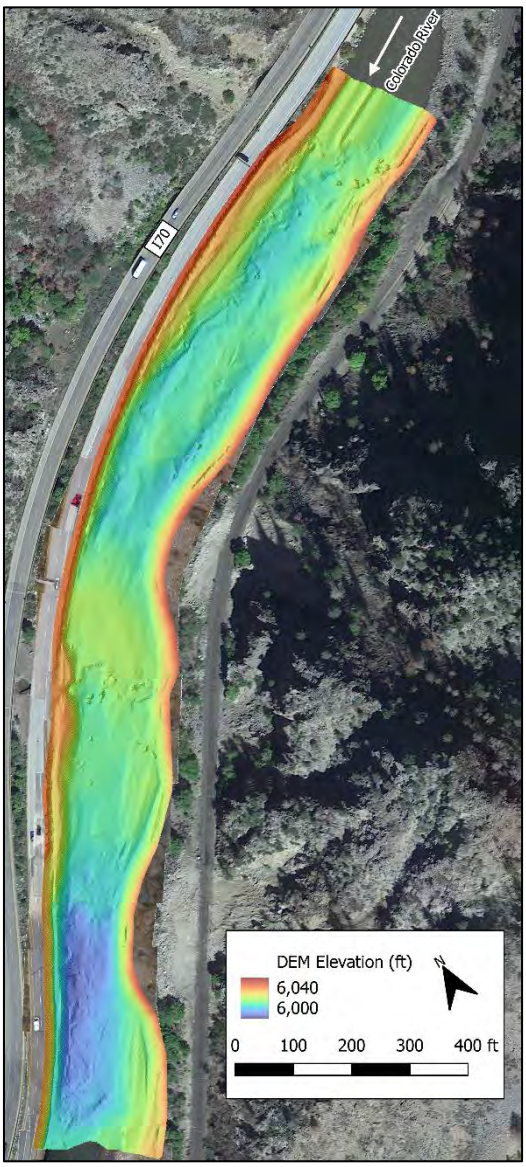

Figure 1. Glenwood Canyon model domain DEM

2. MODELING METHODOLOGY

2.1. Model Overview

Hydrographic survey data (see Glenwood Canyon Survey Report) was used to develop a DEM for the study reach. Point elevations and breaklines were used to characterize bed features like pools, rapids, and individual boulder features. This DEM is available in a geotiff format in the associated data appendices. This DEM was converted into an irregular 2D mesh with a cell sides targeted to a length of 4' within the channel using SMS software. Due to the SMS software interpolating an irregular mesh, a range of cell side lengths were modeled. Both three and 4 sided cells exist in the irregular grid, leading to a range in cell areas. These cells represent the elevations of the bed and provides calculations locations with discrete boundaries for a solver to calculate a depth-averaged result within. Depth-averaged two-dimensional velocity modeling simulates hydraulics in the streamwise and lateral directions, averaging values through the water column in the vertical. SRH-2D is a two-dimensional numerical model widely implemented for hydraulic applications and was used to simulate conditions within the project reach.

The SRH-2D model requires a spatially distributed friction element in addition to elevation for each cell. This can be provided in the form of a Manning's n value layer. For the model, we used spatially discrete Manning's n values based on the bed sediments observed during the survey. The final values for each area can be found in Figure 2, these values were adjusted within a reasonable range during the model calibration process, discussed below.

The upstream end of the 2D mesh was artificially extrapolated 100' upstream. This is visible in Figure 1 where the channel geometry appears stretched. The extra 100' was added to provide an area for the modeled inflow to non-uniformly distribute before entering the area of interest in the model domain. The extrapolated geometry was developed with the upstream cross section of survey data copied to the

upstream location and directly interpolated in between. Results provided from the modeling process used for the habitat analysis excluded all values in this extrapolated area.

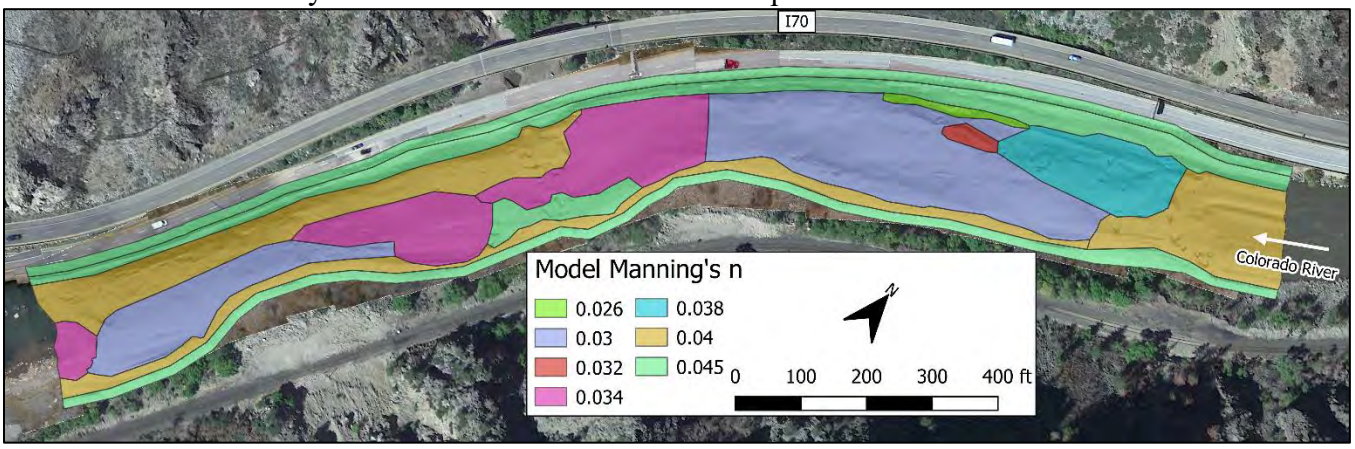

Figure 2. Final spatially distributed Manning's n values used in the SRH-2D hydraulic model

SRH-2D requires an upstream and downstream boundary condition. A steady flow rate was used as the upstream boundary condition for each different flow of interest and the model time was run until a steady state was achieved throughout the model domain. A constant water surface elevation (WSE) was used as the downstream boundary condition for each flow. The downstream boundary in the model domain was set at the crest of a rapid, where the flow exited the pool and passed through the critical state. A known water surface elevation was measured for the survey flow (1020 cfs) and used during the calibration process (discussed below). A 1D critical flow area equation (Eq. 1) based on the geometry of the downstream section of the model was used to calculate the water surface elevation boundary condition for each additional flow of interest. Flows of interest for this study were: 50 cfs, 250 cfs, 700 cfs, 1020 cfs (survey flow), 1250 cfs, 1400 cfs, and 3000 cfs.

Eq. 1 $$Q = \left(\frac{Area^3 * g}{Top\ Width}\right)^{1/2}$$

2.2.Model Calibration

The 2D hydraulic model was calibrated to WSE points captured during the survey flow of 1020 cfs. Calibration consisted of adjusting Manning's n values for different areas of the model within a reasonable range and adjusting the geometry of the DEM at observed control sections that were not sufficiently surveyed for bathymetric data. DEM adjustments were primarily focused on the grade controlling rapid in the middle of the survey area that impacted the large pool upstream and were a challenge to survey in great detail due to safety concerns in the field. The largest adjustment was made on the thalweg on the left side of the channel near the crest of each rapid, where conveyance needed to be increased to match the surveyed upstream water surface slope exiting the pool. After the calibration adjustments were made, the majority of the WSE calibration points were within +/- 0.2' of the model result (Figure 3), which is in line with the expected vertical accuracy of the survey. The majority of the outliers from this range, and the largest outliers, were in the steepest section of the rapid. Here, any given WSE in the model represents a smaller area of the channel. Additionally, less consistent WSE in rapids in the field decreases the accuracy of a given survey value. The large pools and areas of more gradually varying WSE slope all were well matched within the model. Mannings 'n' values were held consistent for all model runs between 50 cfs and 3,000 cfs based on the calibration at 1,020 cfs.

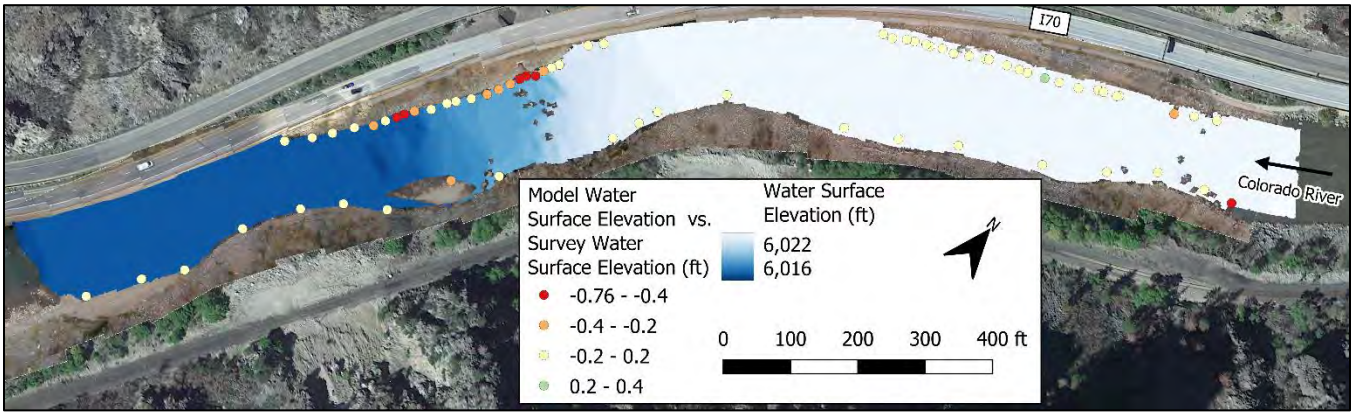

Figure 3. Model Calibration Results

3. RESULTS

3.1. Model Outputs

The model simulations were run until the flowrate into the model came to an equilibrium with the flow rate out of the model and was considered steady state. Results for each were then output for use in the habitat analysis. Results were sampled at the centroid location of each computation cell in the model 2D mesh (Figure 4). These cells represent areas ranging from less than 1 ft^2 to 70 ft^2, with the majority of the cells in the active channel between 5 ft^2 and 15 ft^2. Table 1 lists each of the hydraulic outputs that were sampled at the centroid of each cell.

Table 1. Model Outputs

Output	Unit
Cell Area	ft^2
Centroid X Coordinates	ft
Centroid Y Coordinates	ft
Bed Elevation	ft
Water Surface Elevation	ft
Water Depth	ft
Velocity in X direction	ft/s
Velocity in y direction	ft/s
Velocity Magnitude	ft/s
Froude Number	Dimensionless
Shear Stress	lb./ft^2

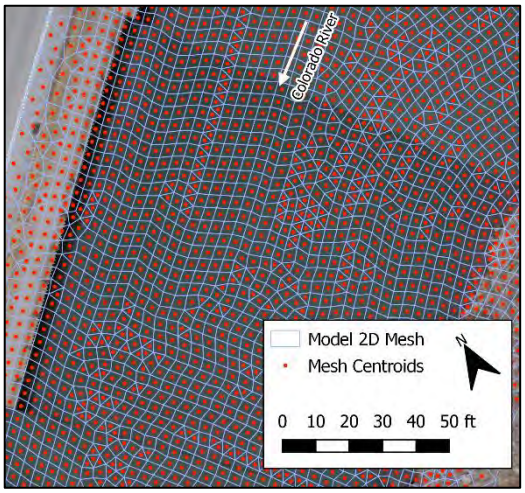

Figure 4. Glenwood Canyon model domain

3.2. Model Results Discussion

The model reach is bound on both sides by steep banks, including areas of vertical concrete in the highway embankment. Across the flow range evaluated the wetted flow area increased 23%. The largest changes in flow area occur around shallow areas of sand deposits near the up and downstream ends of the model as well as in some of the shallow cobble areas of the riffle in the middle of the model. The flow generally increases in velocity and depth as discharge increases (Figure 5). At the lowest modeled flow of 50 cfs

some unwetted areas emerge at the top of the rapid grade control that are larger than just single elevated boulders. At such extreme low flows, it may be reasonable to assume that some of the control section flow would be hyporheic flow between the large bed materials and infiltrate subsurface. The model also represents areas where the channel geometry is overhung by a suspended concrete bike path on the right bank in both pools. The modeled WSE in these areas remains several feet below the path elevations at the highest flow modeled for this analysis, 3000 cfs, but field observations have shown that extreme high flows in the river can reach these vertical obstructions, limiting the applicability of this model to flow levels less than or equal to 3,000 cfs.

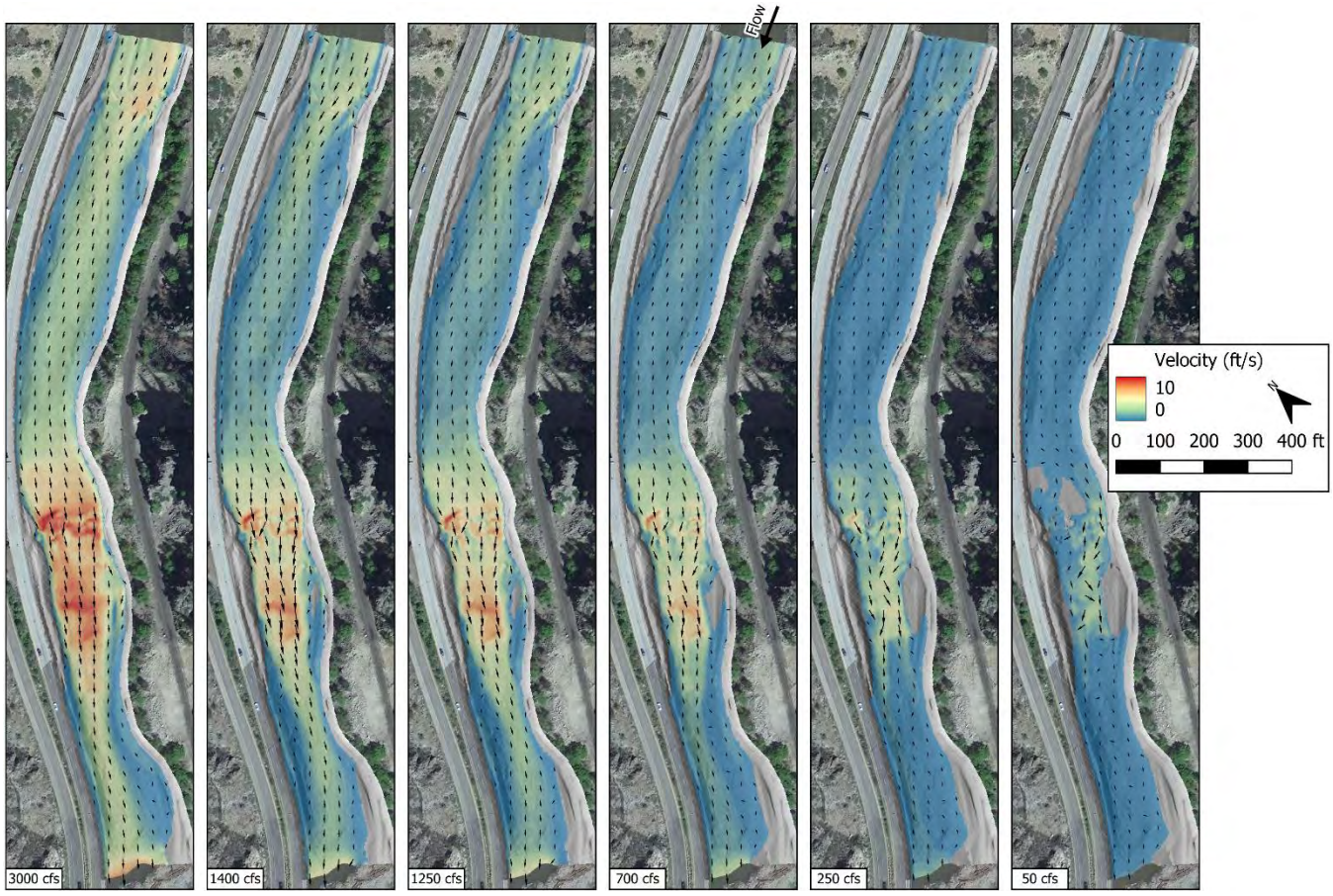

Figure 5. Model results showing velocity at the flows of interest

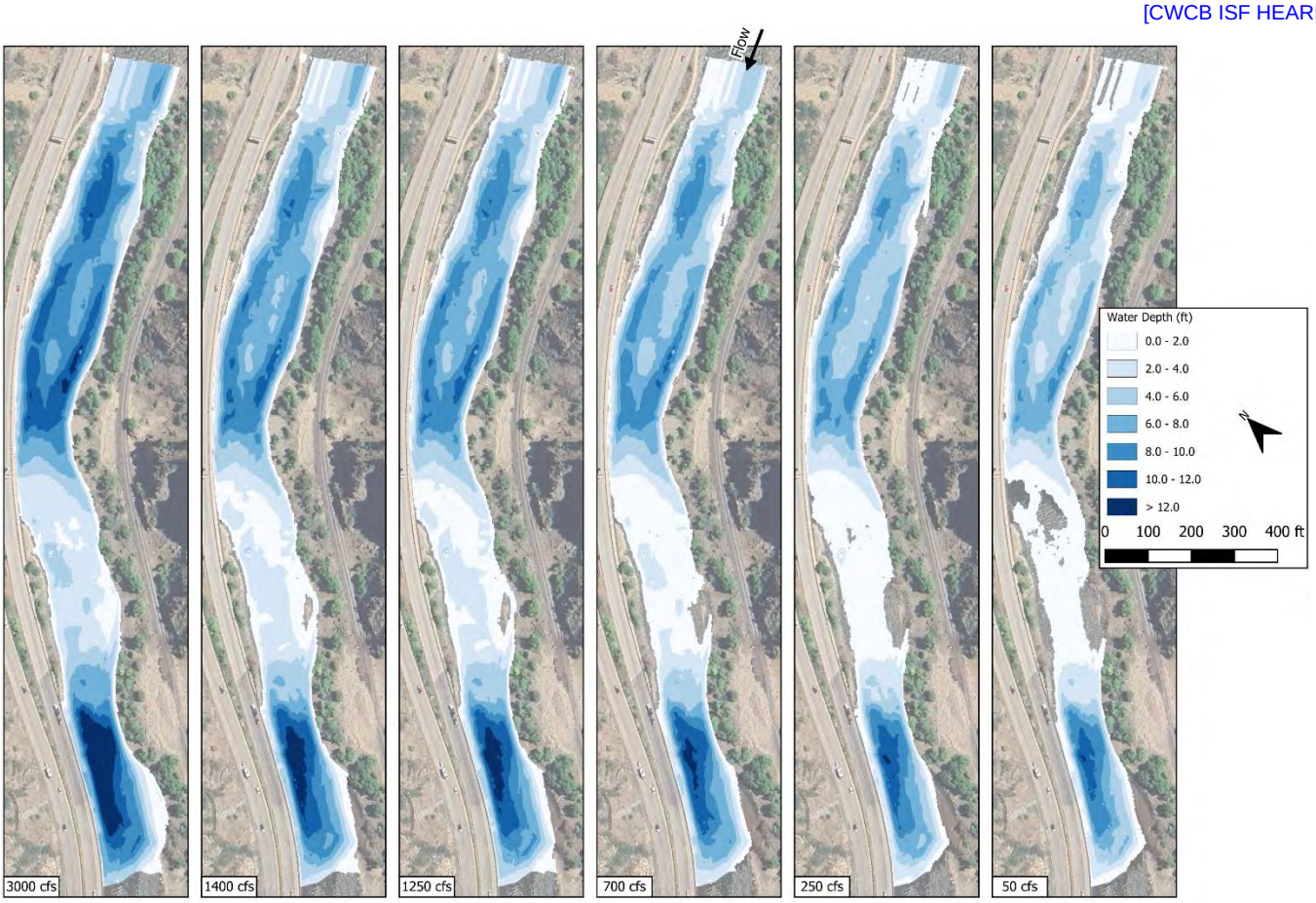

Figure 6. Model results showing depth at the flows of interest

4. SUMMARY

This report explains how survey data collected in Glenwood Canyon were used to create a calibrated 2D hydraulic model. This model was then used to predict hydraulic conditions of the study reach at a range of flows of interest to aquatic habitat at a resolution of approximately 4 ft x 4 ft. The model may have limitations at resolutions less than 4 feet length scale or at flows less than 50 cfs or greater than 3,000 cfs. Results available in the included data appendices can be used in an analysis of the available habitat within the study reach at the specified study flows.

GLENWOOD CANYON AQUATIC HABITAT STUDY
COLORADO RIVER, COLORADO

HYDROGRAPHIC SURVEY REPORT – 2023

PREPARED BY RIVERRESTORATION.ORG, DECEMBER 2023

Corresponding authors: Jason Carey, PE – Project Manager – jason.carey@riverrestoration.org
Russell Bair, PE – River Engineer; russell.bair@riverrestoration.org

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1. INTRODUCTION AND SURVEY METHODS

A hydrographic survey covering 1854 feet of the Colorado River in Glenwood Canyon was conducted on November 6th and 8th, 2023. The survey extent encompassed two pool sections divided by a boulder/cobble rapid and bounded by a rapid on the downstream end. Survey was conducted in the channel up the ordinary high water mark (OHWM) evident in the field. A combination of wading and boat-based survey was used to cover the areas of various depths and velocities (Figure 1). The survey was performed using a combination of RTK GNSS, Single Beam Echo Sounder (SBES), and total station. The survey was conducted using the NAD83 State Plane Colorado Central coordinate reference system (CRS) in US survey feet, vertical datum of NAVD88, and using the CONUS18 geoid model. Survey control was based on points provided by CDOT and tied in local control monuments via GNSS observations. Instruments utilized included Trimble R780 and R10 GNSS units, a boat mounted Ohmex SonarMite SBES, and a Trimble 5603 DR 200+ total station.

In addition to the bathymetric survey, the bed material was characterized at each topographic survey point throughout the survey reach and high-resolution ortho imagery was captured from 100’ and 200’ AGL throughout the reach.

Figure 1. Survey Area Overview Map

Figure 2. Survey Methods. GNSS rover (left) and boat mounted GNSS integrated SBES (right)

2. SURVEY CONTROL

The survey was based on control provided by CDOT for monuments recovered in the vicinity of the Hanging Lake rest area. Two control monuments were utilized with the coordinates provided in Table 1; Point 2528 was held as the location of the RTK GNSS base station during both days of the survey and point 2541 was used to check the initial base set up with RTK GNSS rovers. Eight additional control monuments were found and tied into the control network using 180 second RTK GNSS observations. These monuments were on the bike path that paralleled the survey reach and consisted of brass survey markers and "X" marks scrawled in the concrete placed by CDOT. These monuments were used for internal survey checks and as the basis for a total station set up and backsight but coordinates in Table 1 should not be considered survey control quality based on the limited GNSS constellation observed at the bottom of the Glenwood Canyon. Single beam sonar sound speed was adjusted in the field to match stadia rod depth measurements and integrated with either a total station prism or a RTK GNSS rover at different times to measure locations.

Table 1. Control Point information. NAD83 State Planes Colorado Central US Survey Feet, NAVD88, Geoid CONUS18. Coordinates are based on RTK GNSS survey holding 2528 and should not be considered survey control quality for future surveys.

Source	Point	Northing	Easting	Elevation	Description
CDOT	2528	1643610.52	2523096.51	6125.178	CDOT 1075--Type 5S IN CONC BIKE PATH
CDOT	2541	1644023.31	2523811.81	6117.827	CDOT 1075--Type 5S IN CONC BIKE PATH
GPS est.	193	1640379.889	2519661.18	6023.026	Brass Marker PT 193
GPS est.	194	1640815.124	2519923.869	6027.73	Brass Marker PT 194
GPS est.	195	1641175.599	2520304.564	6026.45	Brass Marker PT 195
GPS est.	196	1641401.255	2520778.948	6029.373	Brass Marker PT 196
GPS est.	300	1641308.444	2520530.666	6027.274	Concrete Scrawl X
GPS est.	301	1641008.418	2520098.404	6027.054	Concrete Scrawl X
GPS est.	302	1640601.825	2519781.121	6024.546	Concrete Scrawl X
GPS est.	303	1640170.93	2519540.383	6022.625	Concrete Scrawl X

3. SURVEY CONDITIONS

Site survey took place on November 6th and 8th, 2023. November 6th conditions were cold and clear while on November 8th, scattered snow showers fell throughout the day. The project reach is located approximately 8.5 miles downstream of USGS stream gage 09070500 on the Colorado River near Dotsero, CO. Shoshone Power Plant was shut down during survey and no diversions were expected between the gage and the site during data collection efforts. There are no major inflows between the project reach and gage, so the gage is assumed to well represent the project reach flows. Figure 3 shows the range of flows during the survey, as well as the slightly lower flows during the acquisition of aerial imagery.

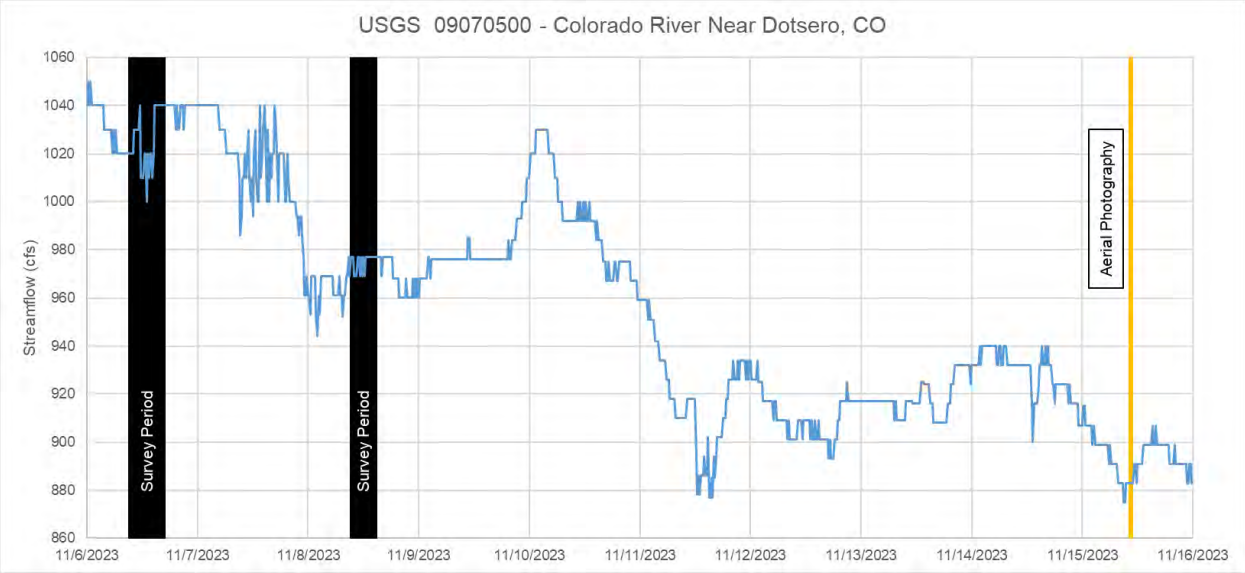


Figure 3. Discharge of Colorado River near Dotsero, Colorado (USGS Gage 09070500) during survey and data aquisition

4. SURVEY RESULTS AND OBSERVATIONS

The survey reach was selected to represent hydraulic characteristics present in the pool/rapid Glenwood Canyon reach of the Colorado River. The survey included two pools divided by one cobble/boulder rapid and was bounded by rapids on the upstream and downstream ends. The rapids generally comprised of large colluvial, and mud and debris flow materials supplied to the main channel from tributaries. Bathymetric and topographic data points were collected to represent bed elevations throughout the survey reach. Information on bed materials including sediment classes and vegetation types were recorded with the points. Areas with depositional sediments and signs of recent maximum high water levels were also recorded, as were water surface elevations (WSE) throughout the reach for the survey flow. There were areas within the survey extent where water was too deep and swift to safely survey on foot or via boat, particularly in some areas around the rapid in the middle of the project reach. Survey was completed to allow for the most accurate interpolation possible in these areas. Additionally, aerial ortho-imagery was collected to help locate larger topographic features such as mid channel boulders.

Survey observations revealed that the bed material varied throughout the study reach. Longitudinal and lateral influences impacted the bed composition. Higher up elevations near the OHWM on each bank consisted of mechanically placed riprap rock materials supporting the highway on river right and railroad on river left (Figure 5). A substantial portion of the river right bank was a vertical concrete wall under a cantilevered bike path with riprap along the right toe (Figure 5). The midchannel consisted of areas of

boulder and large cobbles on the outside of the bend and through the rapids, and large areas of sand deposition on the inside of bends in the pools. Depositional sand included areas of transporting sand over boulders in the upstream pool and also large areas of sand dunes in each pool. A large sandy beach deposit was observed on the inside river left side of the downstream pool. The rapid in the middle of the survey reach and the rapid at the downstream end both consist of large cobble and boulder material (Figure 5) that was delivered from steep tributaries that were impacted by the Grizzly Creek Fire in 2020 and the subsequent debris flows during heavy rain in 2021. The crests of these rapids act as grade controls controlling the water surface elevation of the pools immediately upstream. Sand deposits transition to a lens of alluvially transported large cobble material on the upstream approach of each rapid crest. These cobble materials acted as the hydraulic grade control of each pool at the survey flow. Larger boulders deposited by the tributaries define the main drop in WSE across the rapids. A matrix of small boulders and large cobbles surround the largest boulders with minimal areas of finer depositional material through the rapids until the hydraulic gradient reaches the next pool elevation controlled by the downstream rapid crest and the flow slows. Figure 4 shows the different substrate areas that were identified during the survey overlaid on the final digital elevation model that was created.

Riprap banks throughout the reach were not densely vegetated, but a variety of riparian plant species including willows and cottonwoods were scattered on the banks in pockets around boulders and riprap. Willows, grasses, shrubs, and smaller trees dominated the right bank, while the left bank had more mature cottonwoods.

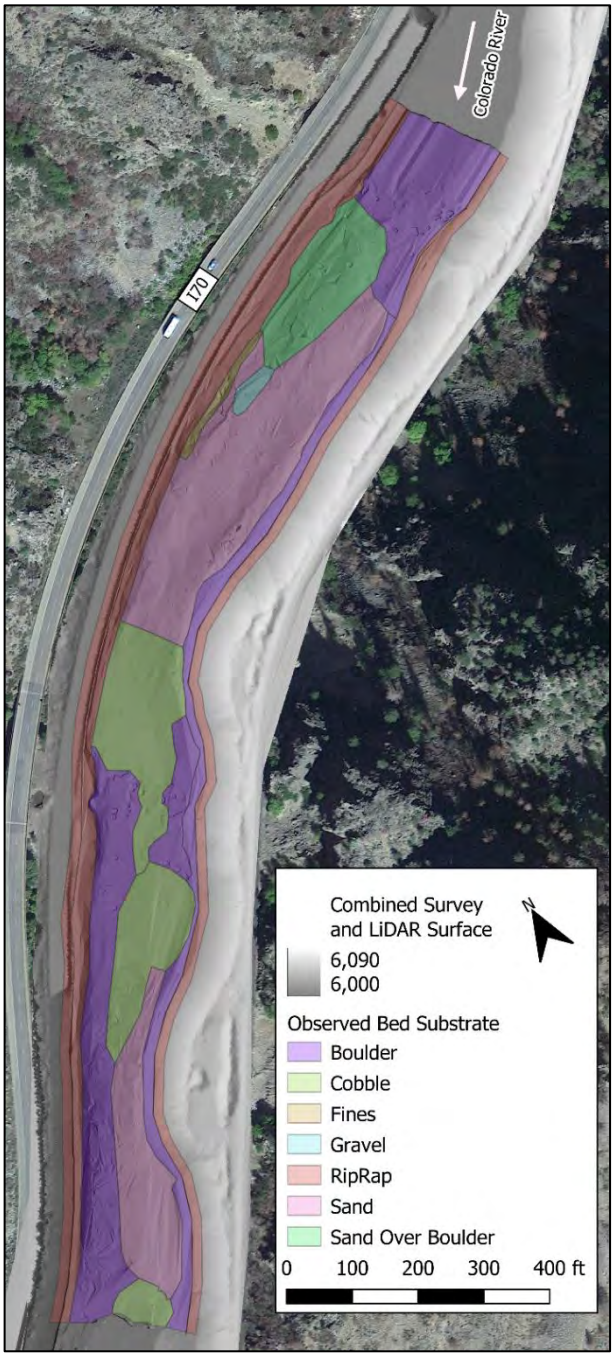


Figure 4. Substrate Areas and DEM

Figure 5. (Left) Looking downstream from the right bank at the rapid in the middle of the survey area. (Right) Aerial oblique drone photo looking downstream from near the upstream end of the survey area. The riprap and concrete nature of the banks can be seen.

5. BASE MAP AND DEM DEVELOPMENT

Survey data were post-processed to remove potential spurious data, mostly in the form of inaccurate SBES depth readings. Interpolation of some topographic data was required in areas that were unsafe to survey, but this was expected from the outset, and the majority of the survey extent was covered by on the ground field survey. A digital elevation model (DEM) was created for the entire surveyed project reach using a triangular irregular network (TIN) to connect surveyed points along with breaklines to represent the existing conditions in the field. Additional breaklines were included to represent boulder clusters and pour overs in rapids based on the collected aerial ortho-images. Elevations for some of these features had to be estimated based on nearby similar elevation features that were surveyed or nearby water surface elevations.

Field survey only took place up to the OHWM. For areas above this elevation, LiDAR data was added to the DEM. This LiDAR DEM data is publicly available data collected on flights in June of 2016 for the Colorado Water Conservation Board (https://coloradohazardmapping.com/lidarDownload). The data is formatted as a geotiff with 3 ft resolution. The LiDAR survey was carried out in the same coordinate reference system as this ground based survey; State Plane Colo. Central, NAD83, NAVD88. The LiDAR survey used the 12B geoid model as opposed to the more recent CONUS18 geoid model, but in the area of interest, this difference is not expected to have an impact. The LiDAR data inserted was well aligned with the surveyed ground elevations and required minimal editing of the DEM to mesh to two surfaces. Because the ground survey went to the elevation of the OHWM, the LiDAR based data inserted at elevations higher than this are not expected to have a meaningful impact on the flow levels of interest for this project.

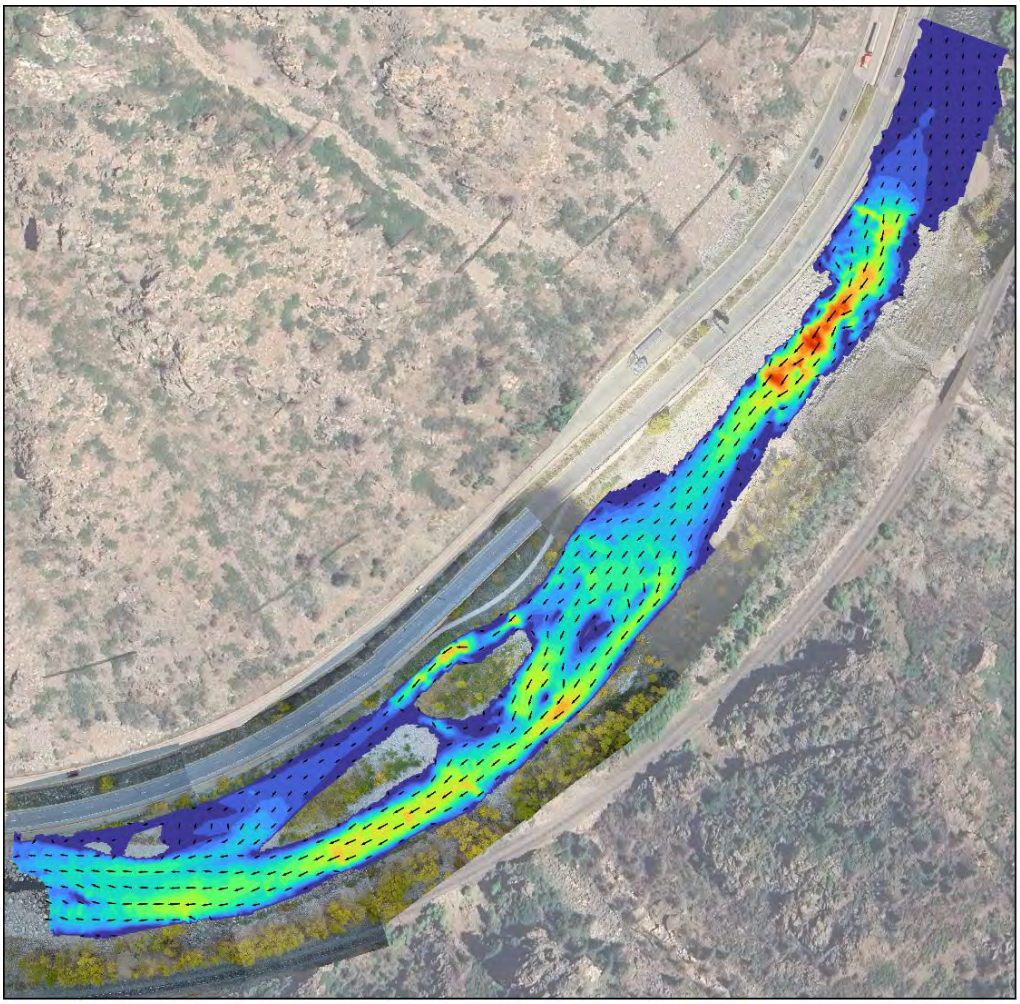
A continuous bathymetric and topographic DEM surface was created using these data described above. This DEM was used in hydraulic modeling efforts, discussed in the Hydraulic Modeling Report.

6. SUMMARY

This survey was successful in collecting sufficient data to develop a detailed DEM of the study reach in Glenwood Canyon. The DEM developed from this survey and the bed material observations were used to model 2D river hydraulics, which is described in the Hydraulic Modeling Report. The data collection described in this report was sufficient for modeling 2D river hydraulics at, or finer than the target resolution for the habitat analysis which was specified as a 25 sqft computational cell size area.

GLENWOOD CANYON AQUATIC HABITAT STUDY
COLORADO RIVER, COLORADO

HYDRAULIC MODELING REPORT – 2024



PREPARED BY RIVERRESTORATION.ORG, JANUARY 2025

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1. INTRODUCTION

A 2 dimensional (2D) hydrodynamic model was used to simulate a variety of low flow conditions for a study reach on the Colorado River in Glenwood Canyon. The model was based on a digital elevation model (DEM) developed from hydrographic survey data collected over an 1,830 foot reach (Figure 1). The goal was to provide spatially discrete data of water depth, velocity, shear stress, and a Froude value for use in a usable habitat analysis.

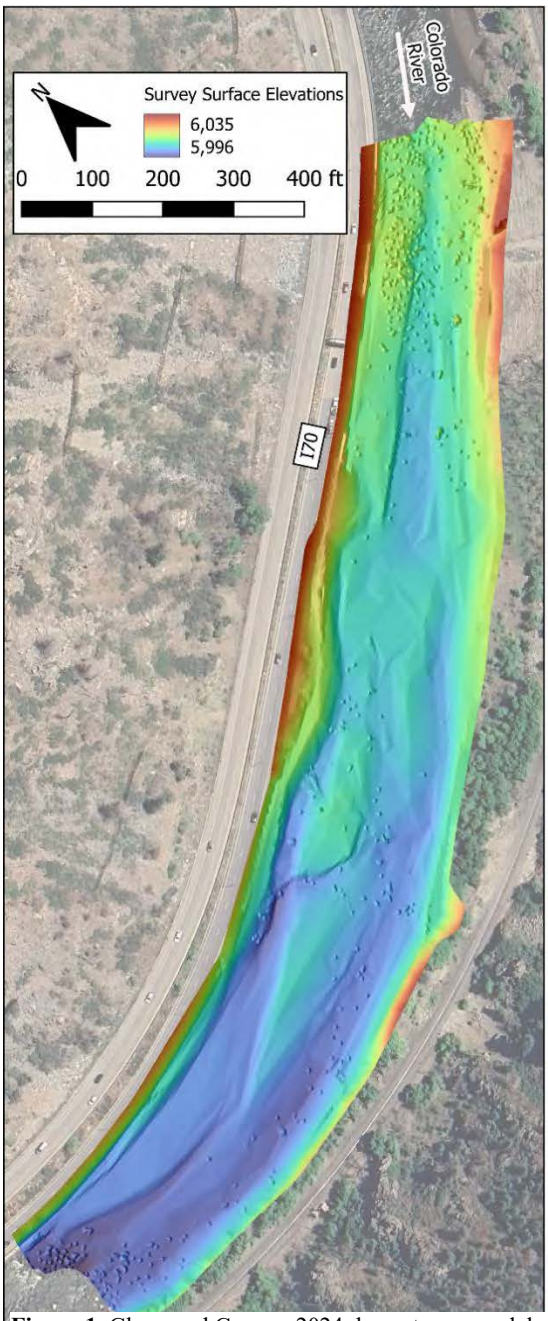

Figure 1. Glenwood Canyon 2024 downstream model domain DEM

2. MODELING METHODOLOGY

Hydrographic survey data (see Glenwood Canyon Survey Report 2024) was used to develop a DEM for the study reach. Point elevations and breaklines were used to characterize bed features like pools, rapids, and individual boulder features. This DEM is available in a geotiff format in the associated data appendices. This DEM was converted into an irregular 2D mesh with a cell sides targeted to a length of 4 feet within the channel using Aquaveo SMS software (Aquaveo, 2015). Due to the SMS software interpolating an irregular mesh, a range of cell side lengths were modeled. Both three and 4 sided cells exist in the irregular grid, leading to a range in cell areas. These cells represent the elevations of the bed and provide calculations locations with discrete boundaries for a solver to calculate a depth-averaged result within. Depth-averaged two-dimensional velocity modeling simulates hydraulics in the streamwise and lateral directions, averaging values through the water column. SRH-2D is a two-dimensional numerical model widely implemented for hydraulic applications and was used here to simulate hydraulic conditions within the project reach (Lai, Yong G. 2009, US Bureau of Reclamation Technical Service Center 2014).

The SRH-2D model requires a spatially distributed friction element in addition to elevation for each cell. This can be provided in the form of a Manning's n value layer. For the model, we used spatially discrete Manning's n values based on the bed sediments observed during the survey. The final values for each area can be found in Figure 2, these values were adjusted within a reasonable range during the model calibration process, discussed below.

In 2023 RiverRestoration completed a modeling effort an 1854 ft reach immediately upstream of the study reach discussed here. The upstream reach represents a deeper pool section of the river. The two reaches combined represent the diverse channel features present in Glenwood Canyon. In the 2023 upstream model, the upper end of the model was artificially extrapolated to allow for the model to non-uniformly distribute flow outside of the area of interest where results were reported. Similarly in the

model presented here the upstream end of the 2D mesh included 300' of bathymetry that was the downstream end of the model created in 2023 (RiverRestoration 2023). This 300' was modeled to provide an area for the inflow to non-uniformly distribute before entering the area of interest in the 2024 model domain. Results and figures provided from the modeling process used for the habitat analysis in 2024 excluded all values in the 300' upstream end.

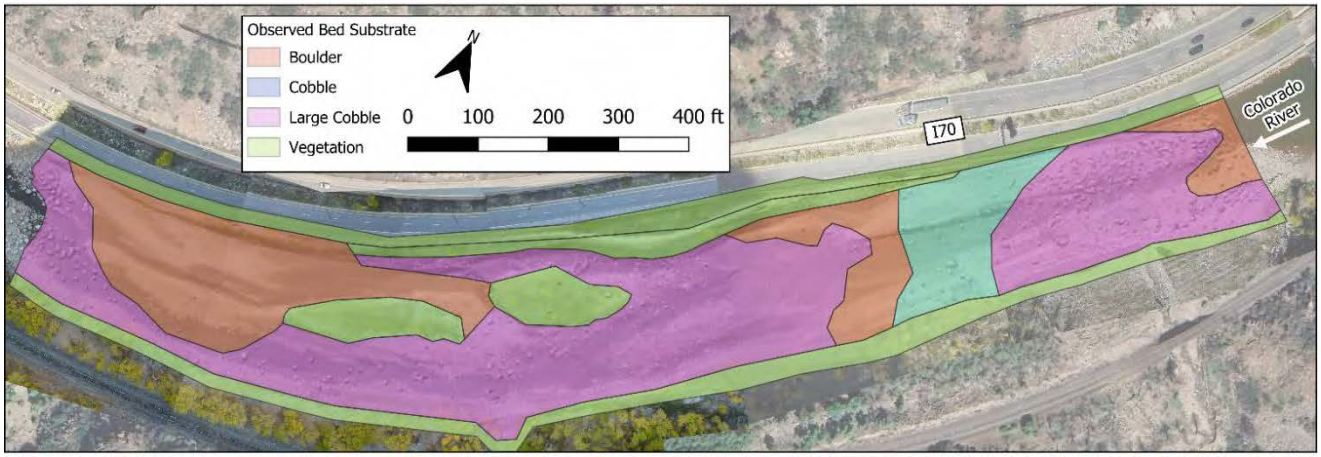

Figure 2. Final spatially distributed Manning's n values used in the SRH-2D hydraulic model.

SRH-2D requires an upstream and downstream boundary condition. A steady flow rate was used as the upstream boundary condition for each different flow of interest and the model time was run until a steady state was achieved throughout the model domain. A constant water surface elevation (WSE) was used as the downstream boundary condition for each flow rate.

The downstream boundary in the model was set near the crest of the next rapid downstream. However, there did not appear as defined of a grade break as the previous upstream model utilized and near zero flow during and after site survey made locating a critical flow cross section subjective. A 1D flow equation was used to solve for a WSE at each flow of interest. Both a critical flow area and Manning's equations were considered. Based on the downstream boundary's position in the river that did not appear to have a sharp drop or constriction of flow and the low elevation values that a critical flow area equation produced, it was determined that Manning's Equation (Eq.1) would better represent the boundary WSE at different flows. Area (A) and hydraulic radius (R) were solved by changing WSE for the selected cross-section. A bed slope (S) value of 0.0074 was used from survey data. An n value of 0.034 was selected. This value is in line with standard values and was calculated by using the Manning's equation on a cross section near the upstream end of the study reach similar in character to the downstream boundary where a known WSE for a flow of 1020 cfs was surveyed in 2023.

Eq. 1 $$Q = \frac{1.486}{n} * AR^{2/3} * \sqrt{S}$$

Flows of interest for this study were: 50 cfs, 250 cfs, 700 cfs, 1020 cfs, 1250 cfs, 1400 cfs, 1500cfs, 1750 cfs, 2000 cfs, 2250 cfs, 2500 cfs, and 3000 cfs.

Flows remained near zero between the time of survey and the time of reporting, meaning that the collection of high flow calibration WSE data was not available. Due to this lack of available calibration data, several modeling assumptions were made based on results from the 2023 modeling efforts of the immediate upstream reach, which had 2023 calibration data available and examined the same range of flows using the same baseline resolution for calculations. A one second time step was used for model

calculation. The ke turbulence model was used within the SRH-2D. A small number of WSE calibration points for flows of 1020 cfs and 3250 cfs were available at the upstream end of the model, though these were mostly in the pool section that was excluded from the results since it was included in the domain of previous model reporting from 2023 (RiverRestoration, 2023). These available data were used to make minor adjustments to the upstream end of the DEM and to adjust spatially discrete Manning's n values, however their applicability may be limited due to the 2024 runoff occurring between the WSE measurement and the bed survey used to develop the model. Unknown channel changes may have occurred during 2024 runoff. Adjustments resulted in WSE values that matched to within -0.2' of the observed WSE at 1020 cfs at the upstream end of the reach. Manning's n values within the model were set to correspond with the observed bed sediment areas in Figure 2. Table 1 shows the final Manning's n values. Mannings n values were held consistent for all model runs between 50 cfs and 3,000 cfs.

Table 1. Model Manning's n region values

Observed bed material	Manning's n value assigned
Boulder	0.042
Large Cobble	0.041
Cobble	0.040
Vegetation	0.045

The 2024 reach represents more of a consistent riffle character with smaller pool areas around specific bathymetric grade controls, compared to the upstream 2023 reach. As such, inaccuracies or a lack of resolution in areas of the DEM that will control WSE, or pool levels, are much less likely to propagate through a large area of the model. Additionally, the near zero flow level during survey meant that the topography of the lowest sections of the channel as well the rapidly varying elevations associated with large boulders and the islands could be more accurately and completely captured resulting in a more detailed DEM in 2024.

3. RESULTS

3.1. Model Outputs

The model simulations were run until the flowrate into the model came to an equilibrium with the flow rate out of the model and was considered steady state. Results for each simulation were gridded (rasterized) for use in the habitat analysis. SRH2D integrates the governing equations spatially providing a continuously spatially variable result which was then sampled to a selected 0.25 ft X 0.25 ft resolution raster grid containing 7 data bands for each flow modeled. Table 2 shows the data reported in each data band.

Table 2. Model Result Output Raster Data Bands

Parameter	Unit
Froude Number	Dimensionless
Shear Stress	lb./ft^2
Velocity Magnitude	ft/s
Water Depth	ft
Water Surface Elevation	ft
Velocity in X direction	ft/s
Velocity in y direction	ft/s

3.2.Model Results Discussion

The model reach is bound on both sides by steep banks, including vertical concrete in the highway embankment at the upstream end, a steep railroad embankment on the entire left side, and riprap embankment below the pedestrian path on the right. The flows in the range modeled do not breach any of these higher infrastructure elevations. The model also represents areas where the channel geometry is overhung by a suspended concrete bike path on the right upper right bank. The modeled WSE in these areas remains several feet below the path elevations at the highest flow modeled for this analysis, 3000 cfs, but field observations have shown that snow melt runoff high flows in the river can reach these vertical obstructions, limiting the applicability of this model to flow levels less than or equal to 3,000 cfs.

Within the channel, varying channel elements like boulders, bars and islands lead to changes in the wetted area as flows increase. Across the flow range evaluated, the wetted flow area increased 100%. The largest changes took place in the downstream half of the reach were large depositional bars including the lower, unvegetated, areas of the island bar inundated. Much of this inundation occurred by 1500 cfs with flows growing deeper afterwards. At all flows, the highest velocities and most concentrated flow was found in the upstream rapid. The flow generally increases in velocity and depth as discharge increases (Figure 3 and 4). Depths within the study reach are generally shallower than the results from the upstream reach pools modeled in 2023. Additionally, the deepest areas also are found in the channel thalweg and also have high relative velocities, with the narrow, deep pool on the inside of the island the outlier to this trend.

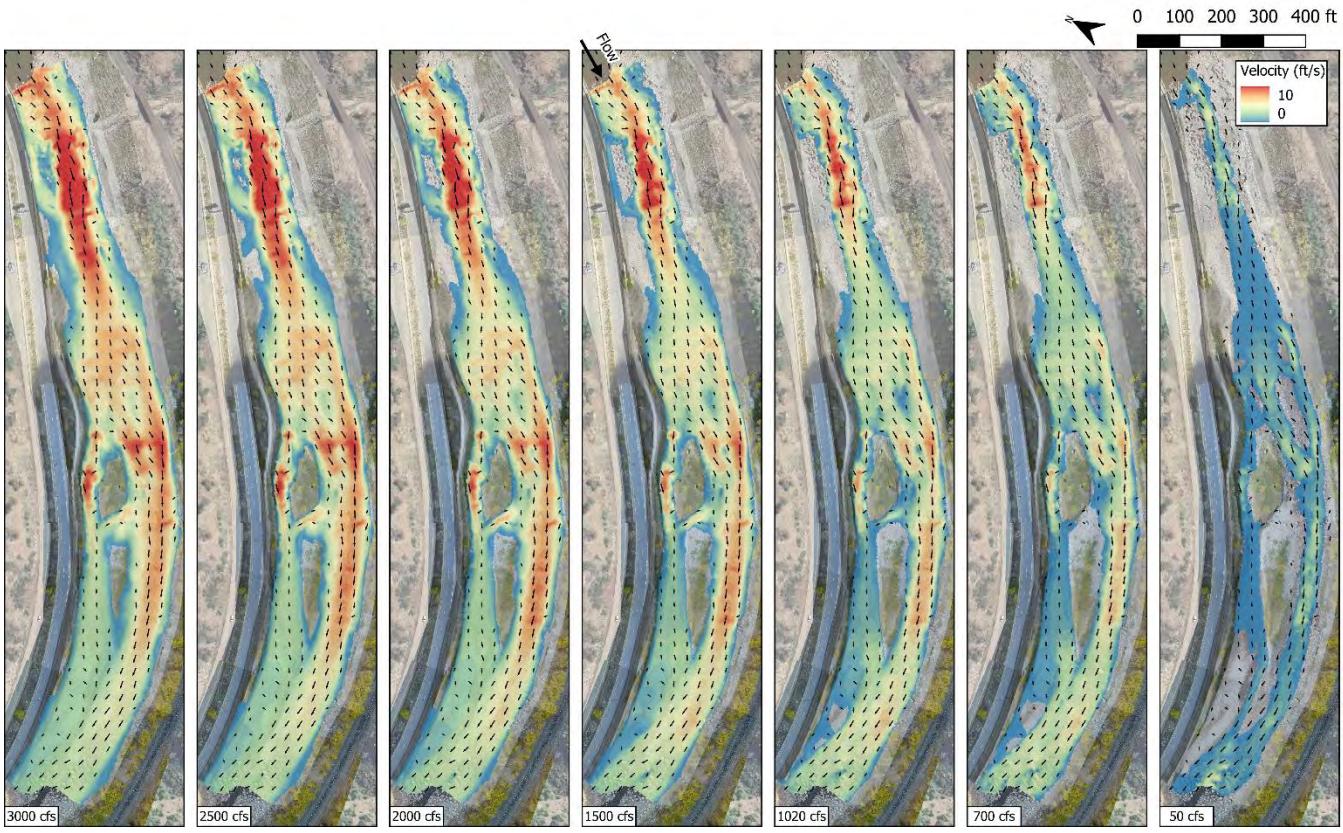

Figure 3. Model results showing velocity at a selection of the flows of interest

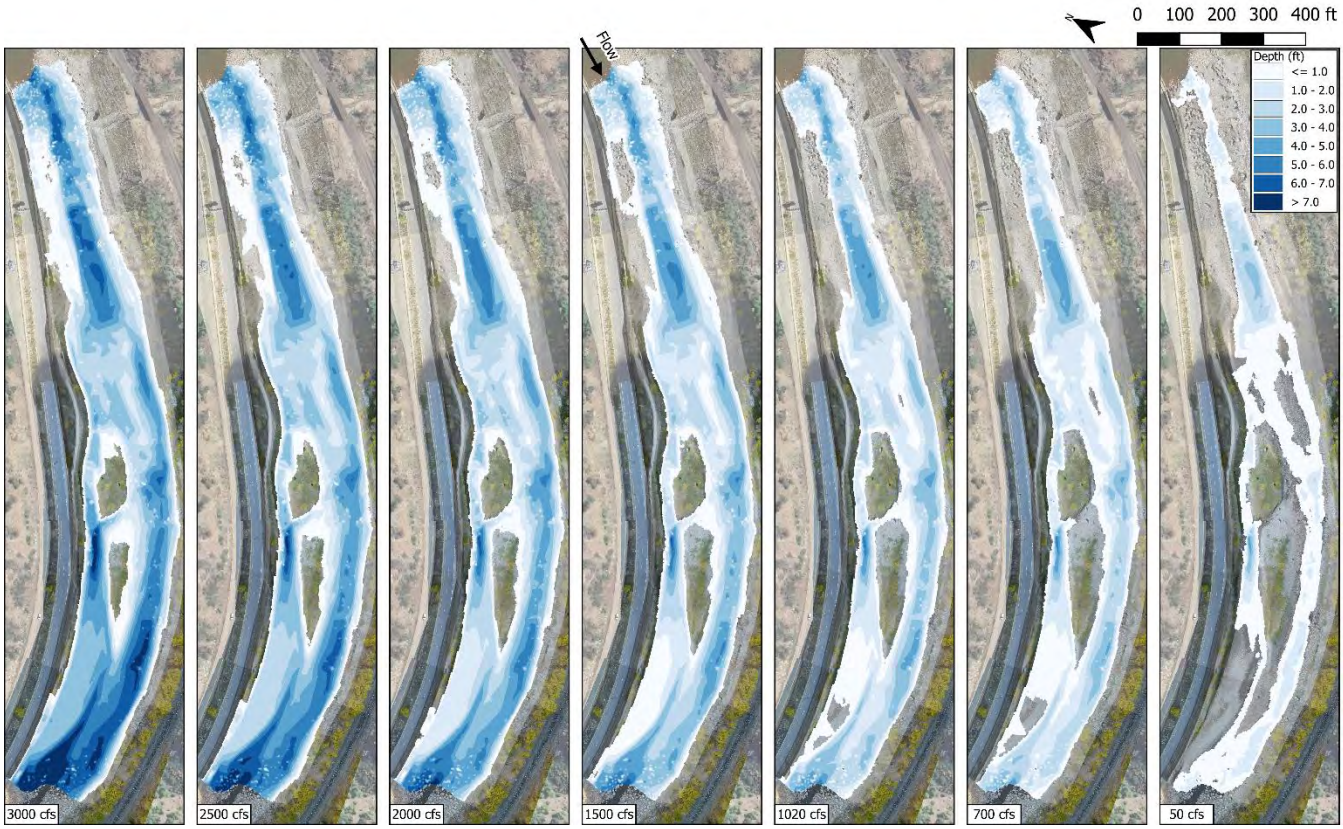

Figure 4. Model results showing depth at a selection of the flows of interest

4. SUMMARY

This report explains how survey data collected in Glenwood Canyon were used to create a 2D hydraulic model. This model was then used to predict hydraulic conditions of the study reach at a range of flows of interest to aquatic habitat at a resolution of approximately 4 ft x 4 ft. The model may have limitations at resolutions less than 4 feet length scale or at flows less than 50 cfs or greater than 3,000 cfs. Results available in the included data appendices can be used in an analysis of the available habitat within the study reach at the specified study flows.

5. REFERENCES

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US Bureau of Reclamation Technical Service Center (2014), *SRH-2D Version 3.0 Sedimentation and River Hydraulics 2D model with Mobile-Bed and Sediment Transport Module*, May 2014

GLENWOOD CANYON AQUATIC HABITAT STUDY
COLORADO RIVER, COLORADO

HYDROGRAPHIC SURVEY REPORT – 2024

PREPARED BY RIVERRESTORATION.ORG, JANUARY 2025

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1. INTRODUCTION AND SURVEY METHODS

A hydrographic survey covering 1830 feet of the Colorado River in Glenwood Canyon was conducted on October 15th and 16th. The survey extent encompassed a boulder/cobble rapid at the upstream end and a pool/riffle/island complex at the downstream end. The upstream end of the survey began at the boulder/cobble rapid of the Devil's Hole Creek confluence, where the previous survey in 2023 ended. The 2023 survey represented a reach characterized by larger pools separated by a defined rapid. Together the 2023 and 2024 reaches represent the diverse types of channel forms found in the Shoshone reach. The survey ended at the beginning of the downstream boulder/cobble rapid of an unnamed gulley confluence. Survey was conducted in the channel up to the ordinary high water mark (OHWM) evident in the field. The survey was performed on foot as there was only minimal flow in the river at the time of survey (Figure 1). The survey was performed using RTK GNSS (Figure 2). The survey was conducted using the NAD83 State Plane Colorado Central coordinate reference system (CRS) in US survey feet, vertical datum of NAVD88, and using the CONUS18 geoid model. Survey control was based on points provided by CDOT and tied in local control monuments via GNSS observations. Instruments utilized included Trimble R12i (rovers) and R10 (base) GNSS units. The base point held during the entire survey was CDOT Point 2528 in Figure 1 and Table 1.

In addition to the bathymetric survey, the bed material was characterized at each topographic survey point throughout the survey reach and high-resolution ortho imagery was captured from 200' and 400' AGL throughout the reach.

Figure 1. 2024 Survey Area Overview Map with low water aerial imagery

2. SURVEY CONTROL

The survey was based on control provided by CDOT for monuments recovered in the vicinity of the Hanging Lake rest area. Two control monuments were utilized with the coordinates provided in Table 1; Point 2528 was held as the location of the RTK GNSS base station during both days of the survey and point 2541 was used to check the initial base set up with RTK GNSS rovers. In November 2023, eight additional control monuments were found and tied into the control network using 180 second RTK GNSS observations. These monuments were on the bike path that paralleled the survey reach and consisted of brass survey markers and "X" marks scrawled in the concrete placed by CDOT. These monuments were used for internal survey checks but coordinates in Table 1 should not be considered survey control quality based on the limited GNSS constellation observed at the bottom of the Glenwood Canyon.

Figure 2. Survey Control Overview Map

Table 1. Control Point information. NAD83 State Planes Colorado Central US Survey Feet, NAVD88, Geoid CONUS18. Coordinates are based on RTK GNSS survey in 2023 holding 2528 and should not be considered survey control quality for future surveys.

Source	Point	Northing	Easting	Elevation	Description
CDOT	2528	1643610.52	2523096.51	6125.178	CDOT 1075--Type 5S IN CONC BIKE PATH
CDOT	2541	1644023.31	2523811.81	6117.827	CDOT 1075--Type 5S IN CONC BIKE PATH
GPS est.	193	1640379.889	2519661.18	6023.026	Brass Marker PT 193
GPS est.	194	1640815.124	2519923.869	6027.73	Brass Marker PT 194
GPS est.	195	1641175.599	2520304.564	6026.45	Brass Marker PT 195
GPS est.	196	1641401.255	2520778.948	6029.373	Brass Marker PT 196
GPS est.	300	1641308.444	2520530.666	6027.274	Concrete Scrawl X
GPS est.	301	1641008.418	2520098.404	6027.054	Concrete Scrawl X
GPS est.	302	1640601.825	2519781.121	6024.546	Concrete Scrawl X
GPS est.	303	1640170.93	2519540.383	6022.625	Concrete Scrawl X

3. SURVEY CONDITIONS

Site survey took place on October 15th and 16th, 2024. Both days were generally mild and clear, with light passing showers. The project reach is located approximately 9 miles downstream of USGS stream gage 09070500 on the Colorado River near Dotsero, CO. During the survey the gage was near 1,200 cfs, however the Shoshone Power Plant was diverting the entire river flow around the project reach. A small amount of flow leaks at the dam cutoff in addition to minor inflow trickles downstream of the dam, meaning there is still a small amount of water in the survey reach. This flow was assumed to be below 10 cfs, but did lead to some deep pool areas remaining.

4. SURVEY RESULTS AND OBSERVATIONS

The survey reach was selected to represent hydraulic characteristics present in the pool/rapid Glenwood Canyon reach of the Colorado River. The survey included one boulder/cobble rapid at the upstream end and an extended riffle/island/pool complex for the majority of the reach. The upstream boundary was a pool included in the original survey and modeling efforts in 2023, and the downstream boundary was the top of the next boulder/cobble riffle going downstream. Bathymetric and topographic data points were collected to represent bed elevations throughout the survey reach (Figure 3). Information on bed materials including sediment classes and vegetation types were recorded with the points. Areas with depositional sediments and signs of recent maximum high water levels were also recorded, as were water surface elevations (WSE) throughout the reach for the extreme low survey flow. Aerial ortho-imagery was collected to help locate and quantify larger topographic features such as mid channel boulders during post processing.

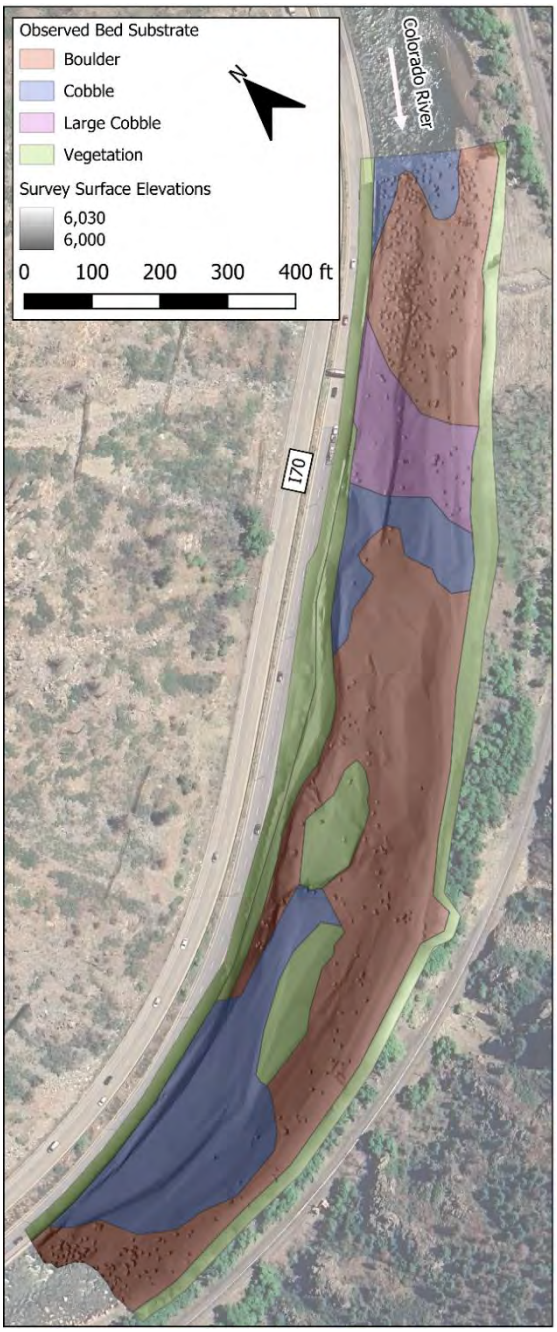


Figure 3. Observed Substrate Areas

The upstream rapid is generally comprised of large colluvial with dozens of boulders ranging from 2'-6' scattered over the top (Figure 4). Much of the material was likely deposited from post-burn flash floods debris flows out of Devil's Hole Creek on the south bank. Many boulders in the rapid were also likely mechanically placed and relocated as part of CDOT or railroad repair and protection efforts. Below the rapid, the bed slope decreases and the remaining reach is dominated by two vegetated islands (Figure 5) near the inside of the bend, a riffle on the outside of the bend, and deeper pools sheltered by the islands on the inside. The majority of the bed through this reach remains coarse and is best described as large cobbles or small boulders, with many larger boulders protruding throughout. Pockets of small material including gravels and sands were found throughout, but generally in proximity to larger boulder features or the islands (Figure 6).

The two islands exist as a part of the same midchannel bar that likely formed downstream of where the riprap right bank extends further into the channel forcing higher flows towards the left bank. The islands are separated by a low portion of the bar were only cobble and boulders are found without vegetation. The upstream island is roughly 2.5' higher in elevation and has more mature vegetation established including small trees, but the majority of the vegetation are mature willows and the downstream island is only willows and similar riparian shrubs. Both islands consist of the same coarse bed material of cobble and boulders, but the upstream island has more and larger boulders and appears more stable. The downstream island appears to be a part of the more dynamic portion of the larger cobble bar.

The left, outer, channel around the islands has more conveyance, and generally a more consistent bed slope at the time of survey. The right, inner, channel is smaller and at the time of survey had a series of beaver check dams (Figure 7) stepping down the water near the upstream island. The channel along the downstream island consists of a large pool that is controlled by a large cobble deposit near the tail of the island (Figure 8). It is anticipated that these areas may change to have more conveyance during the highest of flows. The downstream end of the survey reach is where the tail end of the mid channel cobble bar and inside cobble deposit transition to another steep boulder rapid consisting of material from a gully on the south side of the river that flashed and crossed the railroad tracks following recent wildfires. Some of this material was similarly mechanically moved and placed into the river.

Higher up elevations near the OHWM on each bank consisted of mechanically placed riprap rock materials supporting the pedestrian path and I70 on river right and railroad on river left. The upper 400 ft portion of the river right bank was a vertical concrete wall under a cantilevered bike path with riprap along the right toe.

Both banks were generally well vegetated despite their coarse riprap material, and a clear edge of vegetation boundary existed through most of the reach indicating periods of consistent flow levels through the reach. Deviations from the vegetated banks included the alluvial fan deposits of Devil's Hole Creek where only immature vegetation has established, the upper portion of the right bank where the cantilevered path exists, and the left bank near the downstream end of the reach where the channel is closer to the railroad tracks and the bank consists of steeper and looser material. Devil's Hole Creek tributary channel exhibited some incision which may be ongoing after the 2024 runoff.

Figure 4. Facing downstream at the boulder rapid at the upstream end of survey reach. Devil's Hole Creek enters from the left. The pool at the upstream end (bottom of the image) is where the survey effort ended in 2023.

Figure 5. Facing downstream at the two vegetated islands on the center channel cobble bar. The outside bend riffle is on the left and the beaver check dams and pool are on the right.

Figure 6. Examples of smaller material within the survey reach. Left - depositional sand on the large cobble bar at the downstream end of the reach. Right – Pocket of gravel and sand behind a large boulder in the outside channel riffle near the islands.

Figure 7. First in the series of small beaver check dams pooling water on the inside of the islands.

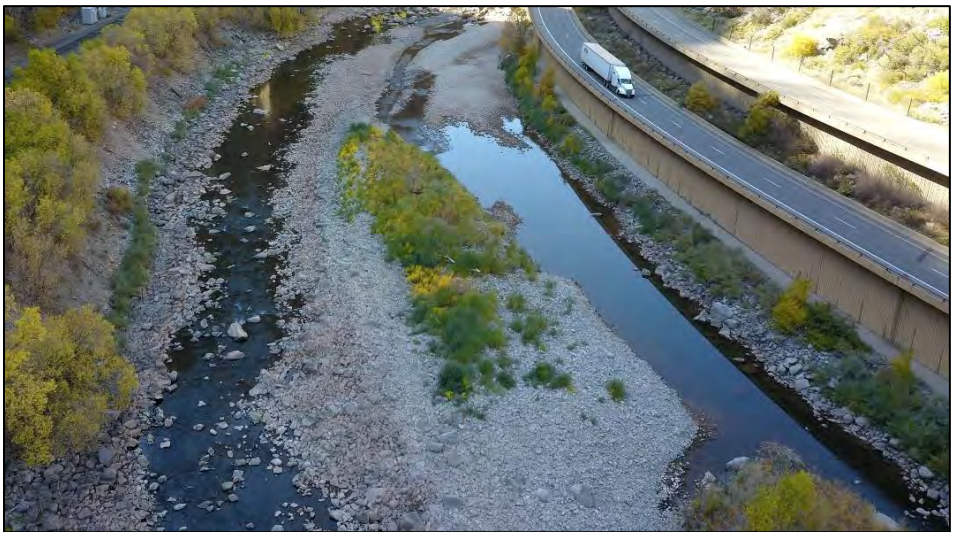


Figure 8. Downstream end of the survey reach. On the left, the outer riffle channel shows larger material and more large boulders that likely originated as colluvium or tributary supply. On the right, the cobble bed pool is currently controlled by the large cobble deposit on the inside of the channel at the downstream end.

5. SEDIMENT SAMPLE SURVEY

Bed materials in the reach were sampled at five locations to quantify the size of typical sediments present, particularly in cobble and gravel areas that may represent better aquatic habitat (Figure 9). Two Wolman pebble counts and three grab samples were completed, the grain size distribution (GSD) of each can be found in the Sediment Grainsize Distribution Appendix. The Wolman pebble counts were performed at the midpoint and downstream end of the main midchannel bar that included the two vegetated islands. These locations represented areas that are frequently inundated and contain fewer large boulder elements. Particle size distributions were similar in both of these locations with most cobbles larger than 4". The sample midway up the bar, between the two vegetated islands, skewed slightly larger, and this area also had more boulders present. A subsurface grab sample was taken in the vicinity of the downstream pebble count and sent to a lab for sieve analysis as it was a much smaller material class (Figure 10). The subsurface GSD had a D_{50} of 10.35 mm and was roughly 1/10 the diameter of the surface pebble count at the D_{10}, D_{50}, and D_{60} benchmarks. This is consistent with expected bed armoring downstream of a dam. The two remaining grabs samples were taken upstream of the islands on the inside of the bend and included both surface and subsurface material. One was taken from a depositional gravel bar above the survey water surface elevation, the other was taken from an apparent trout redd under the water (Figure 11). The trout redd was identified by apparent cleaned and sorted gravels that did not match the condition of the surrounding algae matted or fines veneered bed material. The sample in the redd location contains more coarse gravel and less sand and silt than the nearby gravel bar location. Numerous large trout were observed in the isolated pools during survey. A beaver lodge and beaver activity were also noted during survey.

Figure 9. Sediment sample locations

Figure 10. Sediment sample locations at the far downstream end of the channel center cobble bar. Left – area Wolman pebble count was conducted. Right – subsurface sample location with cobble armor layer removed.

Figure 11. Apparent trout redd sediment sample location. Red circle indicates the redd location.

6. BASE MAP AND DEM DEVELOPMENT

Survey data were post-processed to remove potential spurious data and check for consistency. Interpolation of some topographic data was required in areas where complex topography made detailed survey unsafe, but this was expected from the outset, and the majority of the survey extent was covered by on the ground field survey. A digital elevation model (DEM) was created for the entire surveyed project reach using a triangular irregular network (TIN) to connect surveyed points along with breaklines to represent the existing conditions in the field. Additional breaklines were included to represent boulder clusters based on the collected aerial ortho-images. Elevations for some of these features had to be estimated based on nearby similar elevation features that were surveyed or nearby water surface elevations.

Field survey only took place up to the OHWM. For areas above this elevation, LiDAR data was added to the DEM. This LiDAR DEM data is publicly available data collected on flights in June of 2016 for the Colorado Water Conservation Board (https://coloradohazardmapping.com/lidarDownload). The data is

formatted as a geotiff with 3 ft resolution. The LiDAR survey was carried out in the same coordinate reference system as this ground based survey; State Plane Colo. Central, NAD83, NAVD88. The LiDAR survey used the 12B geoid model as opposed to the more recent CONUS18 geoid model, but in the area of interest, this difference is not expected to have an impact. The LiDAR data inserted was well aligned with the surveyed ground elevations and required minimal editing of the DEM to mesh to two surfaces. Because the ground survey went to the elevation of the OHWM, the LiDAR based data inserted at elevations higher than this are not expected to have a significant error on the flow levels of interest for this project.

A continuous bathymetric and topographic DEM surface was created using these data described above. This DEM was used in hydraulic modeling efforts, discussed in the Hydraulic Modeling Report.

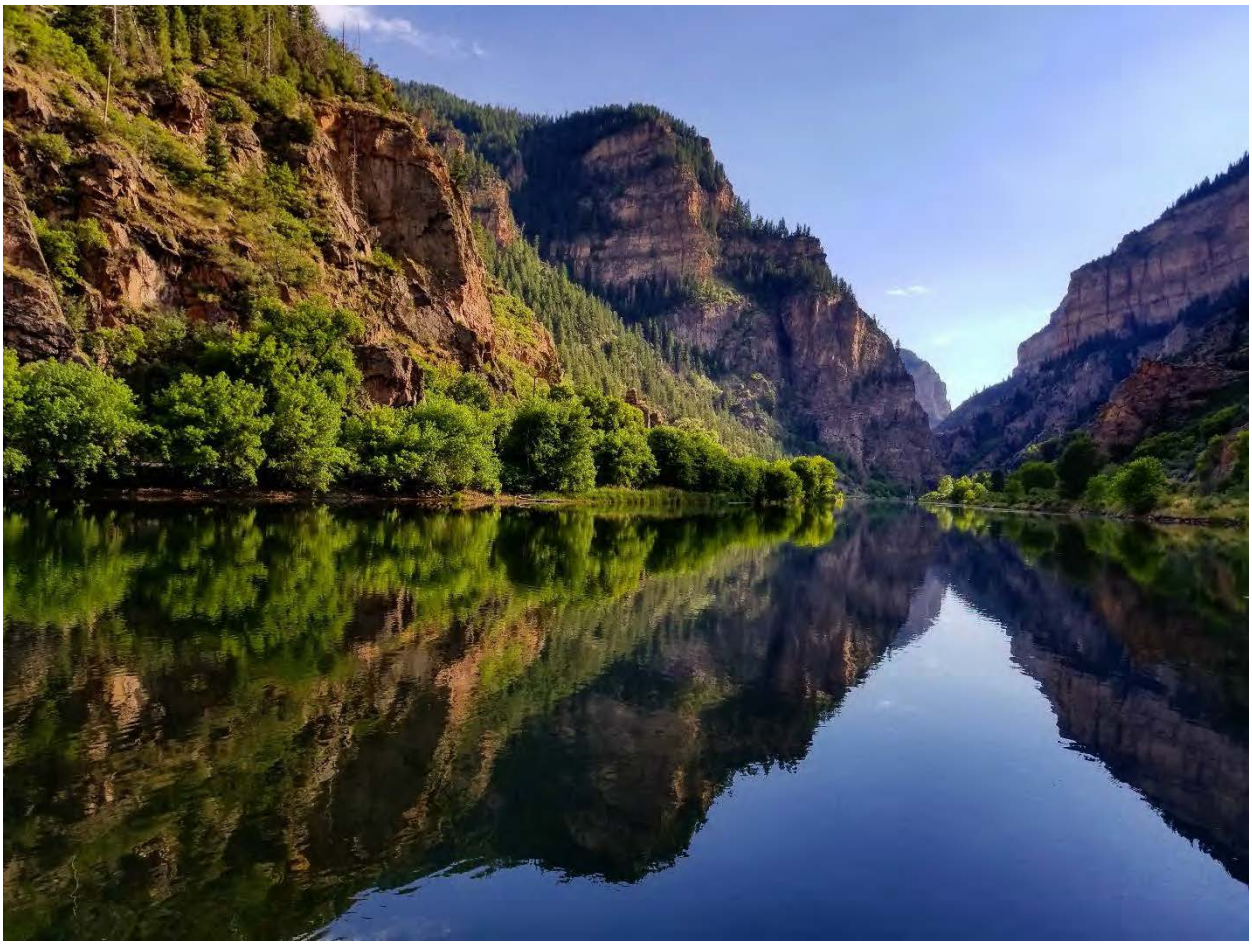
7. SUMMARY

This survey was successful in collecting sufficient data to develop a detailed DEM of the study reach in Glenwood Canyon. The DEM developed from this survey and the bed material observations were used to model 2D river hydraulics, which is described in the Hydraulic Modeling Report. The data collection described in this report was sufficient for modeling 2D river hydraulics at, or finer than the target resolution for the habitat analysis which was specified as a 25 sqft computational cell size area, or a 5 ft x 5 ft cell.

APPENDIX 10

Biological and Recreational Resources Dependent on Colorado River Flows Through Glenwood Canyon

September 2024



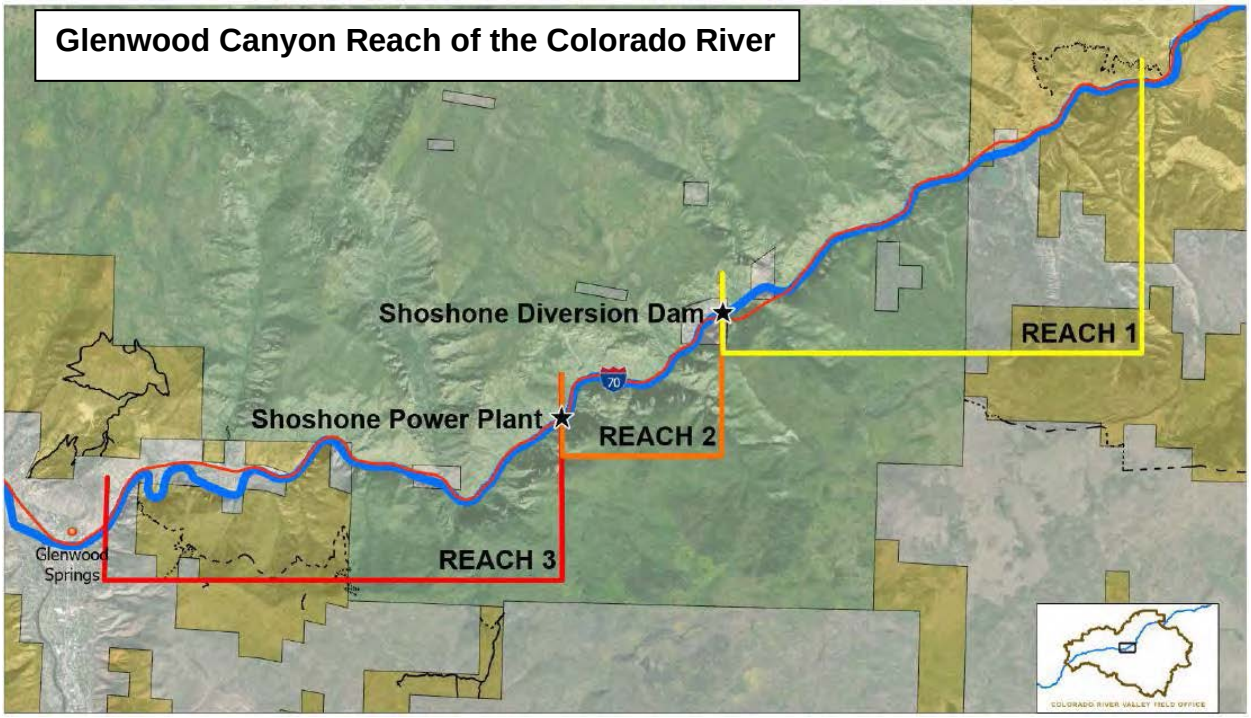
Introduction

This document provides an executive level summary of the natural environment supported by Colorado River flows in Glenwood Canyon, and qualitatively describes the relationship of that natural environment to physical infrastructure and operations of Excel's Energy's Shoshone Power Plant. This document also describes other water-dependent values upstream and downstream from Glenwood Canyon that are highly dependent on consistent flows through Glenwood Canyon. This document does not attempt to quantify natural resource benefits or impacts associated with operation of the Shoshone Power Plant, which would require intensive study of the river channel morphology, hydrology, fish populations, and riparian communities.

This document incorporates biological and recreation information available to the Bureau of Land Management (BLM) and White River National Forest (WRNF), including information from other resource management agencies. Even though this document incorporates information from other agencies, it does not purport to represent any formal position that any agency may take regarding proposed changes to land management or streamflow management in Glenwood Canyon.

Background – Land and Water Management

The Colorado River flows west/southwest through Glenwood Canyon for approximately 18 miles from west of Dotsero, Colorado to Glenwood Springs, Colorado. The river within this reach is naturally confined by a steep and narrow limestone canyon, and further constricted by a four-lane Interstate highway, railroad, and pedestrian bike path. Other infrastructure located within the river corridor includes power lines, two Colorado Department of Transportation (CDOT) rest areas, Excel Energy's Shoshone Hydropower Plant and Dam, the CDOT operations center at Hanging Lake Tunnel, Hanging Lake trailhead, the small community of No Name, and the privately owned Bair Ranch.



Glenwood Canyon is a popular destination for recreation, including but not limited to walking/jogging, biking, whitewater rafting, fishing, and viewing the scenic river corridor and riparian communities. Several small tributaries and two larger streams that contain significant fisheries, Grizzly Creek, and No Name Creek, flow into the Colorado river within this reach. In 2020, the river corridor was impacted by the Grizzly Creek Fire that burned the entire length of the canyon. Rain-induced post-fire debris flow events have impacted the river channel, highway, pedestrian bike path, and the Shoshone Power Plant since the fire.

Despite extensive human modification of the river corridor, the river still supports a regionally significant natural environment that draws many visitors to the canyon. The natural environment supports native and sport fish populations, Rocky Mountain bighorn sheep, and riparian plant communities that are adapted to the ecological constraints within the canyon. Colorado Parks and Wildlife (CPW) periodically monitors fish and big game populations in the canyon but inventories of other biological attributes, including non-game species, have been limited.

The majority of the canyon is National Forest Systems Lands managed by the White River National Forest, and in partnership with CDOT. The BLM manages lesser amounts of lands within the river corridor at each end of Glenwood Canyon. Together the WRNF and BLM emphasize management of visitation and recreation infrastructure while also supporting the ecological function of the Colorado River. In addition to further clarifying the recreational use of the Canyon, the general physical and biological attributes associated with the Canyon are outlined below.

Glenwood Canyon at the Shoshone Dam and Tunnels

In Glenwood Canyon, the Shoshone Hydropower Plant has been in existence for over 100 years and is one of the most senior water rights in the Colorado River watershed within Colorado. This senior water right assures that stream flows make it to the point of diversion when a priority call is made. The hydropower operation consists of three primary components – the Shoshone Dam, which backs up water to the point of diversion, a pipeline from the point of diversion, which operates via gravity flow, and the Shoshone Power Plant, which receives water from the pipeline. When fully operational, the powerplant can place a priority call for two water rights that are diverted to the penstocks of the powerplant, one water right for 1,250 cubic feet per second (cfs) under a 1905 priority and another water right for 158 cfs under a 1940 priority.

In 2016, multiple parties, including the U.S. Bureau of Reclamation, the Colorado Division of Water Resources, water districts, and water users, signed a 40-year agreement referred to as the "Shoshone Outage Protocol."[1] The protocol is designed to maintain the flow regime on the Upper Colorado River, even when the Shoshone Power plant is not calling for water due to operational constraints. The agreement calls for deliveries to the powerplant of 1250 cfs from March 25 to November 10 and 950 cfs from the November 11 to March 24. The agreement includes limits on the volume of water to be delivered to the powerplant each year and it also includes provisions that alter the rate and volume of water delivered to the powerplant during drought conditions.

Wild and Scenic Rivers Management

In 2014, BLM and WRNF amended their respective resource management plans and forest plans to include Wild and Scenic Rivers management prescriptions for Glenwood Canyon and for segments of the Colorado River upstream from Dotsero to Kremmling. Pursuant to study guidance found in the 1968 Wild and Scenic Rivers Act, the agencies determined that the river segments are free flowing (free of impoundments and large diversions), with the exception of the portion of Glenwood Canyon that is occupied by the diversion dam and reservoir associated with the Shoshone Power Plant. The agencies also determined that the river segments support Outstandingly Remarkable Values (ORVs), which are defined as river-related values that are unique or exemplary within the region of comparison. Given those findings, the agencies concluded four river segments are eligible for inclusion in the National Wild and Scenic Rivers System. The river segments analyzed and the ORVs identified are as follows:

Name of Segment	Outstandingly Remarkable Values
Colorado River – Gore Canyon (Segment 4)	Scenic, Recreational (Fishing, Floatboating, and Scenic Driving), Geologic, Wildlife, Historic
Colorado River – Pumphouse to State Bridge (Segment 5)	Scenic, Recreational (Fishing, Floatboating, and Scenic Driving), Geologic, Wildlife, Historic
Colorado River – State Bridge to Dotsero (Segment 6)	Scenic, Recreational (Floatboating, and Scenic Driving), Botanical, Wildlife
Colorado River – Glenwood Canyon (Segment 7)	***Recreational (Whitewater Boating, Scenic Viewing, Hiking), Scenic, Geologic***

As part of the 2014 agency evaluation of whether the river segments are suitable for inclusion in the National Wild and Scenic Rivers System, the agencies received an alternative management plan proposal from the Upper Colorado River Wild and Scenic Stakeholder Group (SG) which is designed to protect and enhance the ORVs. The SG plan was adopted by BLM and WRNF planning decisions on June 25, 2015, with the objective of assisting the two agencies in meeting management requirements under the Wild and Scenic Rivers Act for eligible stream segments on the Colorado River. Specifically, the SG plan was adopted to monitor, protect, and enhance the ORVs identified in BLM and WRNF Eligibility Reports for Segments 4 through 7.

By design, the SG plan focuses on the most highly flow dependent ORVs, specifically recreational float-boating (in segments 4-7) and recreational fishing (in segments 4-6). The

[1] Shoshone Outage Protocol Agreement Number 13XX6C0129 dated June 27, 2016.

intent of adopting the SG plan was that it will complement, and be coordinated with, BLM and WRNF land use authorities and land use decisions, enabling the federal agencies to better fulfill management requirements under the Wild and Scenic Rivers Act. The SG plan offers the benefit of monitoring streamflow through the Wild & Scenic segments, and then supplementing this with coordinated, cooperative, and voluntary water deliveries coordinated by the SG, when available. The intent of the SG plan is to balance permanent protection of the ORVs, certainty for the stakeholders, water project yield, and flexibility for waters users.

It is important to note that the SG Plan[2] relies on the existence of the Shoshone Power Plant water rights as one of its Tier 1 Long-Term Protection Measures:

> *Existing senior water rights*: The Shoshone and Cameo groups of senior water rights generally control the administrative call within the Colorado River Basin. These water rights are located downstream of the subject stream reaches; therefore, an administrative call during dry or average conditions by these water rights can curtail diversions from upstream junior water rights or require the release of water from storage to replace those junior diversions. This administrative call generally results in stream flow through the subject stream segments in amounts greater than would exist in the absence of the administrative call. (Page 36)

Fisheries Summary

The Colorado River within the canyon has three distinct reaches resulting from the presence of Excel Energy facilities: Reach 1 upstream of the Shoshone Dam, Reach 2 from Shoshone Dam to the Shoshone Power Plant outlet, and Reach 3 downstream from the Shoshone Power Plant return flow outlet.

Reach 1, upstream of the dam, is characterized by a flattened/reduced river gradient. The impounded water substantially reduces water velocities, resulting in high sediment deposition above the dam. Aquatic habitat diversity and complexity is reduced due to a lack of riffle-run sequence habitat characteristic of a typical free flowing river. In addition, the dam is a physical barrier to movement of aquatic organisms both upstream and downstream when it is not bypassing river flows and a flow velocity barrier to upstream movement when water is being bypassed. This results in fragmentation of habitat.

Reach 2 encompasses the 2.5 miles of river between the Shoshone Dam and the Shoshone Power Plant return flow outlet. During seasonal low flow periods, the reach is substantially dewatered when the plant is operating. Flows are highly variable throughout the year depending on if the plant is in operation or not. During operations, habitat in the river channel is weakly connected by small inflows of groundwater and tributary streams that fill pools and flow through the large boulder and rock substrate. This reach contains both the lower and higher gradient sections that provide a complexity of habitat when the native flows are allowed to bypass the dam. Habitat persists even during low flow periods, though wetted area in the stream channel is substantially reduced.

Reach 3 begins where native flows are returned to the river during operation of the Shoshone Power Plant and extends downstream to the city of Glenwood Springs. The river regains its natural character with a mix of riffle, run, and deep pool habitats that all contribute to improved channel complexity and diversity.

[2] https://www.upcowildandscenic.com/uploads/1/3/5/3/135388668/amended_and_restated_sg_plan_july_2024.pdf

Shoshone Powerplant

Below is a brief biological summary of the Colorado River within Glenwood Canyon based on fish sampling data, incidental aquatic invertebrate notes, and riparian habitat assessments by BLM and WRNF.

Fishery surveys on the Colorado River are conducted annually by CPW in cooperation with the BLM and WRNF. These surveys include reaches in and near Glenwood Canyon. Based on these surveys, the following fish are considered resident to the Colorado River in Glenwood Canyon:

Sportfish
Brown Trout, Rainbow Trout, Cutthroat Trout, Rainbow-Cutthroat hybrids, and Mountain Whitefish.

Rainbow Trout

Brown Trout

Mountain Whitefish

Native Fishes

Three native species, including Flannelmouth Sucker, Bluehead Sucker, and Roundtail Chub, are referred to the “Three Species” because they are the subject of a multi-state, multi-agency conservation agreement. Other native species include Colorado River Cutthroat Trout, Sculpin, and Speckled Dace.

Flannelmouth Sucker

Roundtail Chub

Invasive/Nonnative Fishes

White Sucker, Longnose Sucker, and Hybrid Suckers

As mentioned previously, the Reach 1 fishery is impacted by the Shoshone Dam, which impounds water, reduces gradient, reduces water velocities, and allows the deposition of fine sediment, resulting in decreased habitat complexity and diversity. The silting in of river substrates and the loss of riffle/run sequences limits macroinvertebrate productivity, native sculpin habitat, and juvenile fish refugia areas. Consequently, fish productivity within the reach is reduced because of limited food supplies. In addition to macroinvertebrate production, riffles and runs provide important fish spawning habitat for desirable native and sport fishes.

Reach 2 is impacted by the hydropower operations via reduced and highly variable flows depending on hydropower plant operational status. When the plant is operating, and during natural seasonal low flow periods, sediment transport is inhibited, wetted habitat is reduced, and channel/flow connectivity is impaired. The highly variable flow rates limit aquatic invertebrate productivity, an important food source for resident fish. Variable flows also can impact fish spawning activities within the reach due to impaired availability of and accessibility to preferred spawning habitat.

In Reach 3, where the natural river flow regime is reestablished, the river harbors a robust sportfish fishery comprised of Brown Trout, Rainbow Trout, and Mountain Whitefish. Despite the threats posed from invasive fish species, native Flannelmouth Sucker and Bluehead Sucker are regularly detected in the Colorado River in and adjacent to Glenwood Canyon, along with Roundtail Chub, Sculpin, and Speckled Dace. The benefits from the hydropower return flows include increased riffle, run, and pool complexes, coupled with abundant large boulders. With flows sufficient for effective sediment transport, this reach contains diverse, high-quality habitat for aquatic species. The resiliency of the aquatic ecosystem is sustained with the greater abundance of riffle habitat that improves macroinvertebrate and resident fish productivity.

Fish species composition is likely similar within the three reaches, but species relative abundance, particularly of fish species that prefer higher gradient and reduced sediment loads (Sculpin, Trout, and Mountain Whitefish), are likely reduced in Reaches 1 and 2 due to the previously mentioned modification of flow rates and channel composition. Species such as Sculpin are particularly sensitive to increases in sediment deposition as they live within the interstitial spaces amongst larger river substrates. Trout and Mountain Whitefish require clean gravel and cobble substrates for spawning and rearing of juveniles.

Importance of Flows to Federally Listed Fishes

In addition to the local fish community, Shoshone water rights help support flows important to four downstream fish species federally listed under the Endangered Species Act: Bonytail, Colorado Pikeminnow, Humpback Chub, and Razorback Sucker. Specifically, flows help support important habitat located in the “15-mile reach” of the Colorado River located from the town of Palisade to the Gunnison River confluence in Grand Junction. This reach is particularly vulnerable to very low flows as substantial water withdrawals occur just above Palisade for agricultural and other uses. This report does not attempt to quantify the timing or magnitude or flows that benefit the 15-mile reach from exercise of the Shoshone water rights.

Shoshone Reach Instream Flow Habitat Data Analysis

Freshwater Consulting, LLC, under contract to the Colorado River Water Conservation District, completed an aquatic habitat analysis for the portion of Glenwood Canyon affected by water diversions to the Shoshone Power Plant.[3] The objectives were to determine the current state of the aquatic habitat and aquatic ecosystem in the Shoshone Reach and determine expected changes to the aquatic habitat and aquatic ecosystem due to hydrologic change if the Shoshone Power Plant water rights were wholly or partially dedicated to instream flow use.

BLM and USFS aquatic resources staff reviewed the report and determined the following:

[3] Shoshone Reach Instream Flow Habitat Data Analysis, Habitat Simulations and Habitat Evaluation of the Colorado River from the Shoshone Diversion to the Shoshone Power Plant Outfall, William J. Miller, PhD, Freshwater Consulting, LLC, August 2024.

- The study utilized broadly accepted scientific procedures for two dimensional hydraulic modeling.

- The habitat suitability criteria used for the fish species of interest, which include multiple species of trout and flannelmouth sucker, appear to be appropriate and incorporate data from multiple river locations in Colorado.

- The study selected cross section and modeling locations with habitat types that are generally representative of Glenwood Canyon, including pools, riffles, rapids and runs.

- The key study conclusions, listed below, appear to be well supported by the habitat modeling results:

    - For older life stages of trout, Mountain Whitefish and Flannelmouth Sucker, the highest habitat availability is at flows that range from 750 cfs to 1,500 cfs.

    - Usable fish habitat gradually declines from 1,500 to 3,000 cfs, but there is still significant habitat available. At higher flow rates, habitat for trout fry decreases significantly.

    - Fish habitat availability quickly declines as flows decrease below 750 cfs.

- The study correctly notes that periphyton, algae, and benthic macroinvertebrates are important food resources for higher trophic levels, and that such resources are significantly impacted by no flow or low flow events caused by diversions to the Shoshone Power Plant.

- The study correctly notes that flow variability, including flood and drought events, are critical for maintaining the overall functioning of aquatic ecosystems, including the riparian communities along the river.

- BLM and USFS concur that any increases in base flows through the reach impacted by Shoshone Power Plant diversions are likely to improve and stabilize aquatic habitat.

Aquatic Invertebrates

A variety of macroinvertebrate species inhabit the Glenwood Canyon. Of primary interest are the EPT taxa (Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Tricoptera (Caddisflies), as the presence and abundance of these taxa reflect the health of aquatic systems. These and other aquatic invertebrates provide important high value food sources for resident fish, birds, and bats and are an important component of the riverscape food web.

Adult Stonefly

Adult Mayfly

Like fish, macroinvertebrate diversity and density, particularly for EPT taxa, are likely higher in Reach 3 below the Shoshone Power Plant where flow is reestablished, because the river contains less fine sediment and increased riffle habitat important for macroinvertebrate productivity. Macroinvertebrate productivity is likely reduced within Reach 2, because of reduced and highly variable flows depending on hydropower operations. Because of the dam, Reach 1 contains very few riffles, and the reduced river gradient allows fine sediments to settle out. A lack of riffle habitat and increased sediment deposition favors sediment tolerant taxa and reduces overall macroinvertebrate densities and diversity within the reach. EPT taxa are particularly sensitive to increased sediment loading and require clean, well oxygenated substrates in which to thrive.

Reduced macroinvertebrate densities can negatively affect the riverscape food web. As with fish, robust macroinvertebrate sampling would be informative regarding perceived differences in species composition and densities within the three reaches.

Rock Covered in Caddisfly Cases

Riparian Vegetation

Riparian vegetation expression is limited within Glenwood Canyon due to several factors, but the most prominent factor is that the reach is within a steep, narrow canyon controlled by bedrock. This geologic context results in a riverscape that contains only a narrow band of alluvial aquifer

on each side of the river that can support riparian vegetation. The canyon contains only short, disjunct reaches supporting significant floodplain acreage. Other factors limiting riparian vegetation extent include confinement from the interstate highway, railroad, bike path, and other previously noted infrastructure.

Glenwood Canyon Riparian Vegetation

Where present, riparian vegetation provides river cover and shading; increased bank armoring and stabilization; habitat for terrestrial insects an important food source for fish, birds, and bats; bird nesting habitat; and scenic and aesthetic values.

Primary riparian vegetation species noted within the canyon include narrowleaf cottonwood, chokecherry, red-osier dogwood, box elder, willow, wild rose, skunkbush, riparian grasses, sedges, and rush. Riparian species composition appears similar within all three reaches, but densities vary throughout the canyon.

Colorado River and Riparian Vegetation – Glenwood Canyon

Despite the natural and human induced constraints limiting the amount and spatial extent of riparian vegetation within the steep canyon, where riparian vegetation exists, it supports scenic attributes, valued ecological functions, and important wildlife habitat. BLM has completed Proper Functioning Condition riparian condition assessments on the lands it manages within Reaches 1 and 3. Given the geological and human induced limitations within the canyon, both BLM-managed riparian segments were found to be in Proper Functioning Condition.

Recreation

Recreation use in Glenwood Canyon and Colorado River segments located upstream between Kremmling and Dotsero relies heavily on flows called by the Shoshone Power Plant water rights. Visitors to these stream reaches are attracted by boatable flows and scenic canyon environments that remain largely in natural condition. Riparian communities along the river provide scenic interest, camping, fishing, and resting locations, as well as habitat for watchable wildlife. In the river segments between Kremmling and Dotsero, certain reaches provide outstanding opportunities for fishing from boat or from shore. In Glenwood Canyon and near Pumphouse and Radium upstream, trail systems parallel the river, providing hikers and bicyclists the opportunity to enjoy wildlife and river corridor views. The Upper Colorado River Scenic Byway also passes through this corridor, providing visitors with scenic driving opportunities.

<u>Kremmling to Dotsero</u>

BLM manages the public lands along with river between Kremmling and Dotsero as the Upper Colorado River Special Recreation Management Area (SRMA). BLM's broad management objectives for the SRMA include delivering personal and social benefits associated with outdoor recreation; protecting fish, wildlife, and plants from public use impacts; generating community stewardship of recreation resource and natural resources; and maintaining tourism employment and revenue for the local economy. BLM achieves these objectives by dividing the river corridor into various management zones and managing each zone for targeted experiences and recreation benefits. To support these objectives, BLM manages nine formal recreation sites between Kremmling and Dotsero, which include facilities such as parking, boat ramps, restrooms, campgrounds, public water supplies, and trailheads.

Private rafting trip taking out at BLM recreation site in Upper Colorado River SRMA.

Visitation to BLM recreation sites is recorded annually in the BLM's Recreation Management Information Systems (RMIS) database. The use at a specific site is captured as "visits" which equates to one person entering onto lands or waters managed by the BLM for the purposes of recreation. A "visitor day" is defined as a visitor spending 12 hours in an area. A family of four camping for three days would count as 12 visitor days. These visitation numbers are derived from multiple methods including records from recreation permits, campground fee envelopes, data from traffic counters, and simple observation. While technically open year-round, visitation to the campgrounds is concentrated in the summer season, generally May through September.

Visitation tracking in RMIS follows the federal fiscal year (FY), which runs from October 1 through September 30 of the following year. Within the SRMA, there were 241,417 visits in FY2020, 242,679 recreational visits in FY2021, and 257,007 visits in FY2022. Visits by recreational users more than doubled over the three-year period and averaged 238,034 visits within the SRMA. This increase in recreational use is consistent with other public lands across Colorado.

Table 1. Estimated Annual Visitation to Upper Colorado River SRMA in Visitor Days

Upper Colorado River SRMA	FY20	FY21	FY22	Average
Kremmling Field Office	149,173	175,203	180,459	168,278
Colorado River Valley Field Office	65,244	67,476	76,548	69,756
Total Annual Visitation	214,417	242,679	257,007	238,034

BLM cooperates with the Upper Colorado River Wild and Scenic Stakeholders Group to collect data concerning the number of visitor days associated with float trips. Between May 1 and September 30, 2022, a total of 42,836 visitor days were logged for commercial outfitters who were taking clients on float boating trips.[4] While the exact percentage of visitor days associated with commercial float trips varies from year to year, the 2022 surveys revealed that approximately 45% of visitor days were associated with commercial float boating trips, while approximately 55% of visitor days were associated with privately-run float boating trips.

[4] Upper Colorado River Wild & Scenic Stakeholders Group – 2022 Annual Monitoring Report.

Visitors experiencing a quiet section of the Colorado River within the SRMA.

Using this data and visitor distribution, BLM estimates there were approximately 53,272 visitor days during 2022 that were associated privately-run boating trips. If visitor days for commercial trips and privately-run boating trips are combined, BLM estimates the number of visitor days for both commercial and private boating trips for 2022 was approximately 96,000.

Much of the visitor use in the SRMA is supported by commercial outfitters, each of whom operates under a Special Recreation Permits issued by BLM. The total number of Special Recreation Permits issued to outfitters for operations within the SRMA is shown in Table 2.

Table 2. BLM Special Recreation Permits for Upper Colorado River SRMA.

Number of Special Recreation Permits	Type of Recreation Use Authorized
2	Kayaking / Canoeing
24	Fishing
50	Rafting / Floating / Rowing

Overall, outdoor recreation types on BLM-administered lands in the Kremmling Field Office and Colorado River Valley Field Office contributes $145.7 million and over 1,100 jobs annually, paying $50.4 million in labor income to Colorado's economy.[5] Public lands play an important role in stimulating the local economy by providing opportunities for recreation. Communities adjacent to public lands can benefit economically from visitors who spend money in hotels, restaurants, gas stations, gift shops, and elsewhere.

[5] BLM 2023. Valuing America's Public Lands 2023. Internet website: https://www.blm.gov/about/data/socioeconomic-impact-report-2023

Glenwood Canyon

WRNF manages the public lands along a majority of the Glenwood Canyon section of the Colorado River. This is the largest canyon on the upper Colorado River with rugged scenic walls rising over 1,300 feet on either side. The 2002 White River National Forest Land and Resource Management Plan provides Management Area direction for this area with a title of *Recreation Rivers-Designated and Eligible* and a theme of *Recreation Rivers are managed to protect and perpetuate eligible and designated recreation river segments*. These areas are managed to protect and perpetuate eligible river segments in their current condition so that their recreation river qualities are not diminished.

WRNF manages the Glenwood Canyon portion of the river as one segment, which starts at the national forest boundary on the eastern end of Glenwood Canyon and extends downstream to the national forest boundary near the west end of Glenwood Canyon. The infrastructure that supports the recreational activities in the canyon includes the Glenwood Canyon Recreation Path, two (2) boat ramps at Shoshone and Grizzly Creek, respectively, and rest areas, trailheads, parking areas, and restrooms at Hanging Lake, Grizzly Creek, and No Name rest areas, with a parking area and restroom at Bair Ranch rest area.

Visitors enjoy one of the many rapids in Glenwood Canyon

Overall visitation on the WRNF managed stretch of the Colorado River, through Glenwood Canyon, is tracked following the federal fiscal year (FY) from October 1 through September 30 of the following year. Estimated visitation includes commercial boater service days along with private boat data collected by WRNF staff at the Shoshone and Grizzly Creek boat ramps throughout the high use summer season, running from late June through late August.

Table 3. Actual and estimated visitation on the Colorado River in Glenwood Canyon based on a 70-day high use season (late June-Late August).

Glenwood Canyon	FY20	FY21	FY22
Commercial	43,089 (actual)	52,131 (actual)	53,687 (actual)
Estimated Private Use	4,138* (estimated 16,092)	1,456** (estimated 6,370)	1,609*** (estimated 3,633)
Total Combined Estimate	59,181	58,501	57,320

*18 days of private data collected,
**16 days of private data collected
***31 days of private data.

In 2018, WRNF conducted an Environmental Assessment to determine the capacity limit for commercial use of the Shoshone Rapids Section of the Colorado River in Glenwood Canyon. Through this process it was determined that 71,500 service days for commercial rafting and 750 service days for commercial kayaking, with a pool of 1,100 service days, and temporary use authorized on a requested basis by institutional type user groups, accounted for a total capacity limit of 73,350. There are currently 68,000 service days allocated to priority special use permit outfitter and guides.

These flow-dependent activities rely heavily on the amount of water in this stretch of the river. Based on input from the outfitters and experience, these commercial operations typically cease when river flows drop below 1,200 cfs. The floating visitor experience diminishes drastically once flows drop below this level.

The Shoshone rapids section of Glenwood Canyon is regionally significant to river recreation, as reliable flows create consistent Class II - IV whitewater conditions for boaters when most other popular rivers in the area have reduced flows, either by natural or controlled means. These dependable flows also contribute to the viability of long-standing outfitter's seasonal business operations and offerings to National Forest visitors.

The total number of outfitter and guide operations or educational institutions that are authorized to operate under a Special Use Permit by USFS to conduct commercial or educational activities on or along this portion of the river are outlined in Table 4.

Table 4. Number and types of 2024 USFS special use permits.

Number of permits	Types of permits	Total Priority Service Days
9	Rafting	66,977
3	Kayak	365
2	Fishing	150
3	Educational Institutions	340

Overall, WRNF directly supports 22,000 jobs with an economic impact of $1.6 billion based on data from 2019 and is considered the most visited national forest in the country.[6] Based on visitation studies conducted on a five-year cycle, forest visitation increased from 12.5 million visits in 2017 to 18.4 million visits in 2022[7]. While 11.5 million of those 2022 visits were from ski areas, the remaining 6.5 million visits were non-ski area visits. The Colorado River and public lands in Glenwood Canyon play a significant role in sustaining the local economy by providing opportunities not only directly related to recreation but also indirectly in the local communities where visitors support numerous local businesses and service providers.

Rafting the Colorado River in Glenwood Canyon.

Summary

The river-related natural environment in Glenwood Canyon has evolved in response to, and is dependent upon, the historical infrastructure and flow regime associated with operation of the Shoshone Power Plant water right. Any significant changes to the historical operation of the water right would result in corresponding changes to the natural environment, especially if the priority call associated with the water right were not exercised, resulting in increased diversions upstream. The Shoshone Outage Protocol[8], an operational agreement signed by Bureau of Reclamation,

[6] FY19 Economic Contributions from National Forests and Grasslands. USDA Forest Service, Ecosystem Management Coordination, Social Science and Economics. 2019.

[7] USDA Forest Service. National Visitor Use Monitoring Data 2017 and 2022.

[8] Shoshone Outage Protocol Agreement Number 13XX6C0129, dated June 27, 2016.

the State of Colorado, multiple local governments, and multiple entities with Colorado River water rights, recognizes the role that the water right plays in preservation of the natural environment in Glenwood Canyon, as well as the natural environment in river locations upstream and downstream. Quantification of the potential impacts associated with modified or terminated operation of the Shoshone Powerplant water right would require a detailed analysis of the historic water right call regime, hydrologic variability, and modeling of the in-channel and riparian habitat in Glenwood Canyon.

Operation of the Shoshone Power Plant water rights also has significant positive impacts both upstream and downstream from the plant. Downstream, operations of the water rights contribute to the flow rates necessary to support threatened and endangered fish species in the 15-Mile Reach near Grand Junction. Upstream, operation of the water rights supports Outstandingly Remarkable Values in three reaches of Colorado River that have been determined to be eligible for designation into the National Wild and Scenic Rivers System. Operation of the water rights also supports economically significant recreation use within BLM's Upper Colorado River SRMA and WRNF Glenwood Canyon Management Areas.

[8]

Shoshone Power Plant

Shoshone Power Plant Diversion Dam

Map 1: Shoshone Instream Flow Reach Project Map

State: Colorado

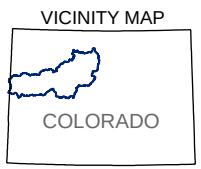
County: Garfield

Created Tuesday, March 4, 2025

0 ¼ ½ 1 Miles

Scale: 1:24,000

Proposed Shoshone ISF Reach Project Boundary



COLORADO RIVER DISTRICT

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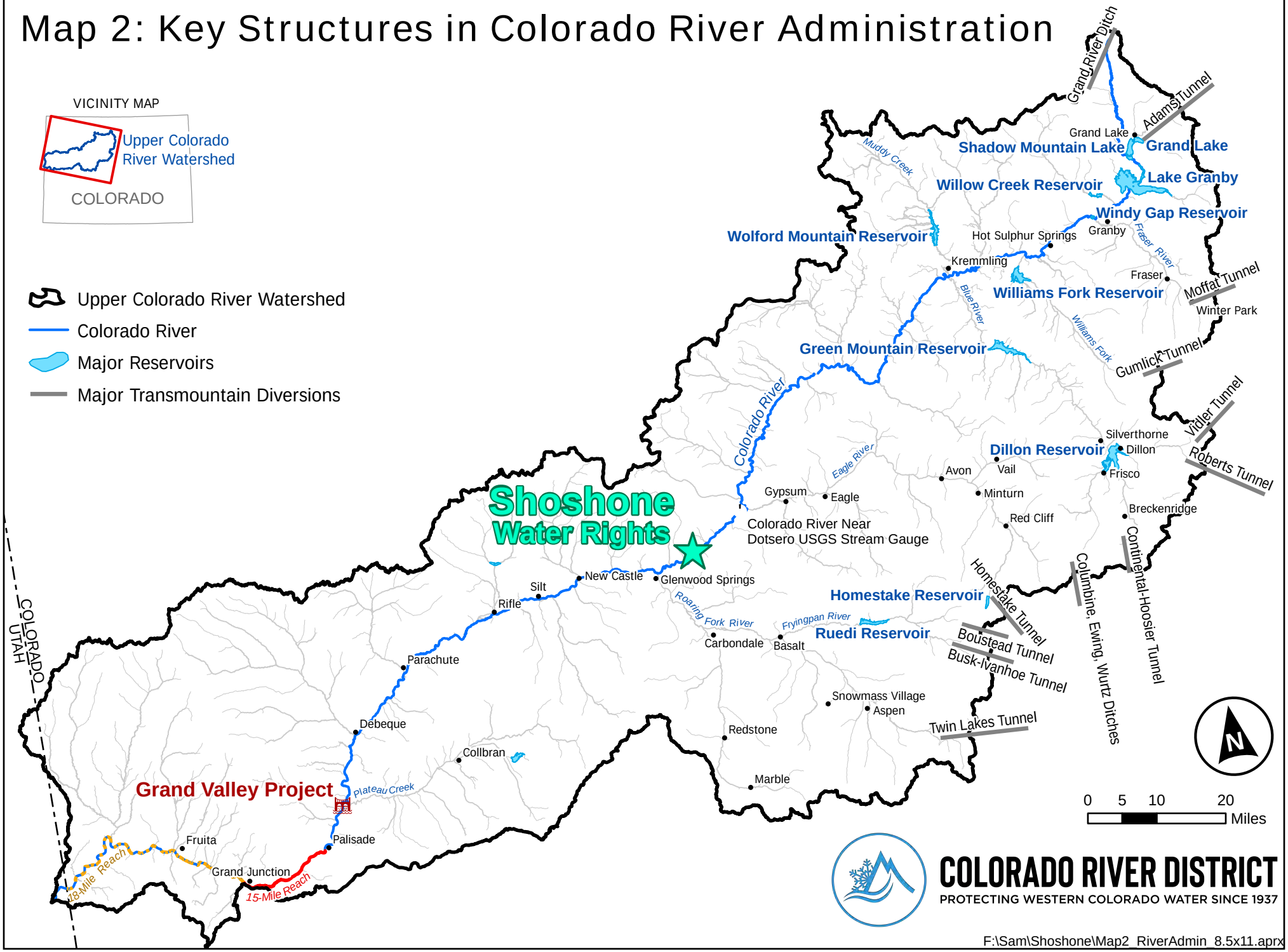
Map 2: Key Structures in Colorado River Administration



COLORADO RIVER DISTRICT
PROTECTING WESTERN COLORADO WATER SINCE 1937

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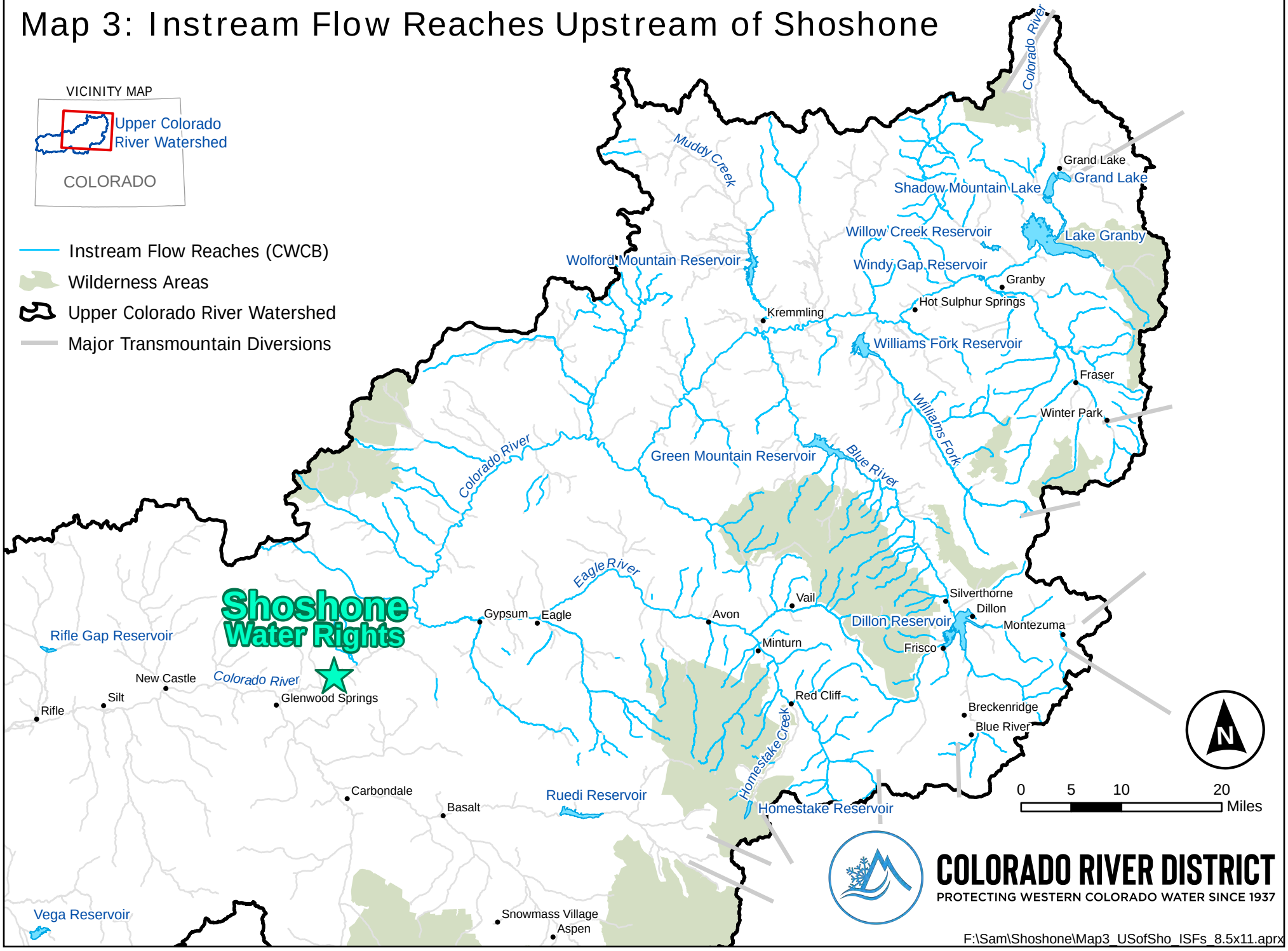
Map 3: Instream Flow Reaches Upstream of Shoshone



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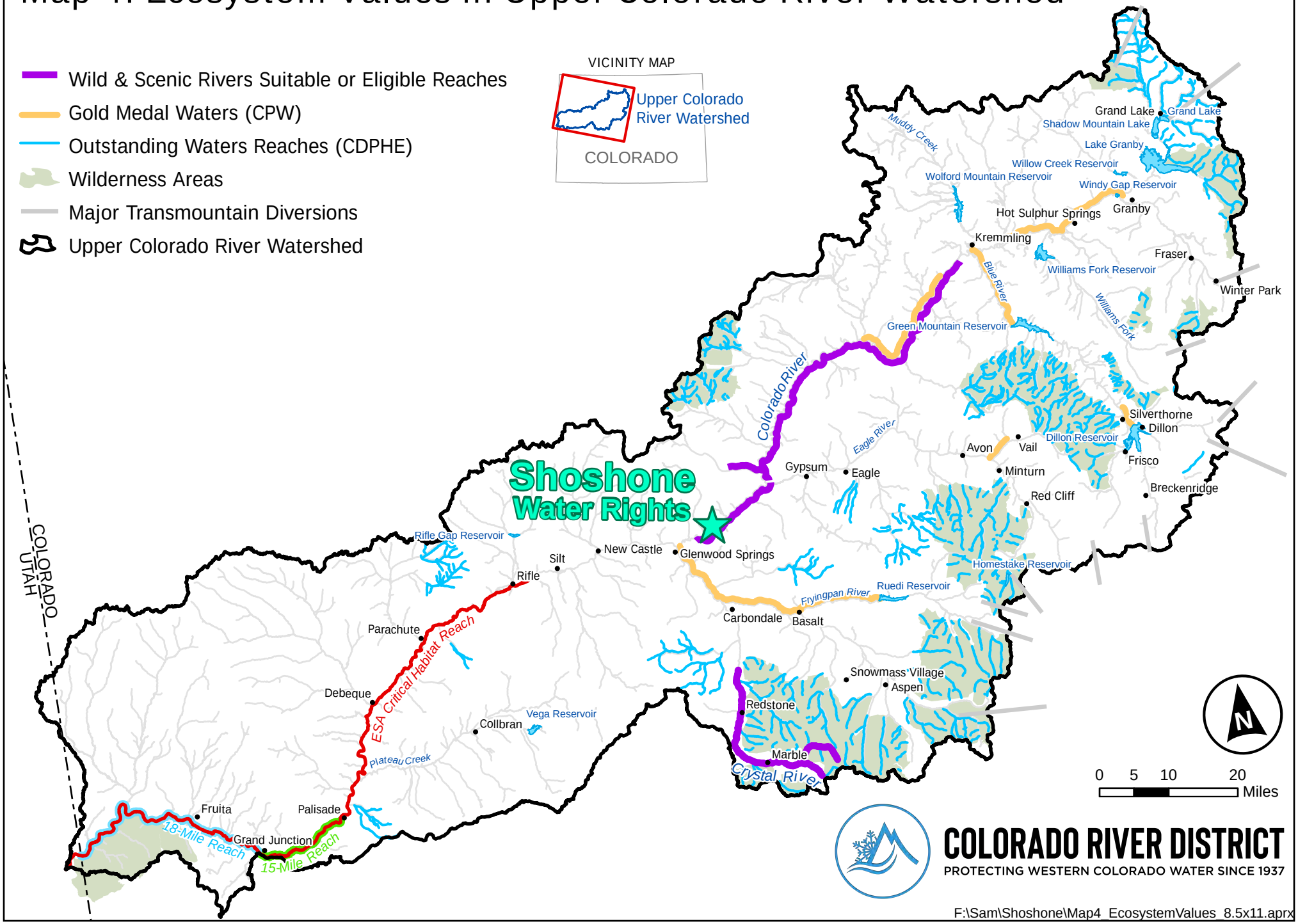
Map 4: Ecosystem Values in Upper Colorado River Watershed



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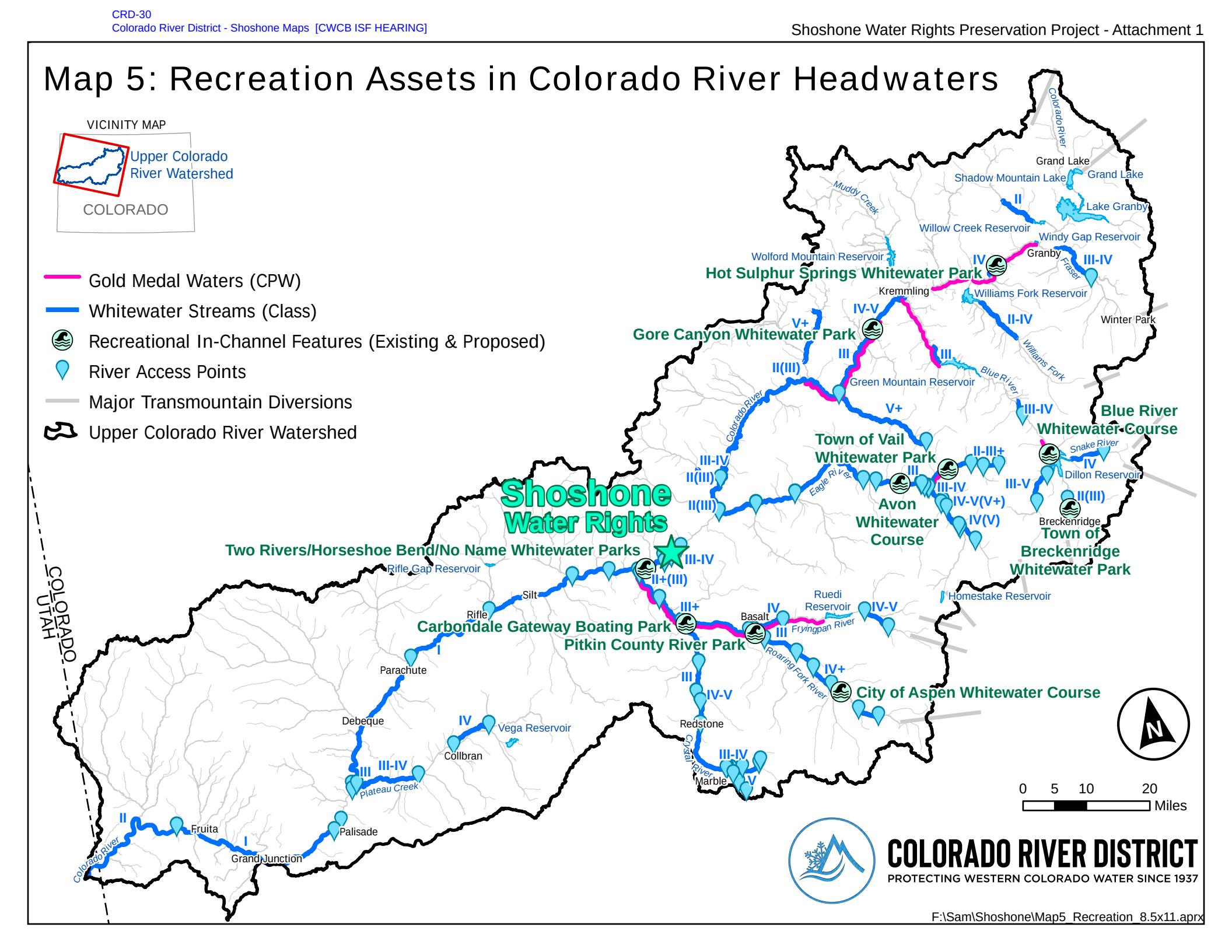
Map 5: Recreation Assets in Colorado River Headwaters



COLORADO RIVER DISTRICT
PROTECTING WESTERN COLORADO WATER SINCE 1937

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COLORADO RIVER DISTRICT
PROTECTING WESTERN COLORADO WATER SINCE 1937

MEMORANDUM

TO: **PETER C. FLEMING, GENERAL COUNSEL**
JASON TURNER, DEPUTY GENERAL COUNSEL
BRUCE WALTERS, ASSOCIATE COUNSEL

FROM: **RAQUEL FLINKER, SENIOR WATER RESOURCES ENGINEER/ PROJECT MANAGER**
BRENDON LANGENHUIZEN, DIRECTOR OF TECHNICAL ADVOCACY

SUBJECT: **SHOSHONE WATER RIGHTS ANALYSIS ON DECREED INSTREAM FLOW REACHES IN THE COLORADO RIVER WATERSHED**

DATE: **APRIL 30, 2025**

The Shoshone Hydroelectric Power Plant (the "Shoshone Power Plant") has two of the largest and most senior non-consumptive-use water rights on the mainstem of the Upper Colorado River. These water rights include the 1905 senior Shoshone Water Right in the amount of 1,250 cubic feet per second ("cfs") and the 1940 junior Shoshone Water Right in the amount of 158 cfs (together, the "Shoshone Water Rights"). The exercise of the Shoshone Water Rights results in an influential "pull" of water down the mainstem of the Colorado River, including through several significant tributaries, which helps to maintain flows both upstream and downstream of the Shoshone Power Plant. To satisfy an administrative call placed under the Shoshone Water Rights, upstream junior water rights are curtailed or are required to provide replacement releases from upstream reservoirs.

The State of Colorado has approximately 350 decreed instream flow ("ISF(s)") water rights on the Colorado River upstream of the Shoshone Power Plant (*see* Figure 1), and over 120 ISF water rights located downstream of the Shoshone Power Plant, including those on tributaries to the Colorado River. River District staff carried out the following analysis to evaluate the benefits that the exercise and administration of the Shoshone Water Rights have on these existing decreed ISF reaches. Representative ISFs located upstream and downstream of the Shoshone Power Plant were selected to better understand how the Shoshone Permanency Project is expected to help protect the identified ISFs. The selected ISFs reviewed in this memorandum that are located upstream of the Shoshone Power Plant include one of the three ISF water rights within the Upper Colorado River Wild and Scenic eligible reaches and one on the mainstem of the Eagle River. The selected ISFs located downstream of the Shoshone Power Plant include two ISFs on the Roaring Fork River. The ISFs studied herein include major and minor tributaries as well as the mainstem Colorado River and were selected to be representative of the range of influence of the Shoshone Call across

the basin. Overall, the exercise of the Shoshone Water Rights has been found to support upstream ISF reaches in meeting target flows, especially in dry years and in critical months during the late irrigation season, while having minimal impact on tributaries downstream of the Shoshone Power Plant, including on the Roaring Fork River.

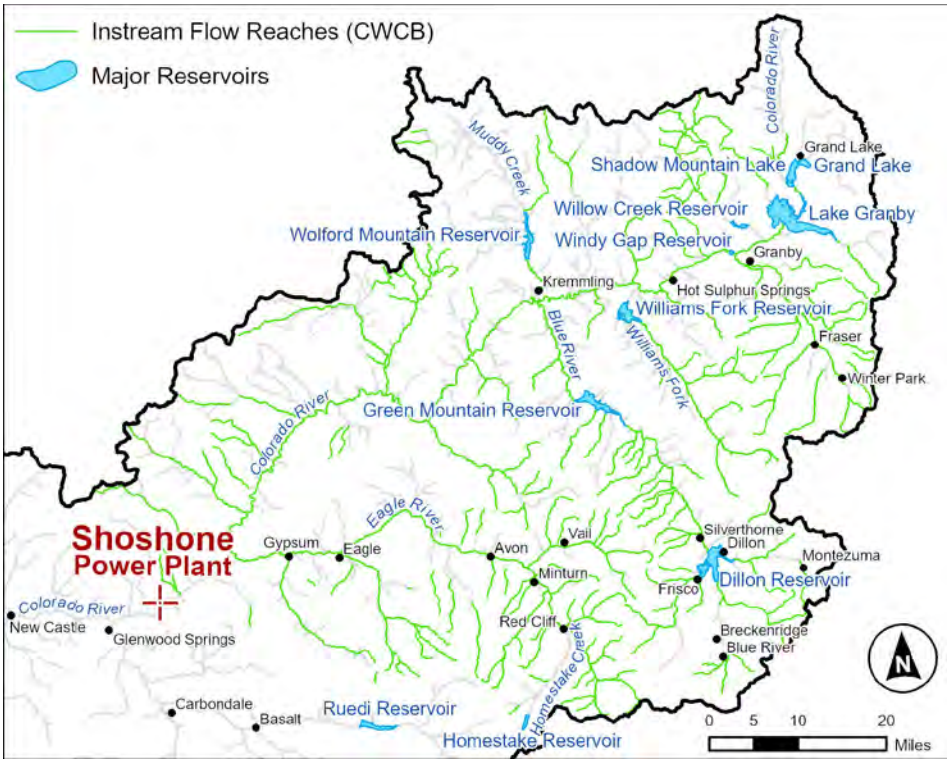


Figure 1 – ISF reaches upstream of the Shoshone Power Plant

The analysis described herein is based on modeled daily average flows from January 1988 to September 2013 at specific locations using the State of Colorado's StateMod 2024 Upper Colorado River Basin Model (the "2024 UCRM"). These average daily flows were modeled by Hydros Consulting, Inc. ("Hydros")[1] in four scenarios: 1) "Shoshone On Current" – Shoshone baseline demands with current basin water demands, [2] 2) "Shoshone Off Current" – Shoshone Water Rights are not active with current basin water demands,[3] 3) "Shoshone On Future" – Shoshone baseline demands with projected future basin water demands,[4] and 4) "Shoshone Off Future" – Shoshone Water Rights are not active with projected future basin water demands.[5] In the first and third

[1]Additional outputs were developed from Hydros' modeling efforts as described in their November 7, 2024, "Shoshone Power Plant Water Rights Yield Assessment – Addendum" and were provided to the Colorado River District in two documents named "CurrentConditions_GageFlows_updated.xlsx" and "FutureConditions_GageFlows_updated.xlsx".
[2] This is equivalent to the "Baseline" current conditions Hydros scenario.
[3] This is equivalent to the "Zero Shoshone" current conditions Hydros scenario.
[4] This is equivalent to the "Baseline" future conditions Hydros scenario. The future water demand scenarios assumed 120,000 acre-feet ("AF") of development including 85,000 AF of transmountain diversions.
[5] This is equivalent to the "Zero Shoshone" future conditions Hydros scenario.

scenarios, when the Shoshone Water Rights are active, the Shoshone baseline demands were developed by the Colorado Water Conservation Board ("CWCB") in the published 2024 UCRM as a "Baseline" scenario to simulate current operations. These demands fluctuate based on daily historical records with demands ranging from 704 cfs (one turbine use as contemplated under the Agreement Concerning Reduction of Shoshone Call effective January 1, 2007 [the "2007 Call Relaxation Agreement"]) to 1,408 cfs.[6] As noted in the Hydros November 2024 *Shoshone Power Plant Water Rights Yield Assessment – Addendum* memorandum, it is important to highlight that the 2024 UCRM has not undergone a formal vetting process, and the outputs are likely less accurate than what would occur under real-time conditions.

The first part of the analysis evaluated the impact of the Shoshone Water Rights on average flows within the identified ISF reaches (such as an increase or decrease in cfs), while the second part of the analysis assessed the impact in meeting the ISFs at each location (number of days the ISF is met). This analysis was done for the current demand comparison (i.e., "Shoshone Off Current" scenario minus "Shoshone On Current" scenario) and the future demand comparison (i.e., "Shoshone Off Future" scenario minus "Shoshone On Future" scenario). It is important to note that the initial part of the analysis focused on average flows over the modeled period to represent the impacts of the Shoshone Water Rights: however, modeled daily flows vary significantly from these averages.

The analysis was limited to days when the Shoshone Water Rights were calling and therefore having an impact on river flows. Thus, the analysis excluded periods such as peak runoff when flows naturally remain above the 1,408 cfs demand of the Shoshone Water Rights. As seen in Figure 2, the Shoshone Call[7] is on more frequently in dry years and during the months of August, September, and October when natural river flows are low. Interestingly, in dry years, the Shoshone Call is on for nearly the entirety of every month from August through December. Therefore, this analysis focused on the dry calendar years of 1989, 1990, 2001, 2002, 2003, 2004, 2012, and 2013,[8] and particularly in the months of August, September, and October during those years, when flows are important to meet minimum ISFs. There is a total of 2,156 dry-year days when the Shoshone Water Rights are calling in the current scenarios and 2,189 days in the future scenarios.

[6] This is equivalent to the "Baseline" scenario in the November 2024 Shoshone Power Plant Water Rights Yield Assessment - Addendum memorandum prepared by Hydros. The scenarios where the Shoshone Call is off are referred to as "Zero Shoshone".

[7] For purposes of the analyses set forth in this memorandum, and unless otherwise defined or limited herein, the "Shoshone Call" means the in-priority demand for administration of water available under the senior and junior priorities for the Shoshone Water Rights (i.e., 1,408 cfs).

[8] The dry calendar year classification is the same as what was utilized by Hydros Consulting Inc. in their November 7, 2024, "Shoshone Power Plant Water Rights Yield Assessment – Addendum".

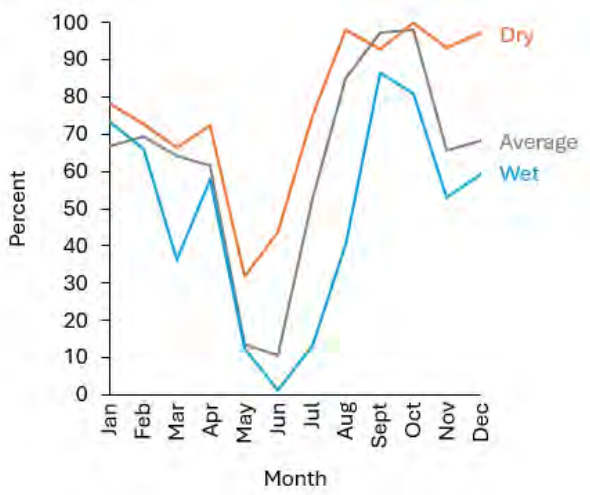


Figure 2 – Percent of modeled days per month when the Shoshone Call was on during dry, average, and wet years under current water demands (January 1988 through September 2013).

ISF Reaches Upstream of the Shoshone Power Plant

The following ISF reaches (Table 1) upstream of the Shoshone Power Plant were selected to better understand the benefits of the Shoshone Water Rights in protecting existing ISF flows. Flows were analyzed at the locations within the ISF reaches identified in Figure 3, below.

Table 1 – Analyzed ISF Reaches Upstream of the Shoshone Power Plant

ISF Reaches	ISF (CFS)	Start Date	End Date	Miles	Appropriation Date	Case Number
Colorado River – Kremmling to State Bridge	500	16-Sep	14-May	23.74	7/12/2011	5-11CW159
	600	15-May	31-Jul			
	750	1-Aug	15-Sep			
Eagle River – Lake Creek to Brush Creek	45	1-Oct	30-Apr	17.64	3/17/1980	5-80CW126
	110	1-May	30-Sep			

Figure 3 – Upstream ISF Reaches and the Associated USGS Gage Analyzed

Colorado River – Kremmling to State Bridge

The Colorado River – Kremmling to State Bridge ISF reach is located within the Upper Colorado River Wild and Scenic eligible sections. It is one of three ISF appropriations that were pursued as long-term protection measures of the Outstandingly Remarkable Values ("ORVs"). The Amended and Restated Upper Colorado River Wild & Scenic Stakeholder Group Management Plan (the "Management Plant")[9] lists the continuation of the Shoshone Water Rights as a long-term protection measure of the streamflow-influenced ORVs. The Management Plan states that the administration of the Shoshone Call generally results in higher streamflow through the upper Colorado River stream segments.

Several major reservoirs and transmountain diversion projects are located upstream of the Colorado River – Kremmling to State Bridge ISF reach, including but not limited to: the Colorado Big-Thompson Project (Adams Tunnel, Granby Reservoir, Willow Creek Reservoir, Green Mountain Reservoir); the Windy Gap Project (Windy Gap Reservoir and Pumps); the Moffat Collection System, Williams Fork Reservoir, Blue River Project (Dillon Reservoir, Roberts Tunnel); the Continental-Hoosier Project; and Wolford Mountain Reservoir. All of these reservoirs and transmountain diversion projects are junior in priority to the senior Shoshone Water Right and are subject to either curtailment or replacement (releases of water stored in reservoirs to allow continued out-of-priority diversions) to satisfy the senior Shoshone Call. Therefore, if the senior

[9] *See* Amended and Restated Upper Colorado River Wild & Scenic Stakeholder Group Management Plan, https://www.upcowildandscenic.com/uploads/1/3/5/3/135388668/amended_and_restated_sg_plan_july_2024.pdf

Shoshone Water Right was no longer exercised, lower flows would be expected throughout this ISF reach as the normal curtailment or replacement releases from reservoirs would be reduced.

Average flows in the Colorado River – Kremmling to State Bridge ISF reach (*see* Figure 4), analyzed at the Colorado River at Kremmling Gage (USGS gage ID 9058000), would be impacted the most in the Dry Years, Aug-Oct when flows would be reduced by 11% or 80 cfs if the Shoshone Water Rights were not exercised in both the current and future demand comparisons. This is equivalent to a reduction in the average flow volume of approximately 4,550 AF/month.

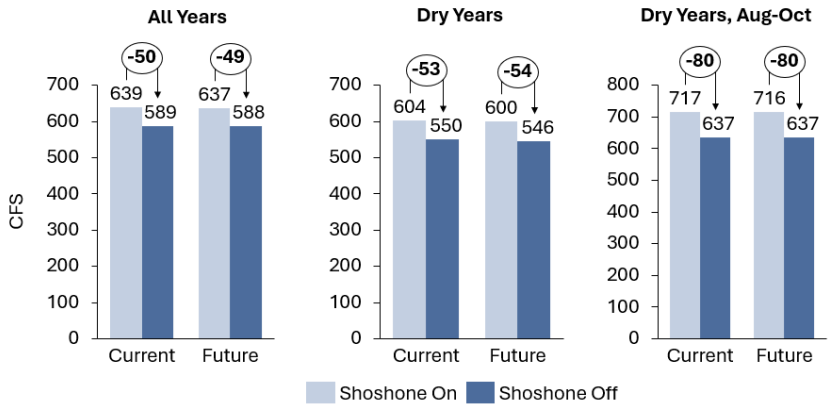


Figure 4 – Average flows at the Colorado River at Kremmling Gage

The reduction in flow in the absence of a Shoshone Call would also translate to fewer days when the ISF is met (*see* Figure 5). The impact to the ISF is highlighted during the Dry Years, Aug-Oct months, when the days the ISF is met are reduced by 31% in both the current and future demand comparisons.

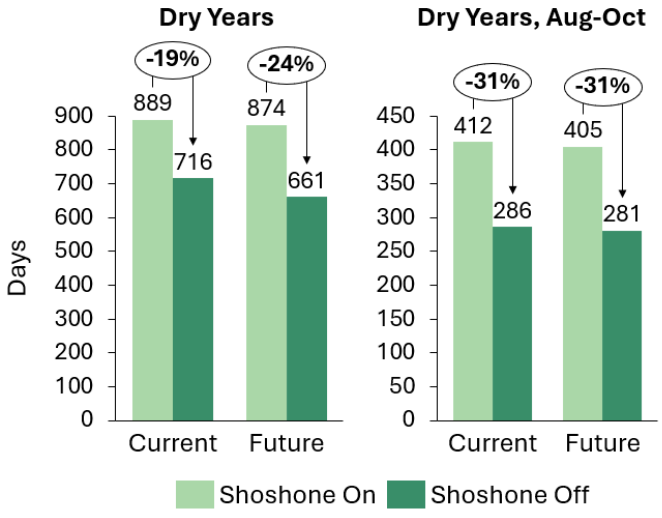


Figure 5 – Minimum ISF exceedance days at the Colorado River at Kremmling Gage

Eagle River – Lake Creek to Brush Creek

As described earlier, the exercise and administration of the Shoshone Water Rights results in an influential "pull" of water down the Colorado River, including through significant tributaries. The Eagle River is one such tributary and it has seven decreed ISFs that span nearly 50 miles. Average flows in this reach (*see* Figure 6), analyzed at the Eagle River near Wolcott Gage (USGS gage ID 394220106431500), would see the most significant average impacts if the Shoshone Water Rights were not exercised in Dry Years where flows would be reduced by 6 to 7 cfs (4% to 5% of the average annual flow) depending on the water demand. This is equivalent to an average reduction in flow volume of approximately 160 AF/month under both the current and future demand comparisons.

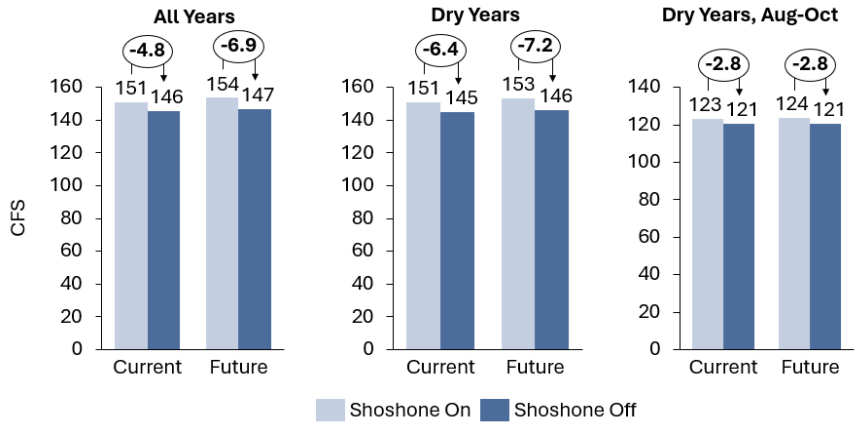


Figure 6 – Average flows at the Eagle River near Wolcott Gage

The reduction in flows from the absence of the Shoshone Call would not significantly impact the number of days the ISF is met and equates to a reduction of three days across the full eight years included in the Dry Years (*see* Figure 7). The ISF at this location is relatively small compared to measured flows. This is illustrated by the fact that in Dry Years, the ISF is met 88% of the time in the current and future demand scenarios.

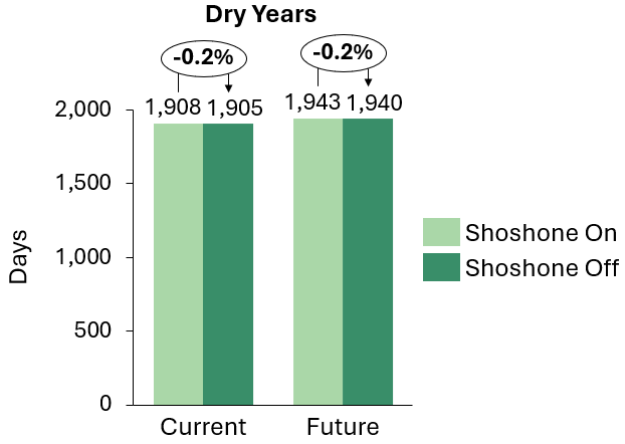


Figure 7 – Minimum ISF exceedance days at the Eagle River near Wolcott Gage

Summary of Upstream ISF Findings

Both upstream ISF reaches evaluated above experienced reduced flows when the Shoshone Water Rights were not exercised. The Colorado River from Kremmling to State Bridge reach saw losses of approximately 80 cfs in August through October in Dry Years, equating to a reduction in days that met the ISF by approximately 31% under current and future demand comparisons. On the Eagle River near Wolcott, the ISF was most impacted across Dry Years with reduced average flows of 6.4 and 7.2 cfs under current and future demand comparisons, respectively. Both reaches see significant responses to the loss of a Shoshone Call as shown in Figure 8 where each reach is shown to have a greater than 75% response in number of days with a realized reduced flow during the Dry Years, Aug-Oct months under current demands.

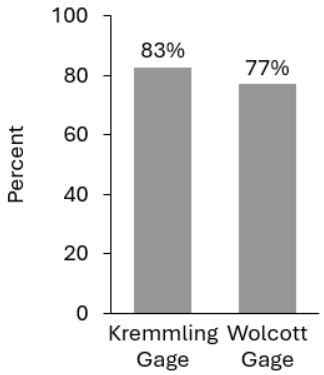


Figure 8 – Percent of August – October Dry Year days when flows are lower if the Shoshone Water Rights are not exercised, under current water demands

ISF Reaches Downstream of the Shoshone Power Plant – Roaring Fork River

This analysis also considered the impact (or lack thereof) that the absence of a Shoshone Call might have on the Roaring Fork River watershed. The absence of a Shoshone Call could cause the downstream "Cameo Call,"[10] to come on earlier and more often, thereby causing earlier administration of tributaries above Cameo including the Roaring Fork watershed. The increased Cameo Call would prompt curtailing transmountain diversions typically only subject to the Cameo Call such as relatively junior water rights including the Fry-Ark Project (Ruedi Reservoir and Boustead Tunnel) and occasionally even relatively senior rights like the Independence Pass Transmountain Diversion System ("Twin Lakes Tunnel"), as well as other West Slope water rights. To evaluate the impact of this occurrence, River District staff carried out a similar ISF analysis on two ISF reaches in the Roaring Fork watershed as detailed in Table 2 and shown in Figure 9.

[10] A conglomerate of significant and senior irrigation rights which divert from the Colorado River in the Grand Valley near Palisade, Colorado.

Table 2 – Analyzed ISF Reaches in the Roaring Fork River Watershed

ISF Reaches	ISF (CFS)	Start Date	End Date	Miles	Appropriation Date	Case Number
Roaring Fork River – Difficult Creek to Maroon Creek	32	1-Jan	31-Jul	8.67	1/14/1976	5-76W2948
Roaring Fork River – Frying Pan to Crystal River	75	1-Oct	31-Mar	13.46	11/8/1985	5-85CW639
	145	1-Apr	30-sept			

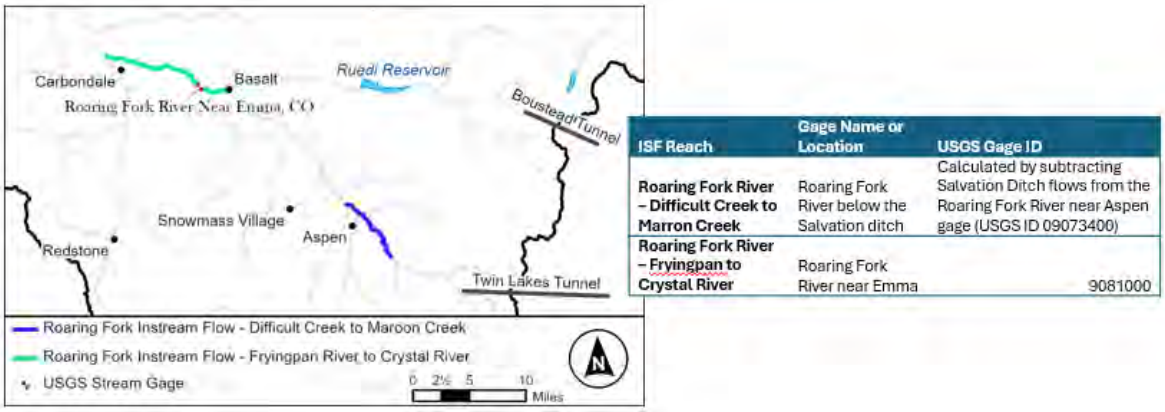


Figure 9 – Roaring Fork Watershed ISF Reaches, and the Associated USGS Gages/Locations Analyzed

Roaring Fork River – Difficult Creek to Maroon Creek

The Roaring Fork River – Difficult Creek to Maroon Creek ISF reach was selected because it is located on the Roaring Fork River immediately below the Salvation Ditch (WDID 3800981), where flows are frequently below the minimum ISF. At this location, if the Shoshone Water Rights were no longer exercised, average flows would increase slightly. During the Dry Years, Aug-Oct months, this increase would be the most impactful but would still be limited to approximately 0.5 cfs or 1% of total flow (*see* Figure 10) in both the current and future demand comparisons. This is equivalent to an average increase in flow volume of approximately 25 AF/month under both comparisons. It is important to highlight that during Dry Years, Aug-Oct months, most days (92%) would have the same flow regardless of whether the Shoshone Water Rights were calling. Interestingly, there would also be times when flows in the ISF would decrease if the Shoshone Water Rights were not exercised.

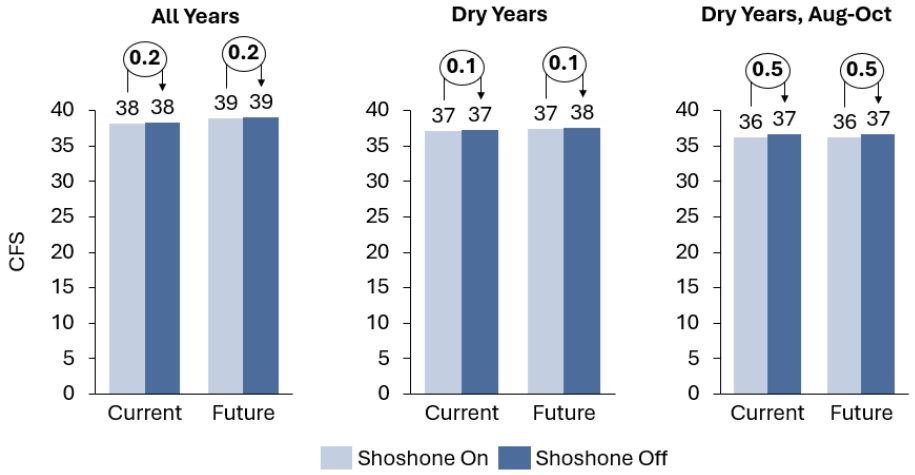


Figure 10 – Average flows at the Roaring Fork River below the Salvation Ditch location

The slight flow increases that are observed if the Shoshone Water Rights were not calling would only lead to an addition of 7 days (current demand comparison) and 6 days (future demand comparison) when the ISF is met across the eight years included in Dry Years, Aug-Oct months (*see* Figure 11). This is equivalent to an increase of approximately 1.5-1.7% of days when the ISF is met. Therefore, if the Shoshone Water Rights were no longer exercised, this reach would see, on average, a slight flow increase during a limited number of days, with only a few additional days when the ISF is met. This is because the Twin Lakes Tunnel is relatively senior in the system and would seldom be impacted by a Cameo Call beyond the administration already in place by the Cameo Call. Importantly, while the complete absence (e.g., future abandonment) of the Shoshone Water Rights could result in a small, modeled increase of 0.5 cfs of flow in the Upper Roaring Fork River, the maintenance of the historical Shoshone Call regime would not result in any change from existing conditions.

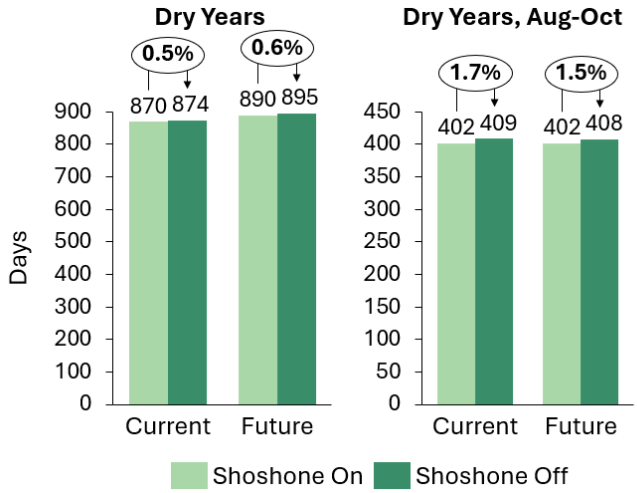


Figure 11 – Minimum ISF exceedance days at the Roaring Fork River below the Salvation Ditch

Roaring Fork River – Fryingpan River to Crystal River

The Roaring Fork River – Fryingpan River to Crystal River ISF reach was selected to capture impacts on the Roaring Fork River from the Fryingpan River where the Fry-Ark Project is mostly located. At this location, if the Shoshone Water Rights were no longer exercised, flows would increase on average by less than 1% (3 cfs) in Dry Years under both the current and future demand comparisons (*see* Figure 12). This is equivalent to an increase in average flow volume of approximately 80 AF/month across Dry Years in the current and future demand comparisons. Although the average flows would slightly increase in Dry Years with the Shoshone Call offline, only 27% of the days were shown to have higher flows in the current demand comparison and 25% in the future demand comparison. Most days (approximately 67% in both comparisons) realized lower flows when the Shoshone Water Rights were not calling.

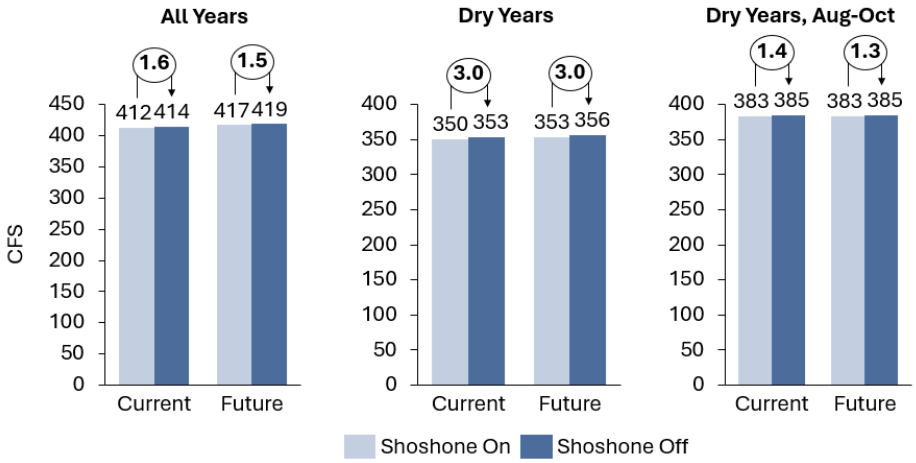


Figure 12 – Average flows at the Roaring Fork River near Emma gage

The average flow increases from the removal of the Shoshone Call would have no impact on the days the ISF is met as seen in Figure 13. The ISF at this location is relatively small compared to typical flows such that the ISF has never been the source of an administrative call on the river. This is illustrated by the fact that in Dry Years, the ISF is modeled to be met 99% of the time in the current and future scenarios.

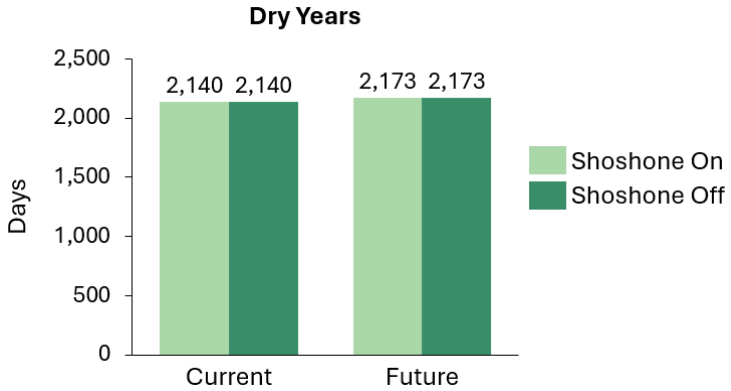


Figure 13 – Minimum ISF exceedance days at the Roaring Fork River near Emma gage

Therefore, while there would be a small increase in flow in the Roaring Fork Watershed if the Shoshone Water Rights were no longer exercised, the increases would be minor. In fact, at the Roaring Fork River - Fryingpan to Crystal River ISF reach, most dry days would see a decrease in river flows.

ISF Reaches Downstream of the Shoshone Power Plant –15-Mile Reach

The benefits of maintaining the Shoshone Water Rights are documented in the November 7, 2024, "Shoshone Power Plant Water Rights Yield Assessment – Addendum" memorandum prepared by Hydros.

Downstream ISF Summary Findings

Without the Shoshone Call, tributaries such as the Roaring Fork River are modeled to see increased impacts from the Cameo Call, which are shown to have variable effects. In the upper reach of the Roaring Fork River, below the Salvation Ditch, flows were shown to have limited increases in flow of less than 0.5 cfs which leads to 6 to 7 additional days of meeting the ISF in Dry Years, Aug-Oct. Similar results were found along the Roaring Fork in the Fryingpan to Crystal River ISF reach with limited increases in flow of up to 3 cfs (less than 1% of total flow) with no associated increase in number of days the ISF is met. Modeling at both sites found variable results with some results finding reduced flows without the Shoshone Call on.

Conclusion

Four separate ISF reaches were evaluated in this memorandum to determine whether and how the Shoshone Call influences hydrology through the selected ISF reaches and how that impacts the number of days each ISF is met. The ISF reaches studied herein include tributaries as well as the mainstem Colorado River and are representative of the range of influence of the Shoshone Call across the basin. Both ISF reaches studied above the Shoshone Reach show average decreases in flow with the Shoshone Call offline, particularly in Dry Years and the late irrigation season months of August through October of Dry Years. For example, average monthly decreases in flows at the Colorado River below Kremmling were shown to be as much as 80 cfs or approximately 11% of the flow, corresponding to an average elimination of approximately 4,550 AF/month in the absence of the Shoshone Call. Findings at Eagle River had similar results, although with relatively smaller flow impacts.

Downstream ISF reaches evaluated focused on the Roaring Fork River at two locations: (1) a segment located near the headwaters below the Salvation Ditch, which runs through the City of Aspen, and (2) a segment located between the Fryingpan River and Crystal River confluence. Findings at these locations showed average increases in flows without the Shoshone Call due to the increased downstream Cameo Call. The analysis found that the Upper Roaring Fork River flows increased up to an average of 0.5 cfs (25 AF/month) and up to an average of 3.0 cfs (80 AF/month) at the Lower Roaring Fork River reach in the August-October months of Dry Years. Only the Upper Roaring Fork River ISF reach experienced additional days of meeting the ISF due to the increase in flows and that was limited to a handful of days across the August through October months of the eight Dry Years evaluated. Much larger and more consistent impacts downstream

of the Shoshone Power Plant through the 15-Mile Reach ISF were examined in the technical report prepared by Hydros.

Overall, the Shoshone Call has been found to support both upstream ISF reaches in meeting the target flows, especially in dry years and in critical months during the late irrigation season while having minimal influence on tributaries downstream of the Shoshone Power Plant such as on the Roaring Fork River.

An Act

HOUSE BILL 24-1435

BY REPRESENTATIVE(S) McCormick and Catlin, Amabile, Bird, Boesenecker, Brown, Daugherty, Duran, Froelich, Hamrick, Jodeh, Joseph, Kipp, Lieder, Lindstedt, Lukens, Lynch, Marshall, Marvin, Mauro, McLachlan, Ortiz, Rutinel, Sirota, Snyder, Story, Taggart, Titone, Velasco, Weissman, Young, McCluskie;
also SENATOR(S) Roberts and Simpson, Baisley, Bridges, Buckner, Cutter, Fields, Gardner, Gonzales, Jaquez Lewis, Kirkmeyer, Liston, Michaelson Jenet, Mullica, Pelton B., Pelton R., Priola, Van Winkle, Will, Winter F., Fenberg.

CONCERNING THE FUNDING OF COLORADO WATER CONSERVATION BOARD PROJECTS, AND, IN CONNECTION THEREWITH, MAKING AN APPROPRIATION.

Be it enacted by the General Assembly of the State of Colorado:

SECTION 1. Continuation of the satellite monitoring system - operation and maintenance - appropriation. (1) For the 2024-25 state fiscal year, $380,000 is appropriated to the department of natural resources for use by the division of water resources. This appropriation is from the Colorado water conservation board construction fund created in section 37-60-121, C.R.S. To implement this section, the division of water

Capital letters or bold & italic numbers indicate new material added to existing law; dashes through words or numbers indicate deletions from existing law and such material is not part of the act.

resources may use this appropriation to install, maintain, and operate satellite-monitored stream gauges and lysimeters for water rights administration and data collection pursuant to section 37-80-102 (10), C.R.S.

(2) The money appropriated in subsection (1) of this section remains available for the designated purposes until it is fully expended.

SECTION 2. Continuation of the Colorado floodplain map modernization program - appropriation. (1) For the 2024-25 state fiscal year, $1,000,000 is appropriated to the department of natural resources for use by the Colorado water conservation board. This appropriation is from the Colorado water conservation board construction fund created in section 37-60-121, C.R.S. To implement this section, the Colorado water conservation board may use this appropriation to continue to assist with the preparation of revised and improved floodplain studies and maps for communities throughout Colorado and participate in federally sponsored floodplain map modernization activities.

(2) The money appropriated in subsection (1) of this section remains available for the designated purposes until it is fully expended.

SECTION 3. Continuation of the weather modification permitting program - appropriation. (1) For the 2024-25 state fiscal year, $500,000 is appropriated to the department of natural resources for use by the Colorado water conservation board. This appropriation is from the Colorado water conservation board construction fund created in section 37-60-121, C.R.S. To implement this section, the Colorado water conservation board may use this appropriation to assist water conservation and conservancy districts with the development of cloud seeding programs to provide benefits to recreation, streams, and reservoirs through snowpack enhancement.

(2) The money appropriated in subsection (1) of this section remains available for the designated purposes until it is fully expended.

SECTION 4. Restoration of litigation fund cash balance - transfer. On July 1, 2024, the state treasurer shall transfer $2,000,000, or so much thereof as may be necessary to restore the balance of the litigation fund to $2,000,000, from the unreserved cash in the Colorado water

conservation board construction fund created in section 37-60-121, C.R.S., to the litigation fund created in section 37-60-121 (2.5), C.R.S., to assist in addressing legal issues associated with compact compliance or any other litigation activities as specified under section 37-60-121, C.R.S.

SECTION 5. Continuation of the Colorado Mesonet project - appropriation. (1) For the 2024-25 state fiscal year, $200,000 is appropriated to the department of natural resources for use by the Colorado water conservation board. This appropriation is from the Colorado water conservation board construction fund created in section 37-60-121, C.R.S. To implement this section, the Colorado water conservation board may use this appropriation to support the Colorado Mesonet, including for the following activities: Operation, maintenance, travel, communications, and database and website management for temperature and precipitation stations.

(2) The money appropriated in subsection (1) of this section remains available for the designated purposes until it is fully expended.

SECTION 6. Continuation of the water forecasting partnership project - appropriation. (1) For the 2024-25 state fiscal year, $2,000,000 is appropriated to the department of natural resources for use by the Colorado water conservation board. This appropriation is from the Colorado water conservation board construction fund created in section 37-60-121, C.R.S. To implement this section, the Colorado water conservation board may use this appropriation to support the development of new ground and aerial remote sensing data, to develop hydrologic modeling practices, to provide reliable volumetric water supply forecasting, and to provide better characterization of snowpack.

(2) The money appropriated in subsection (1) of this section remains available for the designated purposes until it is fully expended.

SECTION 7. Continuation of the modeling and data analyses for the upper Colorado river commission - appropriation. (1) For the 2024-25 state fiscal year, $500,000 is appropriated to the department of natural resources for use by the Colorado water conservation board. This appropriation is from the Colorado water conservation board construction fund created in section 37-60-121, C.R.S. To implement this section, the Colorado water conservation board may use this appropriation to provide

support to the upper Colorado river commission's interstate planning and negotiation efforts, including the following modeling and data analyses: Streamgaging and streamflow, runoff forecasting, consumptive use, reservoir operations and evaporation, and drought contingency planning.

(2) The money appropriated in subsection (1) of this section remains available for the designated purposes until it is fully expended.

SECTION 8. Statewide diversion telemetry project - appropriation. (1) For the 2024-25 state fiscal year, $1,827,500 is appropriated to the department of natural resources for use by the division of water resources. This appropriation is from the Colorado water conservation board construction fund created in section 37-60-121, C.R.S. To implement this section, the division of water resources may use this appropriation to fund the installation of telemetry equipment at sites across Colorado.

(2) The money appropriated in subsection (1) of this section remains available for the designated purposes until it is fully expended.

SECTION 9. Southern high plains groundwater study update - appropriation. (1) For the 2024-25 state fiscal year, $250,000 is appropriated to the department of natural resources for use by the Colorado water conservation board. This appropriation is from the Colorado water conservation board construction fund created in section 37-60-121, C.R.S. To implement this section, the Colorado water conservation board may use this appropriation to update a 2002 study in order to provide scenario analyses and community facilitation to establish groundwater resource goals for residents of the southern high plains of Colorado.

(2) The money appropriated in subsection (1) of this section remains available for the designated purposes until it is fully expended or the study update is complete.

SECTION 10. Continuation of the state turf replacement program - transfer - appropriation. (1) On July 1, 2024, the state treasurer shall transfer $2,000,000 from the Colorado water conservation board construction fund created in section 37-60-121, C.R.S., to the turf replacement fund created in section 37-60-135 (6)(a)(I), C.R.S., to finance the state turf replacement program created in section 37-60-135, C.R.S.

(2) (a) For the 2024-25 state fiscal year, $2,000,000 is appropriated to the department of natural resources for use by the Colorado water conservation board. This appropriation is from the turf replacement fund created in section 37-60-135 (6)(a)(I), C.R.S. To implement this section, the Colorado water conservation board may use this appropriation for the state turf replacement program pursuant to section 37-60-135, C.R.S., including to cover the direct and indirect costs of administering one or more turf replacement programs.

(b) The money appropriated in subsection (2)(a) of this section remains available for the designated purposes until June 30, 2028.

SECTION 11. Drought resilience investment - appropriation. (1) For the 2024-25 state fiscal year, $4,000,000 is appropriated to the department of natural resources for use by the Colorado water conservation board. This appropriation is from the Colorado water conservation board construction fund created in section 37-60-121, C.R.S. To implement this section, the Colorado water conservation board may use this appropriation:

(a) To advance projects within and complementary to the 2023 state water plan that support drought planning, practical implementation of drought mitigation techniques, education, guidance, and training; and

(b) For projects that focus on the following areas: Drought resilience workshops, state water plan outreach campaign, water loss prevention and validator training, adaptive and critical drought projects, storage analysis opportunities and alternatives, and development of a water conservation handbook.

(2) The money appropriated in subsection (1) of this section remains available for the designated purposes until it is fully expended.

SECTION 12. Increased water project loan authorization - Windy Gap firming project. (1) Pursuant to section 37-60-122 (1)(b), C.R.S., the Colorado water conservation board is authorized to make loans in the amount of up to $155,650,000 from the Colorado water conservation board construction fund created in section 37-60-121, C.R.S., to the Windy Gap firming project water activity enterprise for the completion of the Windy Gap firming project.

(2) The money authorized in subsection (1) of this section remains available for the designated purposes until it is fully expended.

(3) The Colorado water conservation board may make loans for the project specified in subsection (1) of this section from money that is or may become available to the Colorado water conservation board construction fund. The total amount of the loans will be in the amount listed in subsection (1) of this section plus or minus the amount, if any, as may be justified by reason of ordinary fluctuations in construction costs as indicated by the engineering cost indices applicable to the types of construction required for the project or as may be justified by reason of changes in the plans for the project due to differing or unforeseen site conditions, errors or omissions in the plans and specifications, changes instituted by regulatory agencies, or changes in material quantities beyond contract limits.

SECTION 13. Northern integrated supply project - loan authorization. (1) Pursuant to section 39-29-109 (2)(a)(I.5), C.R.S., the Colorado water conservation board is authorized to make loans in the amount of up to $101,000,000 from the severance tax perpetual base fund created in section 39-29-109 (2)(a), C.R.S., to the northern integrated supply project water activity enterprise owned by the northern Colorado water conservancy district to develop a new regional water supply project. The project will provide new water supplies annually for eleven communities and four water districts in the northern front range.

(2) The money authorized in subsection (1) of this section remains available for the designated purposes until it is fully expended.

(3) The Colorado water conservation board may make loans for the project specified in subsection (1) of this section from money that is or may become available to the severance tax perpetual base fund. The total amount of the loans will be in the amount listed in subsection (1) of this section plus or minus the amount, if any, as may be justified by reason of ordinary fluctuations in construction costs applicable to the types of construction required for the project or as may be justified by reason of changes in the plans for the project due to differing or unforeseen site conditions, errors or omissions in the plans and specifications, changes instituted by regulatory agencies, or changes in material quantities beyond contract limits.

SECTION 14. Colorado river water conservation district -

purchase of Shoshone power plant water rights - transfer - appropriation. (1) On July 1, 2024, the state treasurer shall transfer $20,000,000 from the severance tax perpetual base fund created in section 39-29-109 (2)(a), C.R.S., to the Colorado water conservation board construction fund created in section 37-60-121, C.R.S., to support the purchase and sale agreement between the Colorado river water conservation district and the public service company of Colorado for the purchase of the water rights associated with the Shoshone power plant.

(2) (a) For the 2024-25 state fiscal year, $20,000,000 is appropriated to the department of natural resources for use by the Colorado water conservation board. This appropriation is from the Colorado water conservation board construction fund created in section 37-60-121, C.R.S. To implement this subsection (2)(a), the Colorado water conservation board may use this appropriation to partner with the Colorado river water conservation district in the purchase of the water rights owned by the public service company of Colorado and currently used for the operation of the Shoshone power plant. The Colorado water conservation board shall vote to release the money to the Colorado river water conservation district after confirming that the closing conditions of the purchase and sale agreement between the Colorado river water conservation district and the public service company of Colorado have been met.

(b) The money appropriated in subsection (2)(a) of this section remains available for the designated purposes until June 30, 2031.

SECTION 15. Grant-making for projects that assist in implementing the state water plan - appropriation. (1) For the 2024-25 state fiscal year, $23,300,000 is appropriated to the department of natural resources for use by the Colorado water conservation board. This appropriation is from the water plan implementation cash fund created in section 37-60-123.3 (1)(a), C.R.S. To implement this subsection (1), the Colorado water conservation board may use this appropriation for grant-making for projects that assist in the implementation of the state water plan pursuant to section 37-60-106.3 (6), C.R.S., through the Colorado water conservation board's application and guidelines process.

(2) The money appropriated in subsection (1) of this section remains available for the designated purposes until it is fully expended.

SECTION 16. In Colorado Revised Statutes, 24-75-228, **add** (2.5)(a.5) as follows:

24-75-228. Economic recovery and relief cash fund - creation - allowable uses - interim task force - report - legislative declaration - definitions - repeal. (2.5) (a.5) NOTWITHSTANDING SUBSECTIONS (2.5)(a)(IV) AND (2.5)(a)(V) OF THIS SECTION, ON OR AFTER JULY 1, 2024, ANY MONEY TRANSFERRED BY THE STATE TREASURER TO THE COLORADO WATER CONSERVATION BOARD CONSTRUCTION FUND, CREATED IN SECTION 37-60-121 (1)(a), PURSUANT TO SUBSECTIONS (2.5)(a)(IV) AND (2.5)(a)(V) OF THIS SECTION MAY BE EXPENDED FOR ANY OF THE PURPOSES SPECIFIED IN SECTION 37-60-121 (13) OR (14).

SECTION 17. In Colorado Revised Statutes, 37-60-121, **add** (15) as follows:

37-60-121. Colorado water conservation board construction fund - creation - nature of fund - funds for investigations - contributions - use for augmenting the general fund - funds created - rules - repeal. (15) NOTWITHSTANDING SUBSECTIONS (13) AND (14) OF THIS SECTION, ON OR AFTER JULY 1, 2024, THE BOARD MAY USE THE MONEY TRANSFERRED PURSUANT TO SECTION 24-75-228 (2.5)(a)(IV) AND (2.5)(a)(V) FOR ANY OF THE PURPOSES SPECIFIED IN SUBSECTION (13) OR (14) OF THIS SECTION.

SECTION 18. Safety clause. The general assembly finds, determines, and declares that this act is necessary for the immediate preservation of the public peace, health, or safety or for appropriations for

the support and maintenance of the departments of the state and state institutions.

Julie McCluskie
SPEAKER OF THE HOUSE
OF REPRESENTATIVES

Steve Fenberg
PRESIDENT OF
THE SENATE

Robin Jones
CHIEF CLERK OF THE HOUSE
OF REPRESENTATIVES

Cindi L. Markwell
SECRETARY OF
THE SENATE

APPROVED Wednesday May 29th 2024 at 10:30 AM
(Date and Time)

Jared S. Polis
GOVERNOR OF THE STATE OF COLORADO

COLORADO RIVER DISTRICT
PROTECTING WESTERN COLORADO WATER SINCE 1937

Shoshone Water Rights Preservation Project

Summary of Financial Commitments

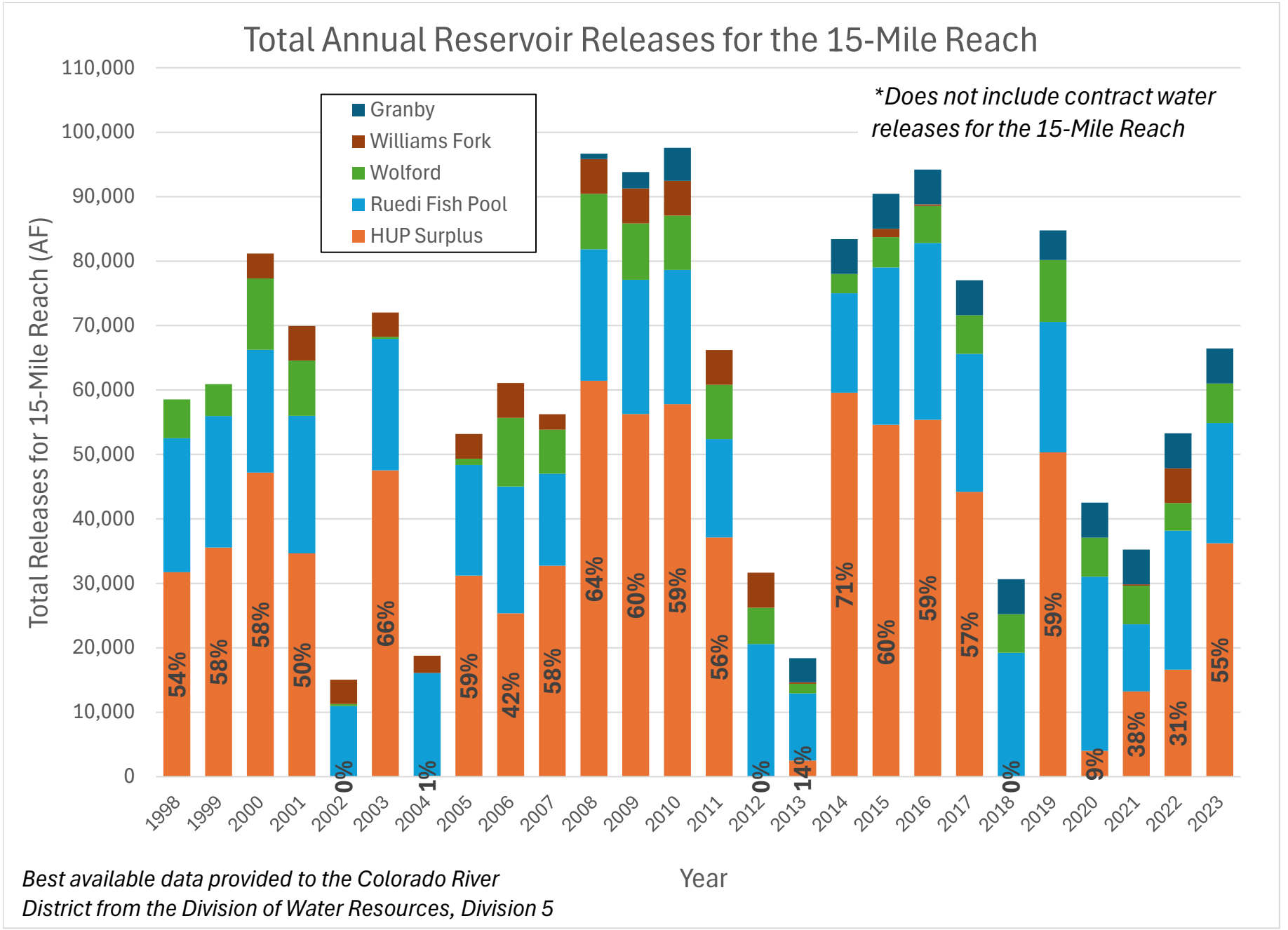
The funding strategy to acquire and permanently protect the Shoshone Water Rights relies on a diverse partnership of local, state, and federal funding sources. Table 1 below summarizes current funding commitments of over $97 million in formal contributions, awards, and commitments. The Colorado River District is continuing efforts to secure local funding with ongoing conversations from additional local and regional partners.

Table 1: Funding Commitments (as of August 1, 2025)

Bureau of Reclamation (Upper Basin Environmental Drought Mitigation Program)	$40 million
State of Colorado (HB24-1435)	$20 million
Colorado River District	$20 million
Garfield County	$3 million
Eagle County	$2 million
City of Glenwood Springs	$2 million
Ute Water Conservancy District	$2 million
Eagle River Water and Sanitation District and Upper Eagle Regional Water Authority	$1 million
Grand County	$1 million
City of Grand Junction	$1 million
Mesa County	$1 million
Pitkin County	$1 million
Summit County	$1 million
Colorado Mesa University	$500,000
Clifton Water District	$250,000
Grand Valley Irrigation Company	$250,000
Basalt Water Conservancy District	$100,000
Grand Valley Power	$100,000
Grand Valley Water Users Association	$100,000
Middle Park Water Conservancy District	$100,000

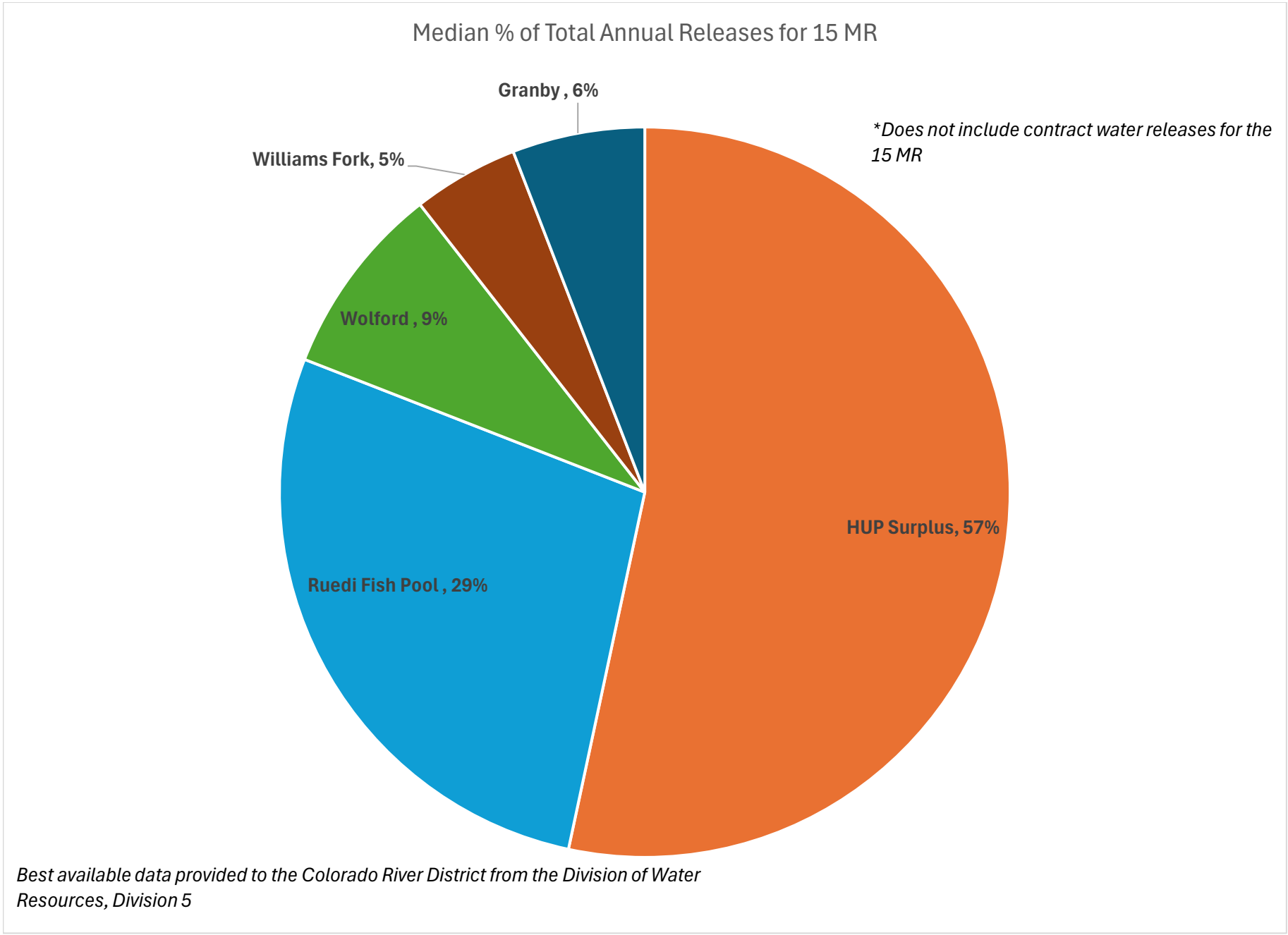
Shoshone Water Rights Preservation Project
Summary of Financial Commitments

Orchard Mesa Irrigation District	$100,000
City of Rifle	$100,000
Snowmass Water & Sanitation District	$100,000
Town of New Castle	$100,000
Town of Silverthorne	$100,000
Town of Silt	$75,000
Mesa County Irrigation District	$50,000
Palisade Irrigation District	$50,000
West Divide Water Conservancy District	$50,000
Kobe Water Authority	$25,000
Town of Parachute	$25,000
Town of Basalt	$10,000
Town of Palisade	$10,000
De Beque Plateau Valley Soil Conservation District	$5,000
Town of De Beque	$1,500
Total:	**$97.2M**



Best available data provided to the Colorado River District from the Division of Water Resources, Division 5

CRD-35
Chart - Median % of Total Annual Releases for 15-Mile Reach
[CWCB ISF HEARING]



Best available data provided to the Colorado River District from the Division of Water Resources, Division 5

Shoshone Water Rights Preservation Project

Upper Basin Environmental Drought Mitigation, Bucket 2 Ecosystem ("B2E") Financial Assistance Program

Project Name: Shoshone Water Rights Preservation Project

Applicant: Colorado River Water Conservation District
201 Centennial Street, Suite 200, Glenwood Springs, CO 81601

Project Manager: Amy Moyer, Director of Strategic Partnerships
201 Centennial Street, Suite 200, Glenwood Springs, CO 81601
Email: amoyer@crwcd.org
Telephone: (970) 930-4186

Date: November 13, 2024

Application Checklist

☑	Project Abstract Summary
☑	SF-424: Application for Federal Assistance, Office of Management and Budget
☑	SF-424A: Budget Information – Non-Construction Programs
☑	SF-424B: Assurances – Non-Construction Programs
☑	Budget Proposal & Narrative
☑	Unique Entity Identifier (UEI): JXCRNNKCHPE5
☑	Environmental and Cultural Resources Considerations
☑	Conflict of Interest Disclosure Statement
☑	SF-LLL: Disclosure of Lobbying Activities
☑	Technical Proposal
☑	Project Location & Project Maps
☑	Letters of Support
☑	Proof of Financial Commitments

Note: All required documents above are viewable by clicking on the subject title.

The Colorado River at the Shoshone Hydroelectric Power Plant

GO BACK TO CHECKLIST

Technical Proposal: Table of Contents

Appendices:

Note: All required documents above are viewable by clicking on the appendix title.

Executive Summary

Shoshone Water Rights Preservation Project

Project Description: For over a century, the Shoshone Hydroelectric Power Plant (the "Shoshone Power Plant"), a unique "run-of-river" power plant located in Glenwood Canyon, Colorado, has harnessed Colorado River water to generate hydroelectric power by means of two of the largest, and most senior non-consumptive-use water rights in the Upper Colorado River Basin (the "Shoshone Water Rights"). The long-standing exercise of the Shoshone Water Rights has led to the creation of a historical flow regime which extends down the Upper Colorado River's mainstem, providing vital ecosystem, habitat, recreational, agricultural, and economic benefits. The Shoshone Water Rights are fundamentally unique, because while other types of water rights deplete flows in the river, the Shoshone Water Rights maintain river flows, and they protect the river from additional junior, upstream depletions.

In December 2023, the Colorado River District signed a Purchase and Sale Agreement (the "PSA", Appendix 4) with Public Service Company of Colorado ("PSCo") to acquire and permanently protect the Shoshone Water Rights for $99 million. The purpose of the Shoshone Water Rights Preservation Project (the "Project") is to allow the water rights to be used perpetually for instream flow use[1] by the Colorado Water Conservation Board ("CWCB") in a manner that mimics the historical use of the water rights for hydropower generation, thereby protecting critical resources for future generations across the state.

Project Need: Over the last two decades, the Shoshone Power Plant has required additional and more intensive maintenance due to the plant's age and has been subject to a series of natural hazards which have resulted in prolonged outages in operations. When the Shoshone Power Plant is not operating, the Shoshone Water Rights cannot be exercised and water otherwise flowing in the river becomes available for diversion by upstream junior water rights—many of which are 100% consumptive to the stream system—thus adversely impacting the historical flow regime. Existing agreements which in some instances are intended to replicate the flows provided by the Shoshone Water Rights are inadequate as a long-term mechanism to protect these critical water rights. And while PSCo has no current plans to cease operations at the Shoshone Power Plant, unless the Shoshone Water Rights are acquired, changed, and made available for instream flow use, the existence of the Shoshone Water Rights would terminate if and when the Shoshone Power Plant is decommissioned, and the historical flow regime created by the exercise of the Shoshone Water Rights on the Upper Colorado River would also cease to exist.

As a result of rising temperatures, changing conditions, and more frequent periods of drought throughout the Upper Colorado River Basin, any reduction or elimination of the exercise of the Shoshone Water Rights would lead to lower flows in drought years, with negative impacts on

[1] As non-consumptive, in-channel, or in-lake use water rights, Colorado's instream flow water rights are intended to preserve, and in some cases improve, the natural environment to a reasonable decree. C.R.S. § 37-92-102(3).

aquatic ecosystems, as well as the agricultural, municipal, environmental, and recreational uses of the river upstream and downstream of the Shoshone Power Plant.

Anticipated Results and Benefits: The Upper Colorado River watershed is a region of immense ecosystem value supported by numerous federal and state designations, including Gold Medal waters, outstanding waters, and Wild and Scenic Eligible and Suitable reaches.[2] When the Shoshone Water Rights are administered, nearly 380 miles of the Colorado River system from the headwaters to Lake Powell experience a benefit. This benefit is more significant during drought conditions when flows are needed to preserve aquatic habitat necessary to protect threatened and endangered fish species while also providing much-needed water security to communities across Colorado's West Slope (*see*, *e.g.*, Section 2.2., below).

Project Timeline: The estimated completion date of the Project is December 2027, which is described in more detail in the Project Description and Implementation in Section 3, below.

Requested B2E Funding: $40,000,000.00

Anticipated Budget:

Funding Partner	**Funding Amount**
Bureau of Reclamation	$40 Million
Colorado River Water Conservation District (applicant)[1]	$20 Million
State of Colorado[2]	$20 Million
Local Partners[3]	$19 Million
Total Project Cost	**$99 Million**

1. In December 2023, the Colorado River District's Board of Directors formally committed $20 million.
2. HB24-1435, signed into law May 29, 2024, appropriated $20 million.
3. As of the date of this application, 26 water entities, local governments, and regional partners have committed $16 million (of the $19 million projected). The River District anticipates securing additional commitments soon.

Following the execution of the PSA in December 2023, the Colorado River District proceeded expeditiously in completing the necessary closing conditions described in the PSA. As a result of this proactive approach, the Colorado River District is confident that the Project can be completed by December 2027, and certainly no later than September 30, 2031. As of November 2024, the Project is bolstered by formal funding commitments of over half the purchase price, strong political and local support, and numerous technical analyses, the totality of which provides a strong foundation to complete the Project within the required timelines.

[2] "Gold Medal" waters are high quality fisheries that consistently provide trout standing stock of at least 60 pounds per acre and produce an average of at least 12 "quality trout" per acre. "Outstanding waters" are streams with high water quality and exceptional recreational or ecological attributes. "Wild and Scenic Eligible and Suitable Reaches" include areas of river that are free-flowing and have at least one outstandingly remarkable value.

1. Introduction and Project Map

The Shoshone Power Plant is owned and operated by PSCo, a subsidiary of Xcel Energy, Inc. ("Xcel"), and produces 15 megawatts of electricity, enough to serve approximately 15,000 customers. The Shoshone Power Plant produces hydroelectric power by means of the Shoshone Water Rights, which include the 1902 senior Shoshone Water Right in the amount of 1,250 cubic feet per second ("cfs"), and the 1929 junior Shoshone Water Right in the amount of 158 cfs. *See* Appendix 14.a. The Shoshone Water Rights enable PSCo to divert water from the Colorado River on a year-round basis to operate the power plant and, because these water rights are by nature non-consumptive, all diverted water is returned to the Colorado River. *Id.*

Figure 1: Shoshone Power Plant

The Shoshone Power Plant diverts water from the Colorado River via the "Shoshone Diversion Dam" which is located upstream of the Shoshone Power Plant. Once water is diverted from the river at the Shoshone Diversion Dam, it is conveyed for approximately 2.4 miles through a tunnel in the canyon walls, before dropping 167 feet through two turbines and returning to the Colorado River via discharge outlets located just below the Shoshone Power Plant. Although this unique project is centered around the Shoshone Power Plant and the 2.4 miles of river in the Colorado River that will directly benefit from the protections afforded by the Project, the geographic distribution of benefits from the Project are numerous and far-reaching throughout the Colorado River Basin. *See* Appendix 1, Map 1.

Recently, the Shoshone Power Plant has been subject to outages due to a series of natural hazards and the additional maintenance required to support the 115-year-old power plant. When such outages occur, the Shoshone Power Plant cannot operate or is only capable of operating at a reduced level. Under these circumstances, PSCo cannot fully exercise the Shoshone Water Rights under Colorado law. The increasing frequency and duration of outages at the Shoshone Power Plant—and the potential of a permanent decommissioning at some time in the future—places the continued existence of the Shoshone Water Rights in jeopardy of reduction or abandonment. This risk exists despite the Shoshone Outage Protocol Agreement (#13XX6C0129) dated June 27, 2016 (the "ShOP Agreement," Appendix 14.d.), which acts as a temporary stop-gap measure to bring some, but not all, of the flows attributable to the Shoshone Water Rights down the river when there is a plant outage. Unlike the ShOP Agreement, which has a limited term and can be terminated at any time, the Project is designed to maintain the Shoshone Water Rights in perpetuity and, by doing so, ensure the permanent protection of the historical flow regime and the numerous ecosystem and habitat benefits attendant thereto. The inability of the ShOP Agreement to sufficiently command and protect the Shoshone flows is described below in Section 3.2.1.

Figure 2: Shoshone Diversion Dam

The Project aims to protect the historical administration of the Shoshone Water Rights (the "Shoshone Call") through a coordinated effort with PSCo and the State of Colorado to change the water rights to include an alternate use of the water rights for instream flow purposes while maintaining their senior priorities consistent with Colorado law. The Project will preserve certainty around the administration of a series of federal laws, water court decrees, agreements, and protocols which—unlike the ShOP Agreement—are permanent and, in some cases, are binding on the entire stream system. *See* Section 3.2.1, below; *see also*, *e.g.*, Appendix 14.c. The practical effect is that the Project will ensure the continuation of historical stream conditions in the mainstem of the Upper Colorado River Basin regardless of whether the Shoshone Power Plant is operational, providing much-needed resiliency in the face of an uncertain water future. More simply, the continued exercise of the Shoshone Water Rights prevents significant, additional depletions from the Colorado River Basin that can automatically occur in the absence of the Shoshone Water Rights by virtue of Colorado's prior appropriation system and without additional construction or the need for state and/or federal permits. *See* Appendix 1, Map 3.

In recognition of B2E's purpose of providing funding for ecosystem and habitat restoration projects that provide environmental benefits, the River District is pleased to submit this application and offers the following technical proposal in support of its funding request. The Project is unique in its action and project type by offering a watershed-scale approach to restoring streams, improving water quality, and creating connectivity through an acquisition that permanently protects river flows rather than through a more traditional stream restoration or water efficiency approach. This application addresses each of the evaluation considerations outlined in the B2E Request for Applications (the "RFA"), including the requested certifications, disclosures, and other forms identified in the RFA.

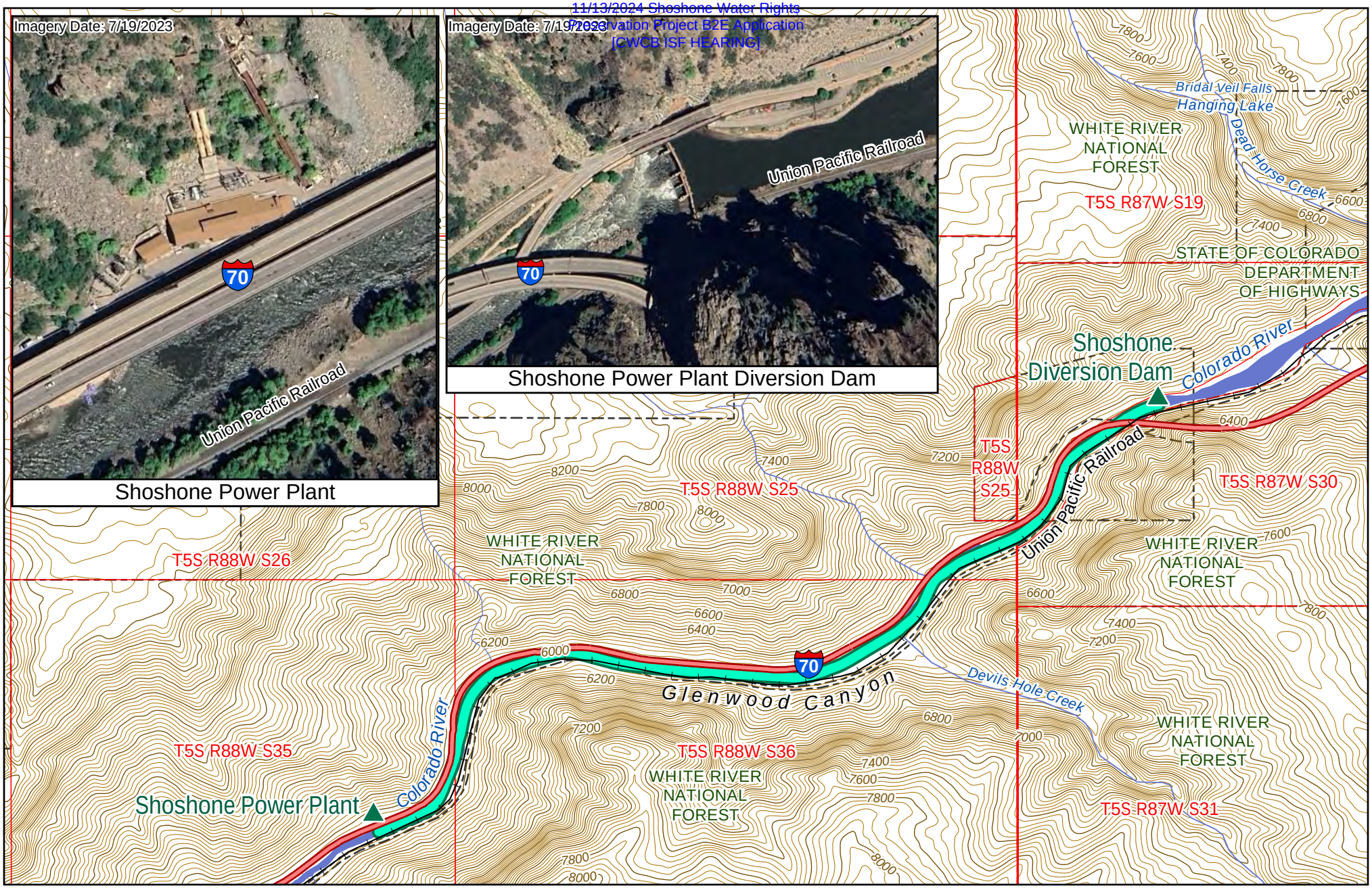


Figure 3: Shoshone Instream Flow Reach Project Map

State: Colorado

County: Garfield

Created Tuesday, November 12, 2024

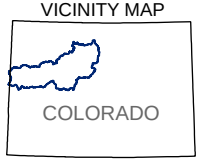
0 ¼ ½ 1 Miles

Scale: 1:24,000

Proposed Shoshone ISF Reach Project Boundary

TRUE-NORTH MAGNETIC-NORTH

VICINITY MAP



COLORADO RIVER DISTRICT

2. Key Project Priorities

The importance of the Shoshone Water Rights to the Colorado River cannot be overstated. This is because the long-standing exercise of the Shoshone Water Rights has led to the creation of a historical flow regime that provides vital ecosystem, habitat, agricultural, recreational, municipal, and other economic benefits up and down the Colorado River's mainstem and throughout the Upper Colorado River Basin. The Project is the culmination of more than a decade of collaboration between the Colorado River District, PSCo, and a coalition of Colorado's local governments, major water entities, and regional partners to secure the permanent protection of the river flow regime created by the historical exercise of the Shoshone Water Rights.

2.1 Current State of the Ecosystem - Drought and Climate Change in Western Colorado:

Even in the wettest hydrologic years, water in the Colorado River no longer reaches the Colorado River Delta. This is due in large part to an imbalance between demand and the river's long-term supply. In the State of Colorado, these demands, combined with diminished flows resulting from multi-decadal drought, have caused pronounced impacts in the Upper Colorado River watershed.

Colorado's Western Slope, where the Colorado River originates and from which it derives its most significant source of supply, is the regional epicenter for a significant and above-average rise in temperature levels and a concurrent decrease in snowmelt runoff. The decrease in annualized surface water yield is particularly problematic given that surface water contributions within the Colorado River District's territorial boundaries alone account for 65% of the Colorado River's natural flows. According to the National Oceanic and Atmospheric Administration ("NOAA"), this region has experienced an increase of more than 4°F in average annual temperatures since 1895.[3] The negative impact of warmer temperatures on water supplies is readily observable and quantifiable. For every 1-degree Celsius rise in average temperature, recorded streamflow reductions range between 3% and 9%, with recent studies leaning heavily towards the 9% end of that range.[4] The upper elevation, snowmelt dominated headwaters are projected to experience the greatest streamflow declines across the southwestern United States.[5] Moreover, the latest scientific data confirms that this current period is the driest in over 1,200 years.[6]

The recently released third edition of the "Climate Change in Colorado" report confirms these trends. Statewide annual average temperatures increased by 2.3°F from 1980 to 2022 with further

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[3] *See* National Oceanic and Atmospheric Administration, U.S. CLIMATE DIVISIONAL DATABASE (NCLIMDIV) (2024), https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series (detailing monthly temperature data at the national, state and county levels between 1895 and 2019 for the lower 48 states).

[4] *See* P. C. D. Milly & K. A. Dunne, *Colorado River flow dwindles as warming-driven loss of reflective snow energizes evaporation*, SCIENCE, vol. 367, issue 6483, 1252–1255 (2020).

[5] Olivia L. Miller et al., *Changing climate drives future streamflow declines and challenges in meeting water demand across the southwestern United States*, JOURNAL OF HYDROLOGY X, vol. 11 (2021), https://www.sciencedirect.com/science/article/pii/S2589915521000018.

[6] *See* A. Park Williams et al., *Rapid intensification of the emerging southwestern North American megadrought in 2020–2021*, NATURE CLIMATE CHANGE, (2022) 12, 232–234, https://doi.org/10.1038/s41558-022-01290-z.

and significant warming expected in all regions of Colorado, across all seasons.[7] According to the report, significant warming is projected to continue over the next several decades. Also, regardless of changes to precipitation, the "Climate Change in Colorado" report finds that future warming will lead to further reductions to Colorado's spring snowpack with models predicting between 5% and 30% reduction in both streamflow volume and snow-water equivalent. The report concludes that warmer temperatures alone will contribute to more frequent and severe droughts in the future, irrespective of precipitation. Temperature increases further accelerate soil aridification which significantly compounds streamflow issues.[8] As temperatures rise, soil moisture decreases. Evaporation increases from soils and water bodies and transpiration increases from plants, creating a soil-water debt which becomes due when snow melts, preventing snowmelt runoff from reaching rivers and streams. This significant drying process was especially evident in 2021, when the Colorado River Basin's snowpack peaked at around 89% of average while the inflow volume to Lake Powell was 32% of average.[9]

Simply put, long-term drought has exposed multiple vulnerabilities to the ecosystems and economies that rely on the water resources of the Colorado River. With respect to the Project, the following vulnerabilities would intensify without the Shoshone Water Rights:

- In recent years, such as 2021 and 2022, low flows and high-water temperatures and associated low dissolved oxygen created critical conditions in the Colorado River headwaters from the Town of Kremmling to the City of Rifle, triggering months-long fishing closures in 2021 and in 2022[10] to protect struggling species. These hot, dry, and poor habitat conditions have become the "new-normal" and create serious impacts to the Colorado River ecosystem, negatively impacting local economies that rely upon recreation and tourism.
- In 2016, Colorado Parks and Wildlife ("CPW") removed the "Gold Medal" status for portions of the Blue River below Dillon Dam located in Summit County due to declining ecosystem health from suboptimal habitat and low flows, which negatively impact the fishery.[11]
- Within Colorado, 154 miles of the Colorado River (from approximately 1 mile downstream of the Windy Gap Reservoir in Grand County to the confluence of the Colorado River with Rifle Creek) are listed as a high priority concern on the federal Clean Water Act's Section 303(d) list of impaired waters for temperature exceedance for aquatic life use.[12] High water temperatures

[7] Becky Bolinger et al., *Climate Change in Colorado, A report for the Colorado Water Conservation Board*, COLORADO STATE UNIVERSITY, 3rd ed. (2024), https://doi.org/10.25675/10217/237323.
[8] *Id.*
[9] These calculations and data are accessible via NOAA's Colorado Basin River Forecast Center, https://www.cbrfc.noaa.gov/lmap/lmap.php (last visited on November 7, 2024).
[10] *See* Travis Duncan, Colorado Parks and Wildlife, *Colorado Parks and Wildlife Enacts Voluntary Fishing Closure on Section of Colorado River*, (July 2021), https://www.coheadwaters.org/hot-water-fish (last visited on November 7, 2024); *see also* Colorado Parks and Wildlife, Fishing Closures (June 1, 2022–November 3, 2023), https://docs.google.com/document/d/1lrbiFauulP5XqnrNvv0ueKUAdbTlWNbZ1L6krfuHYhI/edit?tab=t.0 (copy on file with the River District).
[11] *See generally* Blue River Integrated Water Management Plan Phase 1 Report, Blue River Watershed Group & Trout Unlimited (August 2021), https://www.blueriverwatershed.org/uploads/9/6/3/3/9633489/brimwp_phase_1_final_report_august_2021__2_.pdf.
[12] *See generally* Department of Public Health and Environment, Water Quality Control Commission, Regulation #93 – Colorado's Section 303(d) List of Impaired Waters and Monitoring and Evaluation List, 5 CCR 1002-93.

are harmful to aquatic life and can lead to other serious water quality concerns, such as toxic conditions related to harmful algae blooms.

- In a 2021 written review of the 15-Mile Reach Programmatic Biological Opinion (the "PBO"), the Upper Colorado Endangered Fish Recovery Program (the "Recovery Program") found that during the irrigation season (April–October), in years classified as "dry", mean monthly flows in the 15-Mile Reach fell below the minimum target flows of 810 cfs 39% of the time between 1991-2019.[13] The 2021 review also described a concerning trend that runoff in the Colorado River basin between July and October is likely to decrease as a result of climate change. This would negatively affect the Recovery Program's ability to maintain flows to protect the aquatic habitat of federally listed endangered fishes, which in turn threatens the status of existing environmental permits and operations of dozens of federal, state, and local water projects.[14]

2.2 Ecosystem, Habitat and Environmental Benefits:

The exercise of the Shoshone Water Rights protects Colorado's namesake river for the benefit of numerous and diverse water users, recreation interests, and the abundant natural habitats and ecosystems that rely on the Colorado River for survival. *See* Appendix 1, Map 4. Additionally, the State of Colorado has recognized the importance of the headwaters region and currently holds over three hundred distinct instream flow water rights upstream of the Shoshone Power Plant. The numerous instream flow water rights located in the Upper Colorado River watershed on the mainstem and tributaries upstream of the Shoshone Power Plant benefit from the seniority of the Shoshone Water Rights and their ability to command flows down the Colorado River. *See* Appendix 1, Map 5. If the flows attributable to the Shoshone Water Rights were absent from the Upper Colorado River mainstem, river levels would be significantly lower (especially in drought years and late in the irrigation season), resulting in a negative impact on the riverine ecosystems that are already stressed by prolonged drought and aridification.

2.2.1 Modeling Approach: To illustrate the ecosystem, habitat, and environmental benefits of the Shoshone Water Rights, Hydros Consulting, Inc. ("Hydros") prepared two technical reports: (1) the Shoshone Power Plant Water Rights Yield Assessment, dated September 11, 2024 (the "Yield Assessment," Appendix 5), and (2) the Addendum to September 11, 2024, Shoshone Power Plant Water Rights Yield Assessment (the "Yield Addendum," Appendix 6) dated November 7, 2024. Both the Yield Assessment and the Yield Addendum examine the current and future impacts of the Shoshone Water Rights in preserving essential base flows of the Colorado River utilizing the State of Colorado's StateMod water allocation and accounting model. Hydros first utilized the 2015 Upper Colorado River Basin Model (the "2015 UCRM") in StateMod in the Yield Assessment as it was the most current, validated model at the time Hydros prepared this initial report. The subsequent Yield Addendum followed the CWCB's release in September 2024 of an updated

[13] Upper Colorado River Endangered Fish Recovery Program Director's Office, *A Review of the Upper Colorado River Endangered Fish Recovery Program's Recovery Actions and Endangered Species Response in the Colorado River* (November 2021), https://coloradoriverrecovery.org/uc/wp-content/uploads/sites/2/2022/05/15-Mile-Reach-PBO-Review-and-Cover-Memo-Signed-May-2022.pdf (including the "Reporting requirement in the U.S. Fish and Wildlife Service's 1999 Section 7 Formal Consultation No. ES/GJ-6-CO-99-F-033 – 15 Mile Reach Programmatic Biological Opinion").
[14] *Id.*

UCRM (the "2024 UCRM"), which included overall model updates and the ability to run the model on a daily timestep. It should be noted that the CWCB's 2024 UCRM has yet to undergo any formal calibration and/or validation unlike the 2015 UCRM which underwent extensive calibration and validation.[15] Therefore, the Hydros reports and this application continue to discuss the results of the 2015 UCRM while also providing a discussion of results from the 2024 UCRM.

Hydros focused both of its reports on the upstream terminus of the 15-Mile Reach to understand the impact on the critical reach for the listed threatened and endangered species. The 15-Mile Reach is also immediately downstream of the Grand Valley Project and the suite of water rights and structures known as the "Cameo Call," which is a conglomerate of significant irrigation rights that can divert all flow in the Colorado River in the late irrigation season.[16] As detailed in the Yield Assessment and Addendum, Shoshone's benefits at the Colorado-Utah state line are very similar in magnitude to its benefits at the 15-Mile Reach.

The Yield Assessment evaluated yields of the Shoshone Water Rights under four scenarios incorporating two basic assumptions for Colorado River demands. Demands in StateMod are the maximum amounts called for by the water rights and are distinct from the actual diversions, which will be limited to the available flow in the system at the location, time, and seniority of the water rights and are often less than the total demand. The four scenarios of modeled water demands at the Shoshone Power Plant include "Senior", "Senior-Relax", "Max", and "Max-Relax" scenarios. The "Senior" scenario limits the Shoshone Water Rights' demands to the senior 1,250 cfs water right. The "Max" scenario represents the full 1,408 cfs demand under both the senior and junior priorities. And the "Relax" scenario represents the incorporation of the Agreement Concerning Reduction of Shoshone Call (the "2007 Call Relaxation Agreement," Appendix 14.e.) between PSCo and the City and County of Denver acting through its Board of Water Commissioners ("Denver Water"). The 2007 Call Relaxation Agreement specifies that, whenever certain specific drought conditions are met, Denver Water can cause the Shoshone Call to be relaxed to a single turbine call (i.e., from 1,408 cfs to 704 cfs) from March 14 to May 20. Modeling analyses were conducted under current basin-wide river demands as set by the CWCB in the 2015 UCRM and under future river demands where Hydros increased demands on the Colorado River to represent the anticipated 120,000 acre-feet (AF) development allowance limit in the 15-Mile Reach PBO. Future demands were estimated using contemplated demands from transmountain diversion projects and West Slope development projects. Each of the four scenarios were then compared to a scenario with the Shoshone Water Rights turned off under the respective "Current" and "Future" conditions to provide an estimated yield assessment of the Shoshone Water Rights.

[15] For additional information on the 2015 UCRM calibration and validation, *see* Appendix 7.

[16] For purposes of this application, "Cameo Call" is a generic term that refers to the request delivered to state water officials to curtail upstream diversions of junior water rights to satisfy any or all the water rights legally divertible for irrigation and power generation purposes at the headgates for the Grand Valley Project's Government Highline Canal located near Cameo, Colorado, and the Grand Valley Irrigation Company's Grand Valley Canal located near Palisade, Colorado. For more information about the "Cameo Call," please refer to Appendix 12.

In the reports prepared by Hydros, the scenarios assume a certain demand for the Shoshone Water Rights, although as results show, actual available natural flows[17] (otherwise known as "administrative flow," *see* Section 3.1.2., below) are often less than those demands.[18] The Yield Addendum (Appendix 6) affirms the benefits of the Shoshone Call as reported in the Yield Assessment (Appendix 5). However, the Yield Addendum evaluated that benefit utilizing a slightly different approach. In the 2024 UCRM, the State of Colorado revised the baseline conditions of the UCRM to update river operations and demands for both the Shoshone Water Rights and for transmountain diversions. Thus, in the Yield Addendum, Hydros replaced the "Senior" scenario with the "Baseline" scenario adopted by the CWCB. Under the new "Baseline" scenario, the updated demands for the Shoshone Water Rights fluctuate based on daily historical records and represent demands ranging from 704 cfs (one turbine use under the 2007 Call Relaxation Agreement) to 1,408 cfs. The Yield Addendum utilized a similar Max-Relax scenario and future basin-wide demands as was used in the Yield Assessment.

Notably, the Yield Assessment and the Yield Addendum both confirm the benefit of yields provided by the Shoshone Water Rights to the 15-Mile Reach, with higher yields in drought years and during the critical flow period of August through October. Average annual yields for the Shoshone Water Rights are shown in Table 1 under comparable modeled scenarios. Average annual yields from the Shoshone Water Rights range from 17,800 AF to 34,900 AF while dry-year annual average yields range from 29,400 AF to 44,700 AF. As the model illustrates, these existing yields would no longer be available to the "Shoshone Reach" (*see* Section 2.2.5., below), the 15-Mile Reach, or further downstream if the Shoshone Water Rights were no longer exercised and administered. Even with increased future demands, the model shows that Shoshone Permanency will provide essential flows in the Colorado River and through the 15-Mile Reach.

Table 1: Average Annual Yields of the Shoshone Water Rights to the 15-Mile Reach.

Modeling Scenario (Values in AF)	Dry-Year Averages		Average of All Years	
	Current	Future	Current	Future
2015 Monthly Model- Senior Relax[1]	29,400	44,700	17,800	33,500
2015 Monthly Model- Max Relax[1]	34,800	44,100	24,200	34,900
2024 Daily Model- Baseline (Relax)	33,100	36,800	24,200	26,900
2024 Daily Model- Max-Relax	32,800	36,600	24,000	26,800

1. *"Yield" per the Yield Assessment is defined here as being greater than zero, because the Shoshone Call does not directly result in reduction in flow.*

[17] The "natural flow(s)" means the total flow in a river or stream system without the influence of any developed infrastructure or water use or the introduction of non-native water including releases from off-channel reservoirs.

[18] This modeling approach which simulates full demands aligns with historical assumptions utilized in environmental analyses conducted for projects such as the Windy Gap Firming Project and Moffat Firming Project. While these scenarios are not intended to replicate historical diversions by the Shoshone Water Rights, they are appropriate for an analysis of the benefits that these water rights provide to the Colorado River and the 15-Mile Reach. Moreover, the use of models of this type for water resource planning purposes is not atypical. For instance, the CWCB routinely relies on models (StateMod models) as predictive tools to assess demands and operations in the Colorado River Basin.

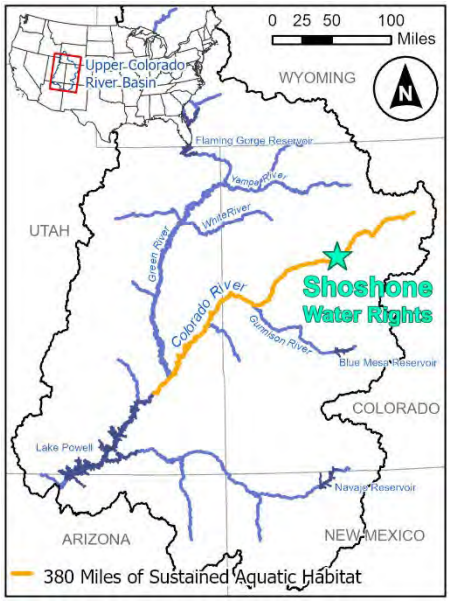
The 2024 UCRM results show yields to the 15-Mile Reach in every modeled year during the critical flow period of August through October. According to the model, the Shoshone Water Rights contribute on average 7% to 17% (14,900 AF to 20,400 AF) of the total available flow during this three-month period under variable hydrologic conditions with the most benefit occurring in dry years when the flows in the 15-Mile Reach are lowest and most critical to maintain. *See* Appendix 6, p. 6. The benefits in the 15-Mile Reach during these low flow conditions were in large part due to the Shoshone Water Rights' ability to delay the Cameo Call by a reported 29% of the calling days on average over the period of record—with each day the Cameo Call is not in place being directly related to more water in the 15-Mile Reach. *Id.*

Table 2: Benefit of Shoshone Call on Flows Through the 15-Mile Reach by year type under the Baseline Scenario of the 2024 Model, Yield Addendum.

Hydrologic Condition	Current Demands			Future Demands		
	Average Annual Benefit (AF)	August - October Average Benefit (AF)	Aug – Oct Benefit as a % of Total Flow	Average Annual Benefit (AF)	August - October Average Benefit (AF)	Aug – Oct Benefit as a % of Total Flow
Dry	33,000	14,900	15%	36,800	15,000	17%
Average	22,600	20,000	12%	24,900	18,700	12%
Wet	18,300	19,600	7%	20,900	20,400	8%

2.2.2 Miles of Sustained Aquatic Habitat: When the Shoshone Water Rights are being exercised, nearly 380 miles of the Colorado River mainstem from the headwaters in Grand County to Lake Powell experience a benefit, particularly during critical low periods when flows are needed to preserve aquatic habitat. The benefits to the sustained miles of aquatic habitat are further discussed in Section 2, below.

Figure 4: Miles of Sustained Habitat



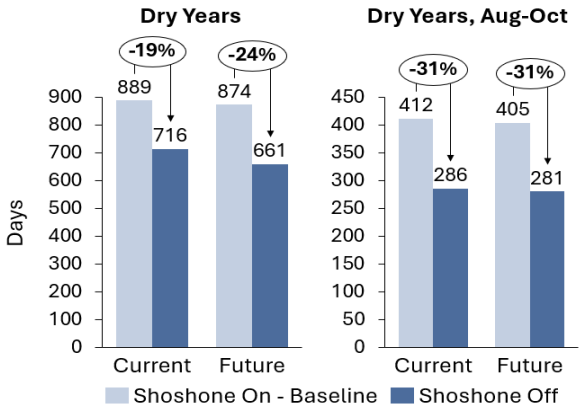
2.2.3 Maintaining Streamflow through Upper Colorado River Wild and Scenic Alternative Management Plan River Sections: The Upper Colorado Wild and Scenic Stakeholder Group ("Stakeholder Group") was formed in 2007 following a report by the Bureau of Land Management ("BLM") on the eligibility of rivers in the Upper Colorado River Basin for Wild and Scenic River designation. The report identified 84 miles of the Upper Colorado River from the Town of Kremmling to No Name Creek in Glenwood Canyon as having Outstanding Remarkable Values ("ORVs") eligible for the federal designation as a Wild and Scenic River. The Stakeholder Group, which includes over 20 entities (including the River District, and the State of Colorado), developed an alternative plan to a federal wild and scenic designation with an intention to balance permanent protection of the ORVs, provide certainty for the Stakeholder Group, ensure water project yield, and provide flexibility for water users along the Upper Colorado River. The Stakeholder Group's "Alternative Management Plan" lists the

Shoshone Water Rights as one of four identified long-term protection measures for streamflow-influenced ORVs on the Colorado River from Kremmling to No Name Creek.[19] The Shoshone Water Rights provide base flows through the subject river segments that support aquatic habitat, lower water temperatures, and maintain minimum boatable flows (700 cfs above Dotsero and 1,250 cfs below Dotsero).

Figure 5: Upper Colorado River: Wild and Scenic Eligibility Segments

The United States Forest Service ("USFS") and BLM released a report in September 2024 titled "Biological and Recreational Resources Dependent on Colorado River Flows Through Glenwood Canyon" (the "USFS-BLM Report," Appendix 10). As observed by federal land managers who oversee these river sections, the USFS-BLM Report confirms the importance of the Shoshone Water Rights to the federal wild and scenic designated reaches given that flows necessary to satisfy the Shoshone Call also support fisheries for native species, sport species, and aquatic invertebrates. *See, e.g.*, Appendix 10, pp. 16–17. The USFS-BLM Report also identifies the foundational need for the Shoshone Water Rights to maintain wild and scenic suitability for recreation through a reach that saw approximately 150,000 boater "visitor" days in 2022. *Id.* at pp. 14, 16. The USFS-BLM Report concludes by stating "[o]peration of the [Shoshone Water Rights] supports [ORVs] in three reaches of [the] Colorado River that have been determined to be eligible for designation into the National Wild and Scenic Rivers System." *Id.* at p. 17.

Figure 6: Colorado River Kremmling Gage Minimum Instream Flow Exceedance Days



Outputs from the 2024 UCRM Baseline scenario were evaluated to understand the Shoshone Water Rights' benefits to the wild and scenic stretch. *See* Appendix 6. In dry years, if the Shoshone Water Rights are no longer exercised, approximately 28,400 AF under current conditions and 29,500 AF under future conditions would no longer reach the Colorado River USGS Kremmling gage (09058000), which is located at the top of the wild and scenic reach. As presented in Figure 6, the loss of flow translates to fewer days when the decreed minimum instream flow water right at the Kremmling gage is met. This is magnified during the dry months of August through October, when the days the instream flow is met would be

[19] *See* Amended and Restated Upper Colorado River Wild and Scenic Stakeholder Group Management Plan (last revised July 2024), https://www.upcowildandscenic.com/uploads/1/3/5/3/135388668/amended_and_restated_sg_plan_july_2024.pdf, p. 63.

reduced by approximately 31%, equivalent to reductions of 80 cfs or 11% of the flow if the Shoshone Water Rights are not preserved.

Most of these flow reductions occur during the critical shoulder seasons when the Upper Colorado River's Wild and Scenic eligible reaches are prone to higher temperatures and lower flows, as well as during the winter months. Therefore, the utilization of the Shoshone Water Rights helps to preserve the natural baseflow and important aquatic habitat in these reaches of the Colorado River.

2.2.4 Sustaining Tributary Flows:

Figure 7: Colorado River Major Tributaries

The exercise of the Shoshone Water Rights results in an influential "pull" of water down the Colorado River, including through significant tributaries, which maintains baseflows to the Shoshone Power Plant and further downstream. The Eagle River is one such tributary of the Colorado River upstream of the Shoshone Power Plant, which has seven decreed minimum instream flow reaches across nearly 50 miles. The 2024 UCRM Baseline scenario results show that dry year average yields from the Shoshone Water Rights in the Eagle River near the Town of Wolcott are approximately 3,400 AF to 3,900 AF under current and future conditions, respectively. Under modeled future development conditions, these results also show that the Shoshone Water Rights pull approximately 2,200 AF down the Eagle River in wet years and 4,200 AF in average years, which amounts are more significant than any existing contractable storage volumes in the Eagle River Basin. The "Eagle River Community Water Plan" identified potential future in-basin and transmountain diversions, all of which would be subject to the Shoshone Call, as high-risk factors that would negatively impact the Eagle River Basin's riverine ecosystems.[20] Modeling results confirm that the Shoshone Water Rights are a powerful tool to aid in the preservation of instream flows and aquatic habitat in the Eagle River Basin every year under future development conditions.

Similarly, the Shoshone Water Rights also support the current flow regime on the Blue River, which begins above the Town of Breckenridge. Assuming the Project is not implemented, and the Shoshone Water Rights are not exercised in the future, the primary beneficiaries would largely be the transmountain diverters which would be able to increase their respective yields at their respective collection systems, thereby impacting various stretches of the Blue River. Under this scenario, streamflow above Dillon Reservoir would likely experience reductions with an increased

[20] *See* Eagle River Community Water Plan (revised October 2024), https://lotic.quarto.pub/community_water_plan/ (follow "Download the full Eagle River Community Water Plan document by clicking here" hyperlink), p 50.

frequency of in-priority transmountain diversions by the Continental-Hoosier Project and the Vidler Tunnel. Additionally, streamflow in the Blue River below Dillon Reservoir could remain at or below 50 cfs in the non-irrigation season for longer periods of time due to increased in-priority diversions into Dillon Reservoir and through the Roberts Tunnel, particularly in drought periods. Streamflow in the Blue River below Green Mountain Reservoir would also likely be lower in the late summer and fall. Reclamation has invested substantial resources in the health of the Blue River and recently approved a $1.8 million grant to the "Blue River Habitat Restoration Project" through the WaterSMART Aquatic Ecosystem Restoration Program.[21] A consistent flow regime made possible by the Shoshone Water Rights will support sediment transport and other ecosystem benefits to the Blue River.

2.2.5 Improving Habitat in Colorado's Glenwood Canyon and the Proposed Instream Flow Reach: Freshwater Consulting, LLC ("Freshwater"), studied the Shoshone Reach, the 2.4 miles of the Colorado River between the Shoshone Diversion Dam and the Shoshone Power Plant for which the Project seeks to establish instream flow use for the Shoshone Water Rights. *See* Appendix 11.

Figure 8: Proposed Shoshone Instream Flow Reach

Using the Instream Flow Incremental Methodology ("IFIM") on a study area of the Shoshone Reach and habitat criteria for one native fish species and three sport fishes, Dr. William J. Miller, PhD, of Freshwater found that flows between 700 cfs and 3,000 cfs provide a benefit to the aquatic habitat for identified fish species within the Shoshone Reach. *See* Appendix 11, p. 20. Outputs from the 2024 UCRM Baseline scenario show that the Shoshone Water Rights can pull down approximately 31,900 AF to 35,500 AF through the Shoshone Reach in an average dry year under current and future conditions, respectively.[22] Thus, protecting the Shoshone Water Rights by adding an alternate instream flow use will serve to improve the Shoshone Reach's aquatic habitat, stabilizing flows through the reach during times when the Shoshone Power Plant is not operating to maintain the historical flow regime. During dry years and through persistent drought conditions, exercising the Shoshone Water Rights will ensure that the historical flow regime is maintained and protected, while preserving and improving the natural environment of the Shoshone Reach.

2.2.6 Supporting Critical Habitat for Threatened and Endangered Species: The exercise of the Shoshone Water Rights benefits 250 miles of critical habitat on the Colorado River beginning in

[21] *See* United States Bureau of Reclamation, *Biden-Harris Administration Announces More Than $51 Million from the President's Investing in America Agenda to Restore and Protect Rivers and Watersheds* (December 19, 2023), https://www.usbr.gov/newsroom/news-release/4704.

[22] These outputs derive from the State of Colorado's 2024 UCRM baseline model, which is accessible at https://cdss.colorado.gov/modeling-data/surface-water-statemod.

Rifle, Colorado, and extending downstream to Lake Powell (*see* Appendix 1, Map 6). The exercise and administration of the Shoshone Water Rights supports four fish species listed under the Endangered Species Act ("ESA"): (1) Colorado pikeminnow, (2) humpback chub, (3) razorback sucker, and (4) bonytail chub. The Recovery Program was established in 1988 "to recover the four fish species listed under the ESA, while allowing water development and management activities to continue."[23] All Colorado River water users in the State of Colorado, whether located on the eastern or western side of the Continental Divide, rely upon the continued success of the Recovery Program and continued ESA compliance for streamlined permitting processes for over 1,250 water projects located in Colorado since 1988.[24] This includes five Reclamation projects on the mainstem of the Colorado River, one on the Fryingpan River (the Fryingpan-Arkansas Project), along with an additional eight included in the Recovery Program area.[25]

Colorado's 15-Mile Reach extends from the point at which the tailrace common to the Grand Valley Power Plant and the Orchard Mesa Irrigation District pumping plant returns to the Colorado River below the Grand Valley Irrigation Company's diversion dam, downstream to the confluence of the Colorado River and the Gunnison River.[26] While the 15-Mile Reach provides important habitat and connectivity for the four species under the ESA, it is often stressed by periods of low flows due to upstream diversions and is increasingly impacted by trends of reduced snowpack and runoff. As previously stated, the Recovery Program has only successfully met the 810 cfs minimum target flows in the 15-Mile Reach PBO 61% of the irrigation season during "dry" years with active Shoshone Water Rights.[27] However, without the Project, the Recovery Program will experience even less success in meeting the PBO's minimum target flows.

Achieving the permanent protection of the Shoshone Water Rights represents a much-needed shift away from the historical reliance on temporary and/or voluntary water contributions towards permanent protection. In 2022, in response to the Recovery Program's review of the 15-Mile Reach PBO, the U.S. Fish and Wildlife Service ("FWS") commended the Recovery Program's "commitment to developing partnerships to augment flows" but expressed concern "with the reliance on voluntary water contributions because of the uncertainty that these augmentations will be available in the future."[28] The Recovery Program cites additional uncertainties, including increases in the demand for water in the upper Colorado River basin and climate induced changes to hydrology as barriers to the Recovery Program's ability to maintain and improve the future water supply for the 15-Mile Reach and has stressed the "need to develop strategies for long-term

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[23] *See* Upper Colorado River Endangered Fish Recovery Program, 2024-2024 Highlights Briefing Summary, https://coloradoriverrecovery.org/uc/wp-content/uploads/sites/2/2024/03/2023-24-Briefing-Book-Final.pdf, p. 8.
[24] *Id.* (detailing 1,272 projects in Colorado that have benefited from ESA Section 7 Consultations from 1988-2023).
[25] Mainstem projects include the Collbran Project, Colorado-Big Thompson, Grand Valley Unit, Grand Valley Project, and the Silt Project. Additional Recovery Program area projects include the Bostwick Park Project, the Lower Gunnison Project, the Meeker Dome Project, the Dallas Creek Project, the Fruitgrowers Dam Project, the Paonia Project, the Uncompahgre Project, and the Smith Fork Project.
[26] *See supra* note 13; *see also* Appendix 12 (summarizing the water court decree entered in Case No. 91CW247, Water Division No. 5).
[27] *See supra* note 13.
[28] *Id*.

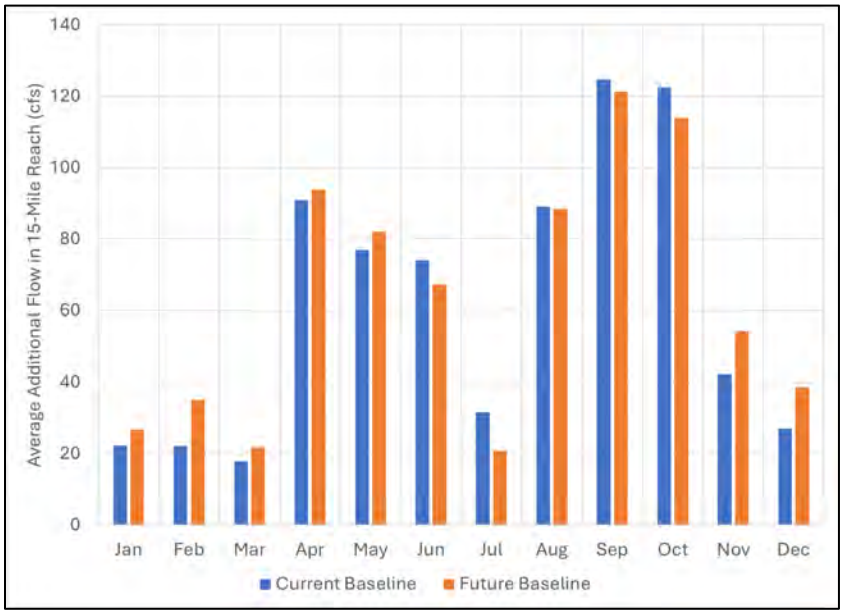
flow protection throughout the upper Colorado River basin."[29] If the river flows provided by the historical exercise of the Shoshone Water Rights are lost, it will be significantly more difficult for the Recovery Program to reach the minimum target flows in the 15-Mile Reach. If the FWS determined that the Recovery Program was not making sufficient progress, any future and/or existing Colorado River water projects would be at risk and could face mitigation requirements for ESA compliance, a costly and timely process.

The results of the Yield Assessment and Yield Addendum at the 15-Mile Reach were evaluated on an annual, monthly, and daily basis using hydrology from 1988-2013. *Compare* Appendix 5 *with* Appendix 6. Hydros found in the Yield Addendum that on average in dry years, the Shoshone Water Rights contribute approximately 33,100 AF to 36,800 AF to the 15-Mile Reach under the Baseline Current and Future scenarios, respectively, of which approximately half (15,000 AF) is contributed during August, September, and October when flows are needed to meet the PBO's minimum target flows. *See* Appendix 6, Table 5, p. 8. These contributing flows represent approximately 15-17% of the total flows in the 15-Mile Reach during the late irrigation months of August through October. *Id.* In the Yield Assessment, annual dry year contributing flows were shown to be as high as 41,000 AF under the current Senior scenario and up to 86,000 AF under the future Max-Relax scenario. *See* Appendix 5, p. 13.

The benefits to the 15-Mile Reach provided by the Shoshone Water Rights are not limited to drought conditions. Increased flows to the 15-Mile Reach occur in all years, particularly during the critical late irrigation season. Under the average and wet conditions, the yields ranged from 18,300 AF to 22,600 AF under the 2024 UCRM Baseline current scenario. *See* Appendix 6, Table 5, p. 8. These results show that the seniority and non-consumptive nature of the Shoshone Water Rights are incredibly helpful in maintaining river flows and habitat in the 15-Mile Reach in all years beyond the larger yields under drought conditions. The Shoshone Water Rights benefits were found to occur in all months, particularly in the spring and late irrigation season months.

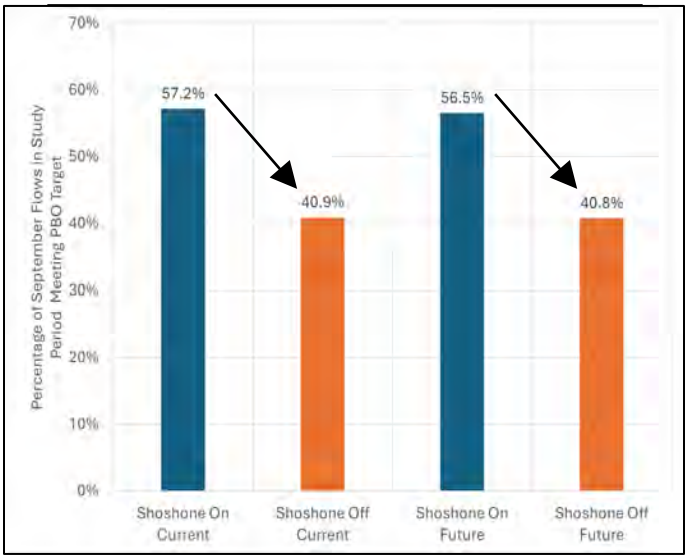
[29] Clinton Riley, Regional Director, Region 6, United States Fish and Wildlife Service, *2021-2022 Assessment of Sufficient Progress for the Upper Colorado River Endangered Fish Recovery Program in the upper Colorado River basin* (February 9, 2023), https://coloradoriverrecovery.org/uc/wp-content/uploads/sites/2/2023/02/Feb-2021-Jan-2022-UCRRP-Suff-Prog_Acting-RD-signature.pdf.

Figure 9: Average Monthly Yield Magnitude Patterns - Current and Future Baseline Scenarios (*see* Appendix 6, Figure 2, p. 10)



Further, per the Yields Assessment and Addendum, in months when the average monthly flow was less than 810 cfs (the lowest PBO minimum target flow), Shoshone Water Rights were responsible for contributing 18% to 26% (*see* Appendix 5, Table 7, p. 12) of the total flow during months when the minimum target flow was not met under the 2015 UCRM. This is re-affirmed under the 2024 UCRM, indicating that the Shoshone Water Rights contribute an average of 15% to 17% of total flow in dry years (*see* Appendix 6, Table 5, p. 8). And this can be shown more specifically by looking at the number of days in September that exceed the minimum flow target of 810 cfs with and without the Shoshone Water Rights as presented in Figure 10:

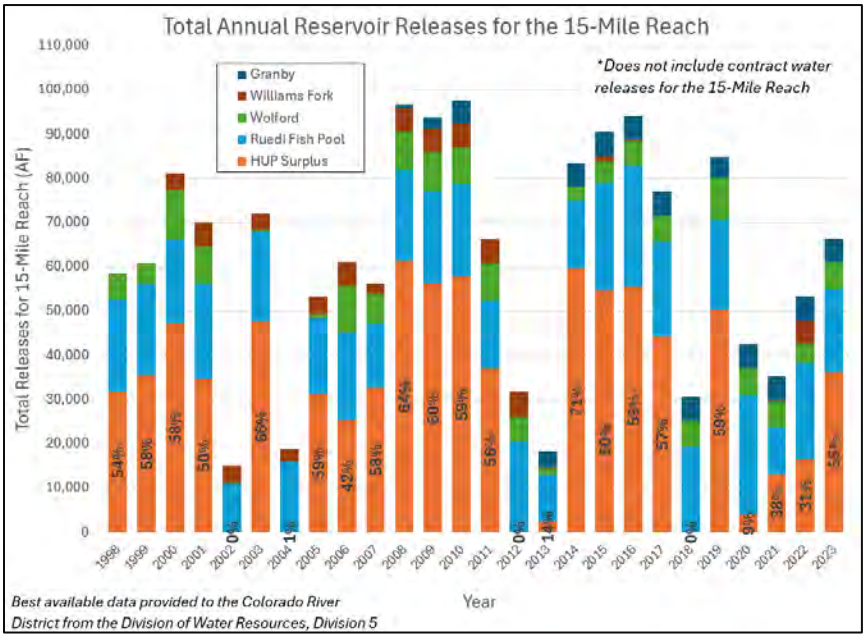
Figure 10: Frequency of September Flows Meeting the 15-Mile Reach PBO Minimum Flow Target of 810 cfs under the 2024 UCRM Baseline Scenario (*see* Appendix 6, Figure 3, p. 10)



Preserving the administration and exercise of the Shoshone Water Rights supports the ability for a "Surplus" to be declared to allow excess water from the 66,000-AF pool within Green Mountain Reservoir (the "Historic Users Pool" or the "HUP") to be delivered to the 15-Mile Reach to help meet flow targets. *See generally* Appendix 12. Maintaining the historical flow regime created by the exercise of Shoshone Water Rights is one of three conditions stipulated to by the co-applicants (the United States, the Orchard Mesa Irrigation District ("OMID"), and the Grand Valley Water Users Association ("GVWUA")) and certain of the opposers in Case No. 91CW247 (the "Check Case"). *Id.* at p. 3. If all stipulated conditions are met, HUP Surplus water may be released from Green Mountain Reservoir and used for non-consumptive purposes (e.g., by the Vinelands Power Plant), with all return flows resulting from such uses made available to the 15-Mile Reach. *Id.*

To the extent that HUP Surplus water has been made available pursuant to the Check Case, such water typically doubles the available supplies to the Recovery Program and is provided free of charge. *See* Figure 11. Historically, the HUP Surplus water provides, on average, 32,000 AF annually to the 15-Mile Reach, a significant addition to the other sources available to the Recovery Program—which total approximately 27,000 AF (in the upstream "fish pools" located in Ruedi, Wolford Mountain, and Granby Reservoirs). However, if the Shoshone Water Rights were lost or abandoned to the stream, one of the three stipulated Check Case conditions would be unmet, and the HUP Surplus could not be relied on as the single largest source of stored water available to supplement low flows in the 15-Mile Reach.[30] Importantly, Hydros evaluated impacts to the "fish pools" which are upstream of the Shoshone Power Plant and release water for the benefit of the Recovery Program by comparing the 2024 UCRM Baseline with the Max-Relax scenario under Current Conditions. *See* Appendix 6, Figure 1, p. 6. As detailed in the Yield Addendum, there are minimal differences between average storage levels in the fish pools with a range less than 10 AF.

Figure 11: Total Annual Releases to the 15-Mile Reach



[30] For a more detailed explanation of the relationship between the Shoshone Water Rights, the Check Case, and HUP Surplus releases to the 15-Mile Reach, please refer to Appendix 12.

Thus, the Shoshone Water Rights not only directly support the 15-Mile Reach by providing an annual average of 18,500 AF during the critical late irrigation season months but also are a vital condition to allow HUP Surplus to be delivered to the 15-Mile Reach. In fact, the Yield Addendum (Appendix 6, p. 7) reports that Shoshone flows provide approximately 100 cfs of water to the 15-Mile Reach in the low flow months of August, September, and October (which is more than 12% of the 15-Mile Reach PBO's minimum target flow of 810 cfs during those months).[31]

2.2.7 Federal Land Benefits: The Upper Colorado River watershed encompasses a substantial portfolio of federal lands managed by BLM, USFS, and the National Park Service ("NPS") (*see* Appendix 1, Map 8). The USFS-BLM Report (Appendix 10) reflects the growing partnership between land management and water management agencies in the Upper Colorado River and underscores the dependence of the natural environment and recreation on federal lands on the historical flow regime created by the exercise of the Shoshone Water Rights. The USFS-BLM Report highlights the importance of the Project as an essential and foundational means of achieving restoration efforts that are in harmony with the secretarial priority to restore and conserve at least 30% of our lands and water by 2030. *See* Appendix 10, pp. 16–17. Additionally, the National Park Service recognizes the benefits of maintaining Colorado River flows downstream to Canyonlands National Park (*see* Appendix 2, pp.12).

2.3 Additional Water Quality, Recreation, and Economic Benefits

In addition to the significant ecosystem benefits described above, the Shoshone Water Rights provide critical water supplies that improve drinking water quality, drive recreational economies, and increase agricultural productivity.

2.3.1 Water Quality Improvements: Communities that rely on the mainstem of the Colorado River for their drinking water supplies, such as Silt, Rifle, Parachute, Battlement Mesa, DeBeque, and Clifton, benefit from the enhanced water quality provided by the exercise of the Shoshone Water Rights because the flows attributable to the Shoshone Water Rights dilute salinity and sediment. These communities can experience high treatment costs during low flow conditions when concentrations of Total Dissolved Solids ("TDS") become elevated. Taste, odor, and color are affected when flows decrease due to the potential loss of the Shoshone Call. Without the higher flows of clean and cold headwater-sourced supplies provided by the Shoshone Call, a higher concentration of salinity and other water quality constituents creates increased costs for municipal drinking and wastewater treatment. Both Clifton and the City of Rifle are identified as disadvantaged communities using the Council on Environmental Quality's ("CEQ's") Climate and Economic Justice Screening Tool.[32] The importance of the Shoshone Water Rights to these drinking water systems is discussed in further detail later in Section 2.5. Further, the "Middle Colorado Integrated Water Management Plan" identifies the permanent protection of the Shoshone

[31] Hydros' modeling efforts are based on the operation of Colorado's UCRMs (the 2015 and 2024 versions). However, the actual future benefits of the Project are dependent upon the historical use determination which will be made by the state water court. The likely outcome of the water court's quantification of the historical use of the Shoshone Water Rights is discussed in Section 3.1.2.

[32] The Climate and Economic Justice Screening Tool is accessible here: https://screeningtool.geoplatform.gov/en/#3/33.47/-97.5.

Water Rights as a critical action item to mitigate the impact of upstream water diversions that alter both the natural flow patterns and overall runoff of the Middle Colorado River watershed.[33]

2.3.2 Recreation Economy: Shoshone's flows benefit Colorado communities both upstream and downstream of the Shoshone Power Plant. Colorado's robust recreational economy relies heavily on the Colorado River mainstem, with Shoshone flows strengthening the state's iconic river recreation industry throughout Grand, Summit, Eagle, Garfield, and Mesa Counties. River recreation in Colorado is estimated to contribute $18.8 billion annually to the state's gross domestic product, with approximately $4 billion coming directly from the Colorado River Basin on the West Slope (*see* Appendix 1, Map 7).[34] As temperatures rise and streams diminish, the Project provides security for this industry, protecting the recreational fishing and boating that sustain local businesses and attract water-based tourism.

According to the Shoshone Outfitter Partnership, the Colorado River through Glenwood Canyon experiences over 70,000 commercial customer trips and an estimated 80,000 private boaters who launch from the Grizzly Creek and Shoshone boat ramps.[35] River recreation drives the summer economy of the City of Glenwood Springs, which sustains local businesses and a foundational tax base for the city through its recreational and tourism-based economies. The Project provides certainty and security for outfitters, the hospitality industry, and all local businesses that rely on resident and non-resident tourists and qualified employees. In 2022, the Colorado River Outfitters Association estimated that commercial river rafting through Glenwood Canyon created an economic impact of $23.5 million.[36]

Additionally, the USFS-BLM Report estimated that in 2022 approximately 150,000 commercial and private boat recreationalists used the Colorado River between Kremmling and into Glenwood Canyon during the summer months with interest in river recreation growing each year. *See* Appendix 10, pp. 14, 16. The USFS-BLM Report goes even further to report on how flows impact recreational experiences, which shows the importance of protecting the Shoshone Water Rights that ensure higher flows are available for recreationalists above and below the Shoshone Reach: "*These flow-dependent activities rely heavily on the amount of water in this stretch of the river. Based on input from the outfitters and experience, these commercial operations typically cease when river flows drop below 1,200 cfs. The floating visitor experience diminishes drastically once flows drop below this level.*" *Id.* at p. 16 (emphasis added). The USFS-BLM Report also reported that outdoor recreation on BLM-administered lands in the Kremmling Field Office and Colorado River Valley Field Office contributes $145.7 million and over 1,100 jobs annually. *Id.* at p. 14.

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[33] *See* Middle Colorado Watershed Council, *Middle Colorado River Integrated Water Management Plan, A Joint Project of the Middle Colorado Watershed Council and the Mt. Sopris, Bookcliff, and Southside Conservation Districts* (February 2021), https://www.coloradosmp.org/wp-content/uploads/2021/03/IWMP-Report-February-2021.pdf.

[34] *See* Business for Water Stewardship, *Economic Contributions of Water-related Outdoor Recreation in Colorado*, https://businessforwater.org/wp-content/uploads/2020/05/SA_BWS_FactSheet_Digital_CO_1PG.pdf.

[35] The Shoshone Outfitter Partnership represents the 16 licensed commercial operators who provide safe and accessible river recreation on the Colorado River through Glenwood Canyon. *See also* Colorado River District, *City of Glenwood Springs Pledges $2 Million for Shoshone Water Right Preservation Campaign* (Friday, May 17, 2024), https://www.coloradoriverdistrict.org/press-release-city-of-glenwood-springs-pledges-2-million-for-shoshone-water-right-preservation-campaign/.

[36] Colorado River Outfitters Association, *2022 Year End Report: Commercial River Use in the State of Colorado 1988-2022*, https://www.croa.org/wp-content/uploads/2023/06/2022-CROA-Commercial-Rafting-Use-Report.pdf.

2.3.3 Agricultural Benefits: Shoshone flows support Colorado's agricultural economy (responsible for generating nearly $12 billion of Colorado's GDP in 2019)[37] in several important ways. First, water security for West Slope agriculture is intimately linked to the Recovery Program where continued cooperative water management allows for continued development and diversion of water resources while maintaining compliance with the ESA. Second, if the Shoshone Water Rights were not exercised, irrigators would be directly impacted by a likely increase in the frequency and duration of the Cameo Call to supply major irrigation water rights in the Grand Valley. *See* Appendix 6; *see also* Appendix 16. The resulting impact would trigger less opportunity for upstream agricultural diversions, a greater frequency of river administration in the month of April, and insufficient replacement supplies for some West Slope augmentation plans. Additionally, irrigators in the Roaring Fork Valley could experience increased instances where their water rights are out-of-priority due to a more frequent Cameo Call, resulting in an expensive and time-consuming process to produce additional augmentation supplies. *See* Appendix 16.

Furthermore, the historical flow regime created by the Shoshone Call protects and improves water quality especially in low flow periods for water users up and down the Colorado River mainstem. Agricultural producers benefit significantly from improved water quality, bringing greater agricultural production to the West Slope. High salinity levels in the Colorado River, which are expressed by the concentration of TDS, can negatively impact water use and crop yields, especially for salt-sensitive cash crops, such as fruits and vegetables by up to 25%.[38] This is further documented by the United States Department of Agriculture and Reclamation via implementation actions and studies published by the Colorado River Basin Salinity Control Program.[39] Reclamation invests millions of dollars every year for salinity control measures that enhance and protect the quality of water available in the Colorado River.[40]

2.4 Community Impact and Partnerships

The Shoshone Water Rights Preservation Coalition (the "Coalition") has raised $56 million in formal commitments towards the purchase price of the Shoshone Water Rights, underscoring the significance of this resource to the region. The Coalition encompasses the most populous regions on Colorado's West Slope with diverse interests across the environmental, recreational, municipal, and agricultural sectors. In December 2023, the River District committed $20 million with the

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[37] *See* Colorado Office of Economic Development & International Trade, *Food and Agriculture*, https://choosecolorado.com/key-industries/food-agriculture/, (last visited on November 5, 2024).

[38] *See* Colorado State University Extension, Master Gardener, *CMG GardenNotes #224 Saline Soils* (revised October 2015), https://cmg.extension.colostate.edu/Gardennotes/224.pdfm, p. 224-1; *see also* United States Geological Survey, *State News Release: New study demonstrates how climate and irrigation influence salinity of waters in the Upper Colorado River Basin* (February 8, 2024), https://www.usgs.gov/news/state-news-release/new-study-demonstrates-how-climate-and-irrigation-influence-salinity-waters#:~:text=High%20salinity%20levels%20in%20the,to%20infrastructure%20and%20crop%20production.

[39] *See, e.g.*, Natural Resources Conservation Service, Colorado River Basin Salinity Project, https://www.nrcs.usda.gov/programs-initiatives/colorado-river-basin-salinity-project, (last visited on November 10, 2024).

[40] U.S. Bureau of Reclamation, Colorado River Basin Salinity Control Program, https://www.usbr.gov/uc/progact/salinity/, (last visited on November 10, 2024) (noting that Reclamation awarded funding totaling $23,567,002 to projects in Colorado and Utah that implement salinity control measures).

signing of the PSA. On January 29, 2024, the CWCB voted unanimously to recommend a $20 million investment in support of the Project. Colorado's General Assembly subsequently approved the CWCB's contribution through the 2024 Water Projects Bill (HB24-1435) with broad bipartisan support. As of the date of this application, 26 water entities, local governments, and regional partners have formally committed $16 million to the Project. *See generally* Appendices 2 and 3 (containing summaries of formal financial commitments and letters of support).

Notably, Colorado's state and federal elected officials and representatives overwhelmingly support this application. Appendix 2 includes 58 unique letters of support that articulate the benefits of the Shoshone Water Rights to their communities. By way of example and not limitation, Appendix 2 includes letters of support from Governor Polis, Senator Bennet, Senator Hickenlooper, the Colorado Speaker of the House, federal and state legislators from throughout the State of Colorado and numerous other state dignitaries. These letters emphasize the importance of the Project and the importance of a healthy Colorado River to local communities and economies.

2.5 Disadvantaged Communities

CEQ's Climate and Economic Justice Screening Tool identifies eight census tracts as disadvantaged that include overburdened and underserved communities along the Colorado River in the West Slope that directly benefit from the Shoshone Water Rights.[41] The eight tracts include portions of the City of Rifle, the City of Grand Junction, and Clifton, which have each made financial commitments to the Project. The City of Rifle committed $100,000, Clifton Water District committed $250,000, and the City of Grand Junction committed $1 million. The census tracts are also included within Garfield and Mesa Counties, which have committed $3 million and $1 million, respectively, highlighting the importance of the Project to these communities.

Clifton, the City of Rifle, and the Towns of DeBeque, Silt, Parachute, and Battlement Mesa are all West Slope communities which draw and treat water directly from the Colorado River as their primary domestic water supply. The Project will sustain critical flows and water levels in the Colorado River on a year-round basis, especially in dry years, thereby maintaining water quality through the dilution of pollutants and sediment naturally present in the river. The presence of sediment is of particular concern for a stretch of 103 river miles from the Colorado River's confluence with the Roaring Fork River to the confluence with the Gunnison River on the "Monitoring & Evaluation List" within Colorado's Section 303(d) List of Water-Quality-Limited Segments Requiring Total Maximum Daily Loads.[42] While this reach is not listed for impairment, the "Monitoring & Evaluation" classification signifies there is "reason to suspect water quality problems". *See supra* note 12.

The City of Rifle, located in western Garfield County, relies on surface water from the Colorado River as its primary source for drinking water. Colorado River water is diverted and conveyed through a pre-sedimentation pond where it is then pumped up to the Rifle Regional Water

[41] *See supra* note 32 (The identified disadvantaged tracts include Tracts Nos. 08045952001, 08077001705, 08077001706, 08077000602, 08077000700, 08077000200, 08077000500, 08077000300.)
[42] *See supra* note 12.

Purification Facility.[43] Similarly, the Clifton Water District, which provides water service to over 13,700 residential and commercial units just to the east of the City of Grand Junction, relies on two different points of diversion from the Colorado River. Clifton's water treatment system includes ultra- and micro-membrane filtration systems that are prone to increased operational costs when turbidity increases, or other factors decrease the water quality. Sustained, year-round river levels, supported by the Shoshone Call, allow for higher water quality and reduce consumer costs by diluting difficult-to-remove pollutants and sediment.

Additionally, the City of Grand Junction and the nearby Ute Water Conservancy District ("Ute Water") both rely on the Colorado River as a secondary source of drinking water and as a key economic driver for the broader Grand Junction community. The City of Grand Junction, home to over 68,000 residents, currently holds conditional water rights on the Colorado River. Similarly, Ute Water, the largest drinking water provider between Denver and Salt Lake City, relies on the Colorado River as a backup supply under severe drought conditions. In 2021, for the first time, Ute Water diverted Colorado River water to meet its peak summer demands in response to exceptional and extreme drought conditions across Ute Water's service area.[44] Across the American West, redundant drinking water sources are becoming critical for municipalities like Grand Junction which continue to experience increased pressures from the impacts of a warming climate including wildfires, drought, and diminished water quality from lower flows. The Shoshone Call also supports recreation on the Colorado River, an important driver for Grand Junction's economy. The recently constructed side channels and amenities at Las Colonias Park in Grand Junction benefit from sustained flows and offer high-quality recreation experiences for residents and visitors.

2.6 Benefits to Federal Projects

The Project enhances existing federal projects and facilities within the State of Colorado. Specific benefits are described below in addition to benefits to federal projects discussed earlier in this proposal regarding the Upper Colorado River Wild and Scenic Alternative Management Plan and the Recovery Program efforts in the 15-Mile Reach.

***Colorado-Big Thompson Project and Green Mountain Beneficiaries*:**

Senate Document 80: The operation of Green Mountain Reservoir is governed by the "Manner of Operation of Project Facilities and Auxiliary Features" provisions of Senate Document 80 "SD-80" (Act of August 9, 1937, 50 Stat. 564) (*see* Appendix 14.b.), which was a project feasibility study prepared by Reclamation that was submitted to the United States Congress in 1937 to support the congressional authorization of the Colorado-Big Thompson Project ("C-BT Project"). The Project is consistent with the express purposes of SD-80. Under SD-80—and consistent with the

[43] City of Rifle, Garfield County, Colorado, DRAFT April 2019 Water Efficiency Plan, https://www.rifleco.org/308/Water-Efficiency (last visited on November 6, 2024).
[44] Michael Booth, *Drought forces Grand Junction to dip into Colorado River for drinking water supplies for the first time in more than 50 years*, THE COLORADO SUN (July 2, 2021, 4:20 AM), https://coloradosun.com/2021/07/02/ute-water-colorado-river-drought/.

1984 Green Mountain Reservoir Operating Policy—Green Mountain Reservoir was constructed as a replacement reservoir to provide water to the Colorado River when senior West Slope demands are exercising their senior priorities under Colorado's prior appropriation system and as compensatory storage for future West Slope water use development. *Id.*

Another key provision of SD-80 provides that, from April 15 through October 15, water from Green Mountain Reservoir's 100,000-acre-foot compensatory storage pool (the "Power Pool") will be released to provide a natural flow of at least 1,250 cfs at the location of the Shoshone Diversion Dam. *Id.* The purpose of this provision is to maintain at least 1,250 cfs at the Shoshone Diversion Dam during the irrigation season, which together with releases from Green Mountain Reservoir during the non-irrigation season for power production, provide the necessary surety to downstream West Slope water users on the Colorado River that they can divert and use water free of senior calls from transmountain diverters. (Note that the preserved flows at Shoshone Diversion Dam identified in SD-80 were limited to 1,250 cfs, as the junior 158 cfs water right had not been adjudicated when SD-80 was drafted.) In addition to the Power Pool, Green Mountain Reservoir also holds a 52,000-acre-foot "Replacement Pool" designed to adequately augment out-of-priority diversions from the East Slope components of the C-BT Project facilities.

The Project aims to maintain the historical administration of the Colorado River and operation of the C-BT Project by ensuring the Shoshone Water Rights continue to operate into the future. Hydros evaluated operations of the C-BT Project in the Yield Addendum under the daily 2024 UCRM with respect to the Project. *See* Appendix 6. Hydros concluded that no significant change in reservoir yield would occur to the East Slope or West Slope components of the C-BT Project between current conditions in the Baseline and Max-Relax scenarios. *See id.* at p. 3 (Table 1). The model results indicate that even year-round demands attributable to the Shoshone Water Rights at 1,408 cfs do not impact project yields at Adams Tunnel, nor do they disrupt storage levels at Granby Reservoir or Green Mountain Reservoir. These three facilities (and appurtenant structures) are significant components of the C-BT Project. *Id.* at pp. 3–4 (Tables 1 and 2). Additionally, Hydros found that minimum and maximum storage levels in Granby Reservoir and Green Mountain Reservoir were identical in the Baseline and Max-Relax scenarios while average storage levels had insignificant changes. *Id.* at p. 3 (Table 1). In other words, the model results demonstrate that permanently protecting the Shoshone Water Rights will not adversely impact the transmountain or in-basin components of the C-BT Project.

Upper Colorado River Wild and Scenic Alternative Management Plan: As discussed in Section 2.2.3, the Shoshone Water Rights protect significant amounts of river flow during dry periods, contributing to lower water temperatures through key segments of the Upper Colorado River mainstem, with recreational fishing and wildlife habitat identified as ORVs in these segments.

Reclamation's Obligations under the ShOP Agreement: The Project would eliminate the need for continued operations under the ShOP Agreement (Appendix 14.d.), and Reclamation's obligations therein would also terminate. The Project is consistent with SD-80 and would achieve the goals of Shoshone permanency much more dependably and effectively than the ShOP Agreement because

the benefits of operating the Shoshone Water Rights would no longer be dependent on the voluntary participation of the ShOP signatories, which is not permanent. *See* Appendix 13, p. 4, ¶ 4. A thorough analysis of the limitations of the ShOP Agreement is set forth in Section 3.2.1., below.

***Fryingpan-Arkansas Project*:** According to the Yield Addendum, the Shoshone Water Rights contribute flows that hold off the Cameo Call, which otherwise would call earlier and would remain on the river for longer durations, adding approximately 29% more calling days. The potential increased frequency and duration of a Cameo Call places additional stress on junior water rights along the Roaring Fork River and in the tributaries above the confluence of the Roaring Fork and Fryingpan Rivers, which includes water rights associated with the Fry-Ark Project. Further, the Yield Addendum found no impact to the Fry-Ark Project between Baseline and Max-Relax scenarios under increased demands from the Shoshone Water Rights. *See* Appendix 6, page 3. Instead, the Yield Addendum observed increased yields to the Fry-Ark Project (i.e., to Ruedi Reservoir and Boustead Tunnel) when compared to the scenario without demands under the Shoshone Water Rights. *Id.*[45]

Without the Shoshone Water Rights benefiting the 15-Mile Reach, water users would be increasingly reliant on releases from Ruedi Reservoir to provide a replacement and/or augmentation supply for junior uses and to support baseflow targets for the Recovery Program. This would increase stress on recreational fishing and potentially exacerbate conflict with the local recreational fishing economy downstream of Ruedi Reservoir as well as recreational boating at Ruedi due to the need for higher storage releases and further drawdowns of the reservoir.

***Silt Project*:** The Silt Project, located on the West Slope near the Towns of Rifle and Silt, is one of the initial projects authorized by the Colorado River Storage Projects Act. It is operated by the Silt Water Conservancy District and uses stored water and water pumped out of the Colorado River to serve the irrigation needs of nearly 7,000 acres of land located in the region. The Silt Project facilities include the Rifle Gap Dam, Reservoir, and Silt Pumping Plant, which pumps water out of the Colorado River using a designated 5,000-AF storage pool in Green Mountain Reservoir.

In addition to important ESA compliance and dilution flows (which reduce the impacts of sediment/salinity) for 7,000 acres of irrigated land, the exercise of the Shoshone Water Rights maintains the hydraulic head on the Silt Project's primary headgate on the Colorado River which is necessary to operate the pump canal. Maintaining the Shoshone Water Rights during the irrigation season delays the Cameo Call, and, in turn, preserves the Silt Project's storage pool.

[45] Similarly, results were found by BBA Water Consultants, Inc. ("BBA"), in its draft October 12, 2023, memorandum titled, "Shoshone Impact on Cameo Call and Roaring Fork Basin Analysis", in which BBA concluded that the Fry-Ark Project is out-of-priority nearly every time the Cameo Call is active. *See* Appendix 16. Therefore, permanently protecting the Shoshone Water Rights is directly related to protecting Fry-Ark Project yields. According to BBA, the average annual benefit provided by the Shoshone Water Rights to the Fry-Ark Project ranges from 800 to 2,400 AF.

***Grand Valley Project**:* The Shoshone Water Rights provide stable flows and the necessary hydraulic head to maintain diversions at the Grand Valley Project Diversion Dam (a/k/a the "Roller Dam") and the subsequent lateral diversion by OMID and the Vineland Power Plant down-ditch of the Roller Dam. *See* Appendix 12. The Grand Valley Project supports over 40,000 acres of irrigated agriculture in the most densely populated area on Colorado's West Slope,[46] which benefits from the increased certainty provided by the Shoshone Call and the water quality benefits fostered by the exercise of the Shoshone Water Rights. These effects are essential to maintaining the Grand Valley's robust and productive agriculture economy. Additionally, the non-consumptive operations which occur at the Vinelands Power Plant and the OMID Pumping Plant benefit from reduced operations of the OMID "Check" structure, as facilitated by the Shoshone Water Rights, because such operations typically result in reduced power generation and pumping efficiency due to increased tailwater elevations caused by the Check. *See* Appendix 12.

In addition, the 15-Mile Reach rests between Cameo's agricultural diversions and the confluence of the Colorado River with the Gunnison River at the mouth of the Grand Valley. Given the proximity, Grand Valley Project beneficiaries are acutely aware of the need to support baseflows in the 15-Mile Reach and recognize that the Shoshone Water Rights provide flows which are critically necessary to meet the Recovery Program's flow targets during the spring, late irrigation season months, and through the winter season. *See* Appendix 6, pp. 8–9; *see also* Appendix 2 (GVWUA's September 4, 2024, "Letter of Support: Shoshone Water Rights Preservation").

Lastly, the Project would provide security in permanently fulfilling the pertinent conditions set forth in the "Stipulation and Agreement" executed as part of the Check Case (Case No. 91CW247), which requires that the Shoshone Water Rights continue to be exercised in a manner consistent with historical operations for hydropower production at the Shoshone Power Plant. If the Shoshone Water Rights are not exercised in a manner consistent with historical practice, a potential breakdown in the Check Case's Stipulation and Agreement would ensue that could increase the Cameo Call to 2,260 cfs (versus the stipulated 1,950 cfs), disrupt the availability of HUP Surplus water to the 15-Mile Reach, and potentially lead to protracted litigation involving the parties to the Check Case. For additional details regarding the relationship between the Shoshone Water Rights and the Check Case Decree and Stipulation, please refer to Appendix 12.

2.7 Economic Value to the Federal Government

The values and benefits afforded by the Project also culminate in a significant economic benefit to the federal government. Consultants at BBC Research and Consulting ("BBC") examined the economic value provided by the Project to the federal government through the recovery of threatened and endangered aquatic fish species, reduction in salinity concentrations, and avoidance of further reductions in Colorado River flows by providing essential flows that stabilize water supply during periods of scarcity. To review BBC's report, the "Benefits from the Shoshone Water Rights to the Federal Government," please refer to Appendix 9.

[46] Joe Simonds, Bureau of Reclamation, *Grand Valley Project* (1994), https://usbr.gov/projects/pdf.php?id=122, p. 18.

Using historic water lease rates for the Recovery Program, BBC determined significant monetary benefits resulting from the exercise of the Shoshone Water Rights by avoiding the need to find and lease equivalent water volumes. *See* Appendix 9, p. 5. For example, the annual benefit is estimated between $1.07-1.45 million, increasing to nearly $2 million annually in dry years. Further, BBC concluded that by diluting salinity in the Colorado River, the exercise of the Shoshone Water Rights results in an equivalent effect of salinity control for 16,896 tons of salt in average years which increases significantly in dry years to 23,109 tons. *Id.* at p. 8. Using the weighted average cost per ton of salinity control projects funded by Reclamation in 2023, this translates to an average financial benefit of $1.3 million - $1.8 million depending on an average or dry year. Finally, BBC's report considers the financial benefit of the Shoshone Water Rights during periods of scarcity, when replacing flows through reductions in consumptive use would be difficult and costly. Using the most recent payment rate for the 2023 System Conservation Pilot Program ("SCPP"), the annual benefit is estimated to be $16.9 million under current demands in dry years, growing to $18.7 million under future demands. *Id.* at p. 11.

Overall, the combined annual benefits range from $14.7 to 16.7 million, depending on current vs future demands and during dry years, these benefits increase in range to between $20.1 and $22.9 million per year. *Id.* at p. 14. The annual benefits to the federal government correspond to a net present value of $547.7 million under current conditions and increasing to $608.8 million with growing demands. *Id.* at p. 17.

3. Project Description and Implementation

3.1 Acquisition of Shoshone Water Rights

As set forth above, the Project seeks to permanently protect a critical historical flow regime in the mainstem of the Upper Colorado River Basin. Securing permanent protection of the river flows attributable to the Shoshone Call will foster improved resilience during future drought conditions while preserving important riverine ecosystems across the mainstem of the Upper Colorado River. The Project location is the Shoshone Reach in Glenwood Canyon, spanning approximately 2.4 miles from the upstream point at the Shoshone Diversion to the downstream point at the discharge outlets below the Shoshone Power Plant. The Project is a collaborative effort between the River District, PSCo, the Coalition,[47] and the CWCB. Unlike many federally funded projects, the Project does not involve any construction activities such as trenching, excavation, or on-site demolition in the Shoshone Reach. Instead, the Project is an iterative process governed by the laws and administrative procedures of the State of Colorado.

The steps necessary to complete the Project are presented as a series of actionable closing conditions in the PSA between PSCo and the River District. *See* Appendix 4. Pursuant to the PSA, to close the transaction and authorize the expenditure of public funds for the acquisition of the Shoshone Water Rights, the PSA contains four closing conditions that must be met by December 31, 2027, unless that deadline is extended by agreement between the River District and PSCo. The four mandatory closing conditions described in the PSA include the following:

[47] *See* Section 2.4, Table 3 above; *see also* Appendix 2 (letters of support).

(1) Negotiate an agreement between PSCo, the River District, and the CWCB to enable the Shoshone Water Rights to be used for instream flow purposes when they are not being used for power generation purposes.
(2) Obtain a change of water rights decree in state water court to add instream flow use as an alternate decreed beneficial use for the Shoshone Water Rights.
(3) Confirm approval of the sale of the Shoshone Water Rights by obtaining any necessary approvals and decisions from the Colorado Public Utilities Commission.
(4) Secure funding for the closing payment to acquire the Shoshone Water Rights.

Each of the four conditions (Appendix 4, p. 5, ¶ 4.4) summarized above is discussed below.

3.1.1 Instream Flow Acquisition Agreement

The PSA between the River District and PSCo contemplates that the parties will negotiate with the CWCB for an agreement ("ISF Agreement") authorizing the CWCB to use the Shoshone Water Rights for instream flow purposes when the rights are not being used to generate power. The River District's conversations with the CWCB's Instream Flow Program staff have been positive.

Section 37-92-102(3) of the Colorado Revised Statutes specifically authorizes the CWCB to acquire water rights "in such amounts as the board determines is appropriate for stream flows [ ] to preserve or improve the natural environment to a reasonable degree." [48] The CWCB has 120 days to determine what terms and conditions it will accept in an acquisition agreement for water, water rights, or interests in water to preserve or improve the natural environment. C.R.S. § 37-92-102(3). Pursuant to the CWCB's rules (the "ISF Rule(s)," 2 CCR 408-2), at least two CWCB board meetings must be held to allow for public input prior to the CWCB taking final action on a proposed acquisition. *See generally* ISF Rules 6a.–6b, 6e., 6i., and 6m.–6n. If no hearing is requested, the CWCB may take final action on the proposal after the expiration of 120 days. Negotiations with the CWCB, PSCo, and the River District staff concerning the instream flow agreement have been underway since February 2024. The River District anticipates that, once formally initiated, the acquisition process will take between 4 to 6 months.

Once the CWCB's administrative process is completed and the CWCB approves the acquisition (*see* ISF Rule 6n.) of the exclusive right to use the Shoshone Water Rights for instream flow purposes when they are not used for power generation purposes, the ISF Rules dictate that the CWCB—together with the River District and PSCo—shall file a change of water right application to obtain a decreed right to use the Shoshone Water Rights for instream flow purposes. To ensure that the Shoshone Water Rights will be perpetually used to protect and improve the natural environment, the Colorado River District has proposed language in the proposed ISF Agreement and proposed change of water rights decree that prohibits any additional, future change of the Shoshone Water Right without the mutual consent of the CWCB and the Colorado River District. To protect the requested financial contribution by the United States, the Colorado River District

[48] Under statute, the CWCB will make a determination of appropriateness related to the amount of water needed to improve the natural environment before acquiring an interest in a water right for that purpose. Then, the process to add an instream flow use as a decreed beneficial use of the Shoshone Water Rights will proceed to state water court. Once in water court, the CWCB's determination(s) are accorded deference under the Colorado State Administrative Procedure Act. *See* C.R.S. §§ 37-92-102(4)(c), (8)(f)(I)(A), and 37-92-305(13)(a).

will support similar binding language in the proposed water court decree that will prohibit any further change in use of the water rights absent the consent of the United States.

- *Anticipated Timeline:* Negotiations with the CWCB, PSCo, and the River District staff concerning the instream flow agreement have been underway since February 2024. The River District anticipates that, once formally initiated, the acquisition process will take between 4 and 6 months.

3.1.2 Water Court Approval

Each water division in the State of Colorado includes a water court which is presided over by a water judge. C.R.S. § 37-92-201. The water judge for each division is appointed by the Colorado Supreme Court and has exclusive jurisdiction in the determination of water rights, the use and administration of water, and all other water matters within the water division. *See generally* C.R.S. § 37-92-203. The water court process is generally initiated by the filing of an application. That application is published in a monthly water court resume and as legal notice in one or more papers of general circulation within the applicable water division. Interested parties may file a statement of opposition to the application setting forth the reasons why the application should not be granted or granted on certain conditions. C.R.S. § 37-92-302(1)(b). The Project will require a joint water court application by the CWCB, PSCo, and the Colorado River District to change the use of the water rights to add instream flow use by the CWCB as an alternate beneficial use when the rights are not being used to generate hydropower. C.R.S. § 37-92-203. Colorado law provides that an alternate use decreed to an existing water right through a change of water rights proceeding, as is contemplated in this transaction, will maintain the priority of the original water right. *See* §§ 37-92-102(3), 37-92-103(5)(a).

Pursuant to statute, the water judge shall approve the application for a change of water right if the requested change will not cause injury to other water users. C.R.S. § 37-92-305(3)(a). If it is determined that any proposed ruling would have an injurious effect, any party may propose terms and conditions to prevent such an injurious effect. *Id.* Because it is the intent of the Colorado River District to maintain the historic flow regime associated with the Shoshone Water Rights, no injury will occur to any other water rights. Thus, the anticipated end-result of the water court process will be a decree that confirms the additional use of the Shoshone Water Rights for instream flow purposes without resulting in any change of the Colorado River stream system that would adversely affect other water rights.

- *Anticipated Timeline:* The River District anticipates that the water court process will take approximately 1.5 years from the filing of this application to receiving a change of water rights decree approved by the water court. While it is difficult to predict the length of a change of water rights proceeding in water court, the PSA includes a condition (*see* Appendix 4, ¶ 4.4(b)) requiring the Colorado River District to engage in substantive negotiations with potential water court objectors to address and ideally eliminate objections that could be raised during the water court process. Long before the PSA was executed, the River District negotiated with several operators of transmountain diversion systems and procured their contractual support for the River District's acquisition of these water rights and in some instances express agreement to not oppose the addition of an alternate instream flow use for the 1,250 cfs available under the

senior Shoshone Water Right. *See* Appendix 13 (summarizing the pertinent agreements with TMD operators, including excerpts of relevant contractual provisions). Since the execution of the PSA, the River District has expended considerable effort in negotiating with potential objectors. While those negotiations have been productive to date, they are still ongoing. Furthermore, the PSA provides that, if necessary, the closing date may be extended by mutual agreement of the River District and PSCo if, for instance, the water court process takes longer than anticipated. That said, the River District confidently maintains that the Project will meet the B2E requirement for complete expenditure of funds by September 30, 2031.

Historical Use of the Shoshone Water Rights

Figure 12: Shoshone Power Plant, Library of Congress

The overarching purpose of a change proceeding in water court is to ensure that use of the water right for the changed purpose is limited to mimic the actual historical beneficial use of the subject water right over a period of time. Confirming the historical use of the changed water right helps to ensure that other water users on the same stream system are protected from injury by preventing enlarged use of the subject water right. The "historical use" of the subject water right is calculated based on the pattern of historic diversions and beneficial use of a decreed water right for its decreed purposes over the representative period. Notably, there is no uniform approach to quantifying the historical use of a water right; instead, it is necessary only that historical use is quantified "in some fashion and to some degree of precision[.]" *State Eng'r v. Bradley*, 53 P.3d 1165, 1171 (Colo. 2002). Furthermore, it is not necessary for the water court to calculate historical use with "mathematical certainty" provided that the vested rights of junior water users are protected. *Southeastern Colo. Water Conservancy Dist. v. Fort Lyon Canal Co.*, 720 P.2d 133, 147 (Colo. 1986). And finally, Colorado water law "does not rigidly require that every year a water owner does not use a water right must be counted as a nonuse year [in a historical use analysis]." *Wolfe v. Sedalia Water & Sanitation Dist.*, 343 P.3d 16, 28 (Colo. 2015).

Considering the legal standards governing a change of water right proceeding as summarized above, the Colorado River District retained BBA Water Consultants, Inc. ("BBA") to prepare a preliminary assessment of the historical exercise of the Shoshone Water Rights for purposes of this B2E Application. A copy of BBA's November 8, 2024, Draft Preliminary Shoshone Yield Assessment (the "Preliminary HU Assessment") is attached to this application as Appendix 8.

In the Preliminary HU Assessment, BBA utilized a 29-year study period from 1975 to 2003 to show the historical exercise of the Shoshone Water Rights. *See* Appendix 8, pp. 8–9. The 1975-2003 study period does not include years after 2003, when the Shoshone Power Plant experienced significant outages totaling 1,466 days over 19 years, as opposed to 89 days of full outage during the selected 29-year study period. *See id.* at p. 5, Table 2. Instead, the selected study period is

representative of the "actual" historical use of the Shoshone Water Rights over a sufficiently long period of time when these rights were consistently used for their decreed purposes, and includes a representative cross-section of wet, dry, and average year types. BBA's approach and findings are consistent with the standards for a change of water rights case as specified under applicable Colorado law, including C.R.S. § 37-92-305(3)(d) which provides as follows:

> "Quantification of the historical consumptive use of a water right must be based on an analysis of the actual historical use of the water right for its decreed purposes during a representative study period that includes wet years, dry years, and average years. The representative study period:
>
> (I) Must not include undecreed use of the subject water right; and
>
> (II) Need not include every year of the entire history of the subject water right."

BBA characterized the historical use of the Shoshone Water Rights utilizing the "administrative flow" (i.e., total gaged flow less shepherded releases for downstream water users) in the Colorado River recorded at the USGS stream gage located near Dotsero, Colorado (USGS Gage 09070500, the "Dotsero Gage"). *Id.* at pp. 7–11. BBA's approach vis-à-vis the administrative flow recorded at the Dotsero Gage is consistent with and replicates the current and historical administration the Shoshone Water Rights by the Division Engineer for Water Division 5. *Id.* Furthermore, relying on the recorded administrative flow for purposes of BBA's preliminary analysis leads to a more accurate quantification of the historical use of the Shoshone Water Rights and the impact on historical stream patterns upstream and downstream of the Shoshone Power Plant because the administrative flow encompasses all diversions and water uses required to operate the Shoshone Power Plant including, but not limited to, tunnel sediment flushing and other historical operations.

BBA's approach with respect to administrative flow limited the available flow to the Shoshone Water Rights based on several reasonable assumptions. *Id.* at p. 10 (listing reasonable adjustments and assumptions). For instance, daily flows included in BBA's assessment were limited to the lesser of the administrative flow or the total 1,408 cfs available to the Shoshone Water Rights. BBA proceeded with an understanding that the Shoshone Power Plant continually operated unless the plant was shut down to address routine maintenance or to conduct repairs. The reasonable assumptions described in the Preliminary HU Assessment are defensible under Colorado law, supported by PSCo records, and provide the most-accurate description of the specific historical use and the impact of the Shoshone Water Rights to upstream and downstream water users.

BBA's Preliminary HU Assessment calculated the 29-year average historical use of the Shoshone Water Rights was 844,644 AF and recommended that this value to be applied against the rights as a 29-year running average volumetric limit to maintain the historical exercise of the water rights in a manner that also replicates historical stream conditions downstream of the Shoshone Power Plant (i.e., return flows). *Id.* at p. 10. The Preliminary HU Assessment also found that the Shoshone Water Rights historically diverted 1,408 cfs at some point in each month throughout the entire study period, confirming that usage of the full decreed rate for the two water rights was intended

at the time of their respective appropriations. Thus, BBA recommended that the full 1,408 cfs diversion rates be continued for the changed use for instream flow purposes so long as the 29-year rolling average volumetric limit is applied as a term and condition to prevent enlarged use.[49] Given the River District's analysis of all historical records available to date and our understanding of applicable laws, standards, and customs which govern proceedings in Colorado water court, the River District has determined that the water court change case is likely to result in a quantification of actual historical use of the Shoshone Rights which may vary by 10% (plus or minus) in relation to the 29-year historical use of the Shoshone Water Rights identified above.

The values presented in the Preliminary HU Assessment are reasonable and are consistent with the 2024 UCRM daily modeled results from the state developed Baseline conditions, where the Shoshone Water Rights demands and diversions bracket and were within 10% of the 29-year rolling average volumetric limit proposed by BBA. *Compare* Appendix 6 *with* Appendix 8. For these reasons, it is unlikely that the actual historical use of the Shoshone Water Rights, once quantified by the water court, would vary substantially from the values presented in the Preliminary HU Assessment.

3.1.3 Colorado Public Utilities Commission ("PUC") Approval Process

The PUC regulates public utilities within the State of Colorado, including PSCo. PSCo will need to seek approval of the sale of its water rights assets from the PUC. The PUC will consider the sale pursuant to C.R.S. § 40-5-105.

- *Anticipated Timeline:* It is anticipated that PUC approval will take between 6 months to 1 year.

3.1.4 Financing for Acquisition of Shoshone Water Rights

Prior to PSCo's commencement of the PUC proceeding, the River District will need to confirm the commitment of sufficient funds to make the closing payment to PSCo for the negotiated purchase price of $99,000,000. The funding commitments secured by the River District to-date are more particularly described above in Section 2.4.

- *Anticipated Timeline:* Written commitments from funding partners sufficient to meet this condition will be provided to PSCo within 30 days of the conclusion of the water court process.

3.2 Alternative Analysis and Considerations

The need for the Project is to make permanent a time-tested solution for combatting drought conditions in the mainstem of the Upper Colorado River Basin while ensuring the continuation of a reliable and clean water supply for ecosystem, agricultural, municipal, and recreation uses on the Colorado River above and below the Shoshone Power Plant. The purposes of the Project include:

[49] Appendix 8 is a summary of actual historical use of the Shoshone Water Rights over a representative period and is subject to revision based on continuing analysis of historical data and feedback from interested stakeholders. The actual historical use of the Shoshone Water Rights will ultimately be determined by a state water judge as part of the water court process. Therefore, BBA's report (and the analysis set forth in this application) may be updated as more information and data become available.

(1) To permanently maintain the Shoshone Water Rights and the historical flow regime in a manner that provides vital ecosystem, habitat, agricultural, recreational, municipal and other economic benefits created by the historical exercise of the Shoshone Water Rights
(2) To eliminate the risk of abandonment or reduction of the Shoshone Water Rights due to plant decommissioning or failure.
(3) To provide for the instream flow use of the Shoshone Water Rights by the CWCB in a manner that preserves and improves the natural environment to a reasonable degree.

Given the purposes of and need for the Project, the River District believes that it will be helpful to provide an analysis of potential alternatives to the Project. While the River District asserts that an evaluation of the Project under the National Environmental Policy Act ("NEPA") is unnecessary given the nature of the Project and Reclamation's involvement thereto, the River District is providing the following alternatives analysis to assist in the evaluation of this application.

Over the past two decades, the Colorado River District and the Coalition have considered numerous alternatives to protect the Shoshone Water Rights on a permanent basis. While the proposed acquisition of the Shoshone Water Rights requires a significant investment, the Project is contemplated under Colorado law and would result in the legal protections necessary to ensure the historical Shoshone Call is maintained in perpetuity. Moreover, the concept of the CWCB's acquisition of the right to use the Shoshone Water Rights for instream flow purposes was built into the heavily negotiated 2013 agreement known as the Colorado River Cooperative Agreement ("CRCA") between the River District, numerous West Slope governments, and Denver Water. *See* Appendix 14.c., Art. VI.C.3. ("The Signatories agree to use their best efforts to . . . devise and implement a mechanism or [ ] mechanisms that will permanently preserve the Shoshone Call[.]").

Aside from the Project, other potential alternatives evaluated by the River District and the Coalition—in addition to alternatives proposed by East Slope interests—either fail to provide sufficient protection of the historical flow regime or are impractical and in some cases unlawful in light of the legal standards which govern water rights in the State of Colorado. Nevertheless, to clarify the overall feasibility of the Project and to better frame this analysis, the River District offers the following analysis of alternatives including: (1) the no action alternative; (2) the permanent ShOP agreement alternative; (3) the new instream flow appropriation alternative; and finally (4) the preferred alternative (i.e., the Project).

3.2.1 No Action Alternative: Applying a NEPA lens to the Project traditionally requires consideration of "no action" with respect to purpose and need. Here, the "No Action Alternative" considers a future scenario under which no action is taken to permanently protect the exercise and administration of the Shoshone Water Rights. In other words, the Project is not implemented. The No Action Alternative is untenable for two primary reasons. First, the ever-present risk of outages at the Shoshone Power Plant due to aging infrastructure, the potential for decommissioning the plant at some future date, natural disasters, and related safety concerns jeopardize the continued existence of the Shoshone Water Rights and the critical flows protected by the Shoshone Call. And second, the existing ShOP Agreement is a temporary agreement that does not have the force and

effect of law (unlike a state water court decree) and includes numerous exceptions for participation by the signatories. As more particularly described below, the No Action Alternative does not meet the purposes of and need for the Project because it would not protect river flows during temporary plant outages, and it would likely eventually result in the discontinued exercise and administration of the Shoshone Water Rights and thereby reduce or even eliminate the critical and historic flow regime created by the Shoshone Call. Simply put, permanent protection of the Shoshone Water Rights would not be realized under the No Action Alternative.

The ShOP Agreement is a temporary agreement that lacks the force and effect of a state water court decree and should not be considered in the No Action Alternative.

Under the ShOP Agreement, the River District, Denver Water, the Middle Park Water Conservancy District, the Municipal Subdistrict of Northern Water, the Colorado State Engineer, and Reclamation agreed to an approach under which the signatories (not including Reclamation or the State Engineer) agree to release or bypass water from their systems during certain conditions when the Shoshone Water Rights would normally place a call but cannot because of an outage.[50]

The ShOP Agreement is an important agreement that, when implemented, ensures the partial continuation of flows attributable to the senior Shoshone Water Right that helps to protect river conditions for certain periods of the year. However, the ShOP Agreement has a limited term and falls short of permanently protecting the Shoshone flows in several significant respects, as follows:

- The ShOP Agreement expressly states that it shall not be construed or interpreted as "Shoshone Permanency" as defined in Article VI.C. of the CRCA. *See* Appendix 14.d., at p. 15, § VIII.

- The ShOP Agreement is limited to a 40-year term (32 years remaining) and cannot be made permanent without formal agreement between the signatories. *Id.* at p. 5, § III.A. Furthermore, under the ShOP Agreement, Reclamation may terminate its participation in the agreement at any time by providing notice to the parties. *Id.* at § III.D.

- The ShOP Agreement does not provide permanent protection of the historical flow regime created by the exercise of the Shoshone Water Rights. By its terms, the ShOP Agreement is limited to the protection of a target flow of 1,250 cfs attributable to the senior Shoshone Water Right during the irrigation season, and the protection of only 900 cfs during the non-irrigation season, which is a reduction from what the plant can legally divert and use. *Id.* at p. 5, § IV.A.2.

- The ShOP Agreement does not provide the legal force and effect of a state water court decree and is vulnerable to changes in state administrative interpretations. Although the Colorado State Engineer is a party to the ShOP Agreement, the ShOP Agreement specifically concedes that the ShOP obligations of the State Engineer must necessarily yield to the State Engineer's

[50] *See* Appendix 14.d. While not parties to the ShOP Agreement, Aurora Water and Colorado Springs-Utilities also participate in a roughly identical ShOP arrangement through separate agreements. *See* Appendix 13 (including excerpts thereto).

statutory obligations (§ 37-92-304(8), C.R.S.) to regulate the distribution of water in accordance with the judgments and decrees of state water courts. *See id.* at p. 16, § X.

- The obligations and rights of the signatories in the ShOP Agreement are not uniformly applied. For instance, the ShOP Agreement outlines several exclusions for when each signatory is excused from participating in ShOP operations during dry year conditions, which means that ShOP is either not implemented or is implemented at a reduced level when the Shoshone flows would otherwise provide the most benefit to the river. Additionally, some signatories reserved the right to terminate participation in ShOP under certain circumstances.

- The ShOP Agreement is enforceable only amongst the signatories who have agreed to voluntarily participate. While a new upstream junior water right would be subject to curtailment by the Shoshone Water Rights, the new junior would not be subject to ShOP. This means that not only would the new junior not be required to participate in ShOP but that the junior could intercept the water contributions of ShOP's participants, including ShOP releases from Green Mountain Reservoir. The ShOP Agreement does not—and cannot—be enforced against other water users that are not parties to ShOP. Furthermore, PSCo, the current owner of the Shoshone Water Rights, is not a party to the ShOP Agreement and is not subject to its terms and conditions with respect to operations at the Shoshone Power Plant.

- Under the express terms of the ShOP Agreement, the Replacement Pool in Green Mountain Reservoir is not available for Reclamation's participation in ShOP. *See id.* at p. 10, § IV.D. Thus, even in wet years like 2023, Green Mountain Reservoir's ability to participate in ShOP operations is limited and insufficient to meet even the limited ShOP goals of 1,250 cfs during the summer season and 900 cfs during the non-irrigation season if the river is forced to rely upon ShOP year-round. Furthermore, if the Shoshone Call is not preserved and the Shoshone Power Plant is permanently decommissioned, this will result in changes to the operation of Green Mountain Reservoir that would be inconsistent with a key purpose of SD-80.

- And finally, while the ShOP Agreement is intended to maintain the historical flow regime influenced by the operation of the Shoshone Power Plant when the plant is offline, the agreement does not contemplate a future scenario under which the plant is permanently decommissioned and/or the Shoshone Water Rights are lost to the stream. Thus, if the Shoshone Power Plant is permanently decommissioned, and/or the Shoshone Water Rights are abandoned, the premise of the ShOP Agreement would be frustrated. From an operational standpoint, this could result in a *de facto* termination of the obligations of the ShOP signatories to participate in ShOP operations to protect the flows provided by the Shoshone Call.

Current and long-term operations of the Shoshone Power Plant face significant risks and uncertainties due to the plant's age, location, and susceptibility to natural hazards.

Construction of the Shoshone Power Plant began in 1906, and it first operated in 1909. While the plant has consistently operated over its 115-year history (and continues to do so today), the risk of

future outages remains, including the likelihood of potentially irreparable damage caused by natural disasters that could lead to a decommissioning of the plant. For instance, the ability of the Shoshone Power Plant to generate power has been frustrated since 2004 due to increased maintenance and repair needs resulting from unforeseen natural phenomena. By way of example, in 2007, the plant experienced a penstock failure and consequent damage to the down-gradient powerhouse that required the plant to be offline for nearly a year.

Figure 13: 2007 Shoshone Power Plant Penstock Failure (photos courtesy of PSCo)

More recently, in 2020, Glenwood Canyon experienced significant natural disasters caused by the Grizzly Creek Fire, which burned over 30,000 acres of land, destroying transmission lines and threatening the Shoshone Power Plant and its associated infrastructure. Subsequently, in 2021, Glenwood Canyon experienced repeated flooding and debris flow events carrying mud, rocks, and woody materials into the drainage basins of the canyon. These natural phenomena caused the Shoshone Power Plant to go offline for the majority of 2021 due to rock debris and other impacts from the debris flows.[51] Additionally, the plant was offline for more than 15 consecutive months in 2023 and 2024 due to a combination of maintenance problems and geologic hazard mitigation. As articulated above, recent climate projections anticipate that wildfires and extreme weather events will be amplified into the future due to ongoing drought and impacts from climate change.

3.2.2 Alternative 1 - Permanent Shoshone Outage Protocol Agreement: All of the limitations of the ShOP Agreement summarized above (apart from the temporary nature of ShOP) would continue to apply to any effort to convert this into a permanent agreement. The River District discussed the potential of making ShOP permanent with the highest levels within Reclamation in 2019 and was informed that Reclamation viewed ShOP as a water supply contract and that Reclamation was therefore prohibited from entering a perpetual contract under applicable law. Additionally, the Colorado River District previously approached Front Range water entities to propose a discussion of a permanent ShOP agreement. This discussion did not move forward due to a refusal by the Front Range signatories to engage in such discussions. Moreover, as discussed above under the No Action Alternative, the current ShOP Agreement only offers limited protection to the senior Shoshone Water Right up to 1,250 cfs during the summer season and 900 cfs during

[51] United States Geological Survey, *Glenwood Canyon Flooding and Debris Flows*, https://landslides.usgs.gov/storymap/grizzlycreek/ (last visited November 7, 2024).

the non-irrigation season when the plant is offline. The ShOP protections do not extend to the 158 cfs junior Shoshone Water Right.

3.2.3 Alternative 2 - Junior Instream Flow Appropriation: This alternative—which has been proposed by a transmountain diverter—considers whether a new instream flow appropriation could protect the historical flow regime created by the historical exercise and administration of the Shoshone Water Rights. As discussed, the tremendous value of the Shoshone Water Rights in maintaining flows in the mainstem of the Upper Colorado River is entirely dependent on permanently protecting the senior priorities of the Shoshone Water Rights. This is because, under Colorado law, the value of a water right is primarily informed by its priority relative to other water rights. Thus, the proposal for a new instream flow appropriation would not result in any of the protections afforded by the Project because a new instream flow water right cannot lawfully inherit the senior priorities of the Shoshone Water Rights. At best, a new instream flow appropriation would protect against only new junior post-2024 appropriations. In contrast, the Project's proposed change of water right would secure the existing senior priorities of the Shoshone Water Rights for instream flow use. The natural consequence of a new junior instream flow proposal would be that junior water rights upstream of the Shoshone Power Plant—including major transmountain diverters—would be in-priority more often and divert increased yields that would inevitably lead to reduced flows in the Colorado River. In other words, this proposal (couched as an "alternative" by one transmountain diverter) would result in an interruption of historical stream conditions upstream and downstream of the Shoshone Reach (and consequently a reduction in return flows) thereby injuring downstream junior appropriators and the health of the Colorado River ecosystem, especially during extended drought periods while providing allowing upstream junior water rights, including rights held by transmountain diverters, to further deplete the river of its natural flows.

3.2.4 Preferred Alternative – The Project: On balance, the Colorado River District and the Coalition determined that while the cost to acquire the Shoshone Water Rights is significant, the public benefits that will be secured in perpetuity justify the expense. This is particularly true when weighed against the range of impractical alternatives summarized above, which would not meet the goals of permanently protecting the historical flow regime in a manner that provides vital ecosystem, habitat, agricultural, recreational, municipal and other economic benefits down the Colorado River's mainstem and throughout the Upper Colorado River Basin. In addition, the CWCB's acquisition of an interest in water rights and the subsequent change of such rights to include a decreed instream flow use is specifically contemplated under Colorado law (unlike Alternative 2) and is supported by precedent.

Further, the Project has been memorialized within numerous foundational agreements. *See* Appendix 13. In 2013, the Colorado River District, together with numerous other West Slope governments, entered the CRCA with Denver Water (Appendix 14.c.). The CRCA established a long-term partnership between Denver Water and the West Slope concerning numerous and far-ranging goals and actions, aimed at benefitting water supply, water quality, recreation, and the environment on both sides of the Continental Divide. A fundamental component of the CRCA's goals and actions involved a consensus among the signatories as to the need for long-term

protection of the river flow regime created by a call for 1,250 cfs attributable to the senior Shoshone Water Right.[52]

The CRCA's clear distinction between a temporary solution to address outages at the Shoshone Power Plant (i.e., ShOP) and "Permanency of Shoshone Call Flows" has been memorialized in a series of agreements with Front Range entities that demonstrate a joint commitment to achieve the permanent management of the flow of the Colorado River created by the Shoshone Call. A summary of those agreements (including relevant excerpts) is set forth in Appendix 13.

3.3 Environmental and Cultural Resources Compliance

The River District does not envision any issues surrounding environmental and cultural resources with respect to implementation of the Project. Nevertheless, to facilitate Reclamation's review of this application, the River District provides the following answers to questions listed in the RFA:

- *Has the applicant previously received federal funding for this project or a project(s) adjacent to the proposed project? If so, provide environmental compliance and permitting documentation.*

The Colorado River District has not previously received federal funding for this project or any projects adjacent to the proposed project. Thus, there are no existing environmental compliance or permitting documentation that the Colorado River District has access to.

- *Have previous environmental analyses been completed for this project? If so, attach reports or summaries of findings.*

The Colorado River District is not aware of any previous environmental analysis that has been completed other than the biological studies identified below.

- *Have biological studies, inventories, or literature searches been conducted? If so, please provide reports.*

The Colorado River District commissioned Dr. Miller of Freshwater to provide a report titled "Shoshone Reach Instream Flow Habitat Data Analysis, Habitat Simulations and Habitat Evaluation of Colorado River from the Shoshone Diversion to the Shoshone Power Plant Outfall". *See* Appendix 11. Dr. Miller's report documents his evaluation of instream flows for aquatic resources in the Shoshone Reach of the Colorado River between the Shoshone Diversion Dam and the Shoshone Power Plant outfall. The purpose of Dr. Miller's report was to determine the current state of the aquatic habitat and ecosystem in the Shoshone Reach for purposes of determining what the anticipated changes to the aquatic habitat and ecosystem would be with the change of the Shoshone Water Rights. Additionally, the BLM/USFS Report provides a summary of the natural environment supported by Colorado River flows in Glenwood Canyon, describing the relationship of that natural environment to the Shoshone Water Rights. The BLM/USFS Report also describes

[52] The concept of permanently protecting the Shoshone Call is expressly contemplated and defined in Article VI.C. of the CRCA (Appendix 14.c.) as "Permanency of Shoshone Call Flows."

other water-dependent values upstream and downstream from Glenwood Canyon that are dependent on consistent flows through Glenwood Canyon. *See* Appendix 10.

- *What measures will be taken to minimize potential for spread of invasive plant species and/or noxious weeds?*

This question is not applicable to the Project. The Project will not include any new infrastructure, nor will it modify any existing infrastructure. There will be no ground disturbing activities associated with the Project. Accordingly, there is no potential for the spread of invasive plants.

- *What measures will be taken to minimize potential for spread of aquatic invasive species?*

This question is not applicable to the Project. The continuation of the historical operations of the Shoshone Water Rights will not promote or exacerbate the spread of aquatic invasive species. With respect to the Project, no activity will take place in the Colorado River or in its riparian areas.

- *Is the project area located in/on, crosses or is adjacent to a lake, river, stream, wetland, or other waterbody? If so, describe or show on a map and describe if the project would modify or impact the waterbody in any way.*

The Project is located on the mainstem of the Colorado River in Glenwood Canyon, Colorado. As noted above there will be no construction of new facilities, no modification to existing facilities, or changes made to the Colorado River with respect to the Project.

- *Does the project contain or is it adjacent to existing facilities, buildings, or other structures? If so, please list and provide estimated age of facilities or structures if known.*

The Project is adjacent to existing facilities that are owned and operated by PSCo. These facilities include the Shoshone Diversion Dam, the tunnel, the plant complex and discharge outlets. The Shoshone Power Plant was constructed between 1906 and 1909.

- *Describe if the project would result in any modification of or changes to the existing facilities, buildings, and/or structures.*

The Project will make no modifications or changes to the existing facilities.

- *Provide a brief history, if applicable, of the facilities or structures being modified or changed and approximate age.*

Not applicable, please see above.

- *Have archaeological or cultural resources surveys been conducted yet for the project area? If so, were any concerns or sites identified?*

To the best of the Colorado River District's knowledge, no archaeological or cultural resources surveys have been conducted in the project area.

- *Is the applicant aware of any tribal concerns or interests in or near the project area?*

The Colorado River District is not aware of any tribal concerns or interests in or near the Project.

3.4 Required Permits or Approvals

Please refer to Section 3 above for a discussion of the CWCB's administrative process for formalizing an instream flow agreement, the water court process for approval of a change of water rights, and the PUC-approval process for the sale of the Shoshone Water Rights to the River District.

The Project does not involve extensive permits or approvals for implementation beyond the state administrative, water court, and PUC processes described in Section 3. For instance, the River District does not foresee the need to secure any federal, tribal, and/or county permits or approvals for Project implementation. Nor does the Project contemplate any improvements to federal projects or facilities and, therefore, it is not expected that any necessary easements, land use authorizations, or special permits are necessary. Nevertheless, the River District acknowledges that all projects to be evaluated for B2E funding must comply with NEPA. For the reasons explained above in Section 3, the Colorado River District maintains that the preservation of the historical flows attributable to the Shoshone Water Rights will result in no change to the human environment. Thus, to the extent that any NEPA review is deemed necessary, such review should be minimal.[53] Furthermore, as noted in Section 3, the Project includes no ground disturbing activities, no construction of new structures, and no modification to existing structures. Additionally, there will be no modifications made to the Colorado River or to surrounding riparian vegetation because of the Project.

Perhaps most importantly, as identified in Section 3.1.2, the River District, PSCo, and the CWCB will need to file an application with the water court to change the use of the Shoshone Water Rights to add an alternate use for instream flow purposes by the CWCB when the water rights are not otherwise being used to generate hydropower at the Shoshone Power Plant. Pursuant to Colorado law, a change of water rights cannot be decreed by the water court if it causes injury to other water users or if the change would constitute an enlargement of historical operations and use of the water rights. Thus, by statutory design, the change of water rights process will ensure that current conditions are maintained. With respect to the Shoshone Water Rights, the water court will only enter a change decree if the change will not result in injury to vested water rights and the historical exercise of the water rights are maintained and not enlarged. In other words, the process to change the Shoshone Water Rights will ensure that no water rights are injured, including those associated with projects owned and operated by Reclamation.

[53] "A bureau proposed action is subject to the procedural requirements of NEPA if it would cause effects on the human environment (40 CFR 1508.14) and is subject to bureau control and responsibility (40 CFR 1508.18)." 43 CFR §46.100

Governor Polis Celebrates Historic Investments in Colorado's Water Future, Including $40M for Shoshone Water Rights

FRIDAY, JANUARY 17, 2025

GLENWOOD SPRINGS – Today, Governor Polis celebrated a historic round of grants from the U.S. Bureau of Reclamation for projects in Colorado totaling $176.8M from the Inflation Reduction Act, including up to $40M for the Colorado River Water Conservation District's acquisition of the water rights associated with the Shoshone power plant.

"The Colorado River is a lifeline for the Western Slope and the thousands of Coloradans who call it home. This support for the Shoshone water rights is a

huge step towards ensuring that the river will continue flowing to western Colorado farmers, ranchers, communities, and businesses," said Gov. Polis.

Colorado allocated $20 million of state funding towards the purchase of the water rights from Xcel Energy, contingent upon the purchase and sale agreement between the District and the Public Service Company of Colorado. In August 2024, Gov. Polis wrote a letter to the Bureau of Reclamation urging the agency to provide this funding so that businesses, farms, ranches, and outdoor recreation on the Western Slope can continue to thrive.

"The Department of Natural Resources is pleased to see such a significant federal investment from the US Bureau of Reclamation for drought resilience and watershed health in Colorado," said Dan Gibbs, Executive Director, Colorado Department of Natural Resources. **" These funds were established to assist Upper Colorado River and other river basins to fund climate resilient projects as we face impacts to our water supplies and aquatic ecosystems from a hotter, drier future. These funds will provide more water in our rivers and streams, restore our river systems and wetlands and provide needed upgrades to our water infrastructure. DNR and our Divisions were proud to partner with many local entities to help bring these impactful funds for needed projects throughout Colorado.**

"Securing the Shoshone water rights has been a priority of West Slope water entities and local governments for over eighty years," said Colorado River District Board President, Kathy Chandler-Henry. **"This funding award is a huge step forward in what is a continuing effort, and we are thankful for the leadership shown by the Bureau of Reclamation and Commissioner Touton in bringing these critical funds to West Slope communities."**

"We are beyond grateful for the Bureau's historic investment and their work with us to protect our state's namesake river," said Andy Mueller, General Manager of the Colorado River District. **"To be clear, there is still more work to be done, but today's announcement would not have been possible without the State's partnership and financial support, as well as the leadership of Governor Polis, the Colorado General Assembly and Colorado's Congressional delegation."**

Xcel Energy and the Colorado River Water Conservation District finalized an agreement in December 2023 to transfer ownership of the Shoshone Water Rights to

the district for $99 million. In partnership with the State of Colorado, the district will work to convert the rights to instream-flow purposes by 2027.

Colorado recreation on the Colorado River contributes $14.6 billion annually to the State's GDP, with nearly $4 billion coming directly from the Colorado River basin on the Western Slope. Acquiring the Shoshone water rights provides security for this industry as well as protect the recreational fishing and boating that sustain and attract local businesses.

The Shoshone water rights are among the most senior on the Colorado River, contributing steady flows for more than 250 miles from the Continental Divide to the Utah border. These rights play a critical role in sustaining agriculture, providing reliable water for ranchers and communities, and bolstering the outdoor recreation economy.

Awarded projects in Colorado can be found on the U.S. Bureau of Reclamation's website and recent press release.

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