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Colorado Water Conservation Board
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TO: Colorado Water Conservation Board Members

FROM: Linda Bassi, Chief
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Stream and Lake Protection Section

DATE: March 21, 2019

AGENDA ITEM: 27. Instream Flow Appropriation on Himes Creek in Water Division 7

Introduction

This memo is intended to provide the Board with sufficient technical information so that the Board, in accordance with the Rules Concerning the Colorado Instream Flow and Natural Lake Level Program (ISF Rules), has a basis to declare its intent to appropriate an instream flow (ISF) water right on Himes Creek. The memo includes an overview of the technical analyses performed in support of this appropriation by the U.S. Forest Service (USFS), Colorado Parks and Wildlife (CPW), and CWCB Staff. Additional detailed analyses are contained in the attached executive summary and appendices of the supporting scientific data. This memo also addresses various issues that have arisen in discussions with stakeholders.

Staff Recommendation

Staff recommends that the Board:

1. Pursuant to ISF Rule 5d., declare its intent to appropriate an ISF water right on the stream segment of Himes Creek listed on the attached Tabulation of Instream Flow Recommendation, in the amount of all of the unappropriated flow.

2. Establish the following initial schedule for the notice and comment procedure pursuant to ISF Rule 5c.:

Date	Action
March 21, 2019	Board declares its intent to appropriate and hears public comment
May 15-16, 2019	Public comment at CWCB Meeting
May 31, 2019	Notice to Contest due
June 10, 2019	Deadline for notification to the ISF Subscription Mailing List of Notices to Contest (no notification if none received)
July 1, 2019	Notices of Party Status and Contested Hearing Participant Status due At the July 17-18, 2019 Board meeting, if necessary, Staff informs Board of Parties and Participants; Board sets hearing date
November 2019	ISF Contested Hearing conducted in conjunction with CWCB Meeting

Background

The USFS first considered Himes Creek for an ISF appropriation in March 2014, as part of discussions related to Water Court Case No. W-1605-76B, the USFS application for federal reserved water rights in the San Juan National Forest. In an attempt to move discussions regarding resolution of this case forward, Himes Creek, Little Sand Creek, Vallecito Creek, and Rio Lado Creek were selected as streams that the USFS would use in a pilot process to evaluate whether the USFS could rely on Colorado's Instream Flow Program to achieve its stream protection goals on streams within the San Juan National Forest. These four stream segments were selected based in part on the requirement from the Southwestern Water Conservation District and Dolores Water Conservancy District ("Districts") that any proposed ISF segment be located above existing headgates and solely on USFS public lands. The USFS also selected these streams to reflect a range of natural resource protection goals. The USFS originally recommended all four proposed segments to the CWCB at the January 2016 ISF workshop. In 2017, the Board appropriated ISF water rights on Little Sand Creek and Vallecito Creek below the wilderness boundary, which were decreed in 17CW3046 and 17CW3045, respectively. The USFS tabled Rio Lado Creek and the wilderness portion of Vallecito Creek to allow for additional data collection and discussion of issues with stakeholders. Himes Creek is the only remaining pilot stream that is currently being recommended for an ISF appropriation at this time.

Since January 2016, Staff has been collecting, reviewing, and analyzing data for Himes Creek while collaboratively working with the USFS, CPW, and the Districts. The USFS submitted its formal recommendation for Himes Creek to the CWCB on November 30, 2017 (attached). Staff communicated its intent to bring this recommendation to the March 2018 meeting for the Board to form its intent to appropriate an ISF water right. At the March 2018 Board meeting, Staff informed the Board that it needed additional time to meet with stakeholders to address their concerns.

During this time, the Districts expressed concerns related to the natural environment and flow quantification on this stream. Although Staff continued to work with the Districts, and all involved have agreed at this point that the Himes Creek natural environment is important and merits protection, these efforts have not resulted in agreement about the amount of water needed to preserve the natural environment of Himes Creek. In addition, the Districts have expressed concerns regarding the precedent that they believe this appropriation could set with regard to future ISF appropriations.

Staff evaluates each recommendation on a case-by-case basis, based on the natural environment of a recommended stream reach and the best available science that supports the flow needed for reasonable preservation. Consequently, Staff asserts that the recommended ISF appropriation on Himes Creek would not set any type of precedent for future recommendations in the San Juan Basin or anywhere else in Colorado. Staff is confident that the information that follows in this memo, including the attached executive summary, scientific data and related analyses, provide a sound basis for the Board to form its intent to appropriate an ISF on Himes Creek.

The USFS recommendation differs from most ISF recommendations in that it recommends that the CWCB appropriate all of the unappropriated flow in Himes Creek to preserve the natural environment to a reasonable degree. This approach ensures protection of the variability in flows that includes base flows, snowmelt runoff, annual flood flows from monsoonal thunderstorm events, and less frequent, but equally important, large magnitude flood events. While the flow rates protected by this ISF water right would vary in response to natural variations in hydrologic conditions, at most times the flow rates would be low, often less than 1 cfs.

Staff Investigations and Analysis

The USFS, CWCB, and CPW have conducted a number of studies and assembled a body of evidence and analysis that supports the finding that the natural flow regime is necessary to preserve the natural environment of Himes Creek. To formulate its recommendation, the USFS collected biologic, hydrologic data, conducted literature reviews, and consulted numerous experts. The USFS also contracted with an expert in fisheries biology to assess the Himes Creek fishery, perform a literature review, and comment on the fisheries habitat and associated flow requirements. CPW personnel have prepared a number of documents to support the overall USFS efforts for ISF protection for Himes Creek: the 2017 "Himes Creek Habitat Survey and Inventory Report," four years of fish survey reports, the 2018 genetics paper, and the 2019 aquatic ecology literature review. CWCB Staff assisted CPW in some of these efforts. CPW, through its membership in the Instream Flow Council, requested and received a peer review of the USFS's written flow recommendations; this peer review came from ISF and Colorado River cutthroat trout experts with the Wyoming Game and Fish Department. In addition, Staff hired an expert to provide information about step-pool channels and assess the state of the science to model sediment transport in these environments. The following is a list of supporting documents for the Himes Creek recommendation (these documents are included as appendices to the Executive Summary):

- CPW and USFS Fish Survey reports (1994, 1998, 1999, and 2007) – demonstrate the number of fish surveyed through time.
- CPW genetics paper (Rogers et al., 2018) – research that discovered populations of the San Juan lineage fish.
- CPW and CWCB modified R1R4 Habitat Study (Skinner, 2017) – survey and assessment of the habitat available in Himes Creek.
- White papers pertaining to the recommendation:
    - Dr. Ellen Wohl, April 2018, "Himes Creek and Flow Diversions," which describes geomorphology of step-pools and state of the science in modeling sediment transport in these systems.
    - Dr. Brett Roper, April 2018, "Himes Creek Cutthroat Trout," which addresses habitat needs of the San Juan lineage trout in Himes Creek.
    - Jay Skinner, March 2019, "Literature review on the importance of a natural flow regime to aquatic ecology in rivers and streams."

- Letter from Paul Dey and Dave Zafft – peer review of Himes Creek ISF recommendation from an outside agency.
- Journal articles – a list of references that provide scientific support is contained in Executive Summary appendices.
- CPW Press releases, 2018 – Nature of the San Juan Cutthroat trout discovery.

The following sections summarize both the scientific basis for the recommended ISF on Himes Creek and provide a summary of the information that will form the basis for the Board's statutory determinations. This information will support the Board's formation of its intent to appropriate an ISF water right on this stream.

1. Natural Environment

To appropriate an ISF water right on Himes Creek, the Board must determine that there is a natural environment on this stream. The USFS has conducted field surveys and studies of Himes Creek and have found a natural environment that can be preserved. Himes Creek is a step-pool system that contains a self-reproducing population of the San Juan lineage of Colorado River cutthroat trout (San Juan lineage trout) that was thought to be extinct.

The USFS initially was interested in Himes Creek because the stream was known to support a Core Conservation population of pure-strain Colorado River cutthroat trout. During the ISF data collection process, genetic investigations confirmed that the fish in Himes Creek have the same genetic markers as museum samples of the San Juan lineage trout. The San Juan lineage trout was thought to be extinct. In January 2018, CPW researchers published a paper titled "Rediscovery of a lost Cutthroat Trout lineage in the San Juan Mountains of Southwest Colorado," which discusses the genetic analyses that lead to the discovery of this extremely rare lineage of fish. The importance of finding a relict population of the San Juan lineage trout in Colorado cannot be overstated.

Himes Creek contains one of only five known distinct populations of the San Juan lineage trout. The total number of San Juan lineage trout in all known populations is estimated to be as few as 1,000. The total number of stream miles that the fish exists in is estimated to be 9.3 miles. Himes Creek contains the longest continuous section of known habitat.

Himes Creek is a small tributary to the West Fork San Juan River located in the San Juan National Forest. The drainage basin is 1.85 square miles and the recommended reach is just 2.0 miles. Himes Creek is a step-pool channel characterized by very steep slopes and large size sediment and wood that form steps and plunge pools. Himes Creek is exceptionally steep with channel gradients approaching 15% to 20% in many areas. Himes Creek is also quite small, just five feet wide on average. The sediment is dominated by large cobbles with many large boulders and bedrock throughout. Himes Creek also contains fine sediment supplied by eroding hillslopes adjacent to the stream. This creates a large range of sediment sizes throughout the reach. The abundant large wood within the bankfull channel creates channel complexity, entrains sediment, and creates fish habitat (Skinner, 2017). However, the steps created by large boulders and wood within the active channel pose challenges for fish movement and underscores the importance of pools to provide fish resting areas and sufficient depth for fish to jump over steps. Himes Creek also contains a dense riparian corridor that includes willows and conifers that supply a source of large wood and shade the channel protecting the thermal regime.

Although Himes Creek is a tributary to the West Fork of the San Juan River, they are rarely connected. The Himes Ditch, located at the proposed lower terminus, is decreed for up to 8 cfs and has the potential to divert the entire flow of the creek. When the ditch is operating, the channel below the diversion is dewatered. In addition to this, CPW constructed a barrier in 2001 downstream from the Himes Creek Ditch. The purpose of the barrier is, "to protect the population from subsequent invasions of nonnative salmonids" (Rogers et al., 2018). Both the ditch and the barrier serve to isolate the Himes Creek fish population from the West Fork San Juan River and to protect them from competition with nonnative fish.

Active management and conservation of cutthroat trout in Colorado and throughout the West has been a top priority of CPW, federal land management agencies including the USFS and BLM, and other state wildlife agencies. Cutthroat trout subspecies fall into various management categories ranging from "species of greatest conservation need" to "threatened or endangered" status under the Endangered Species Act. In Colorado, the USFS currently designates and manages Colorado River cutthroat trout as a Sensitive species, defined as "those plants and animals … for which population viability is a concern as evidenced by: a) Significant current or predicted downward trends in population numbers or density, b) Significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution." The USFS further directs that "Sensitive species of native plant and animal species must receive special management emphasis to ensure their viability and to preclude trends toward endangerment that would result in the need for Federal listing" (USFS recommendation letter). The CPW currently designates and manages Colorado River cutthroat trout as Tier 1 Species of Greatest Conservation Need, regarded as "species which are truly of highest conservation priority in the state" (2015 CPW Wildlife Action Plan). CPW and USFS aim to proactively manage the San Juan lineage to demonstrate that the fish can be adequately protected without the need for more restrictive federal actions.

Both the USFS and CPW believe that the Himes Creek fish population is vulnerable and at a higher risk of extirpation due to Himes Creek's limited available habitat, and its lack of connectivity to other streams and to any other populations of San Juan lineage trout. Because of what this species represents for the genetic biodiversity of native cutthroat trout in the West, both agencies have identified protection of this species and the entire Himes Creek natural environment as a top priority.

2. Basis of the Recommendation

The USFS recommends that all of the unappropriated flow in Himes Creek is the minimum flow necessary to preserve the natural environment to a reasonable degree. Further, the recommendation states the importance of maintaining the natural flow regime to preserve the limited available habitat in Himes Creek throughout the year. Baseflows, snowmelt runoff, and short duration high flow events all support different aspects of the natural environment as summarized here:

> Baseflows (typically August to March) are required to support macroinvertebrate life cycles, maintain temperature regime during summer, provide juvenile rearing and overwintering habitat, and prevent pools from freezing.
>
> Snowmelt Runoff Flows (typically March through July) are necessary to recharge aquifers to support riparian vegetation, remove fine sediment to maintain pool depth and volume for overwintering, and maintain spawning gravels for successful spawning.
>
> Short Duration Peak Flows (typically July through October) are necessary to entrain large woody debris, scour and form new pools, and maintain the riparian corridor.

Prior to reaching this conclusion, the USFS investigated using the R2Cross methodology to determine the flow rates necessary to preserve the natural environment. The USFS found that R2Cross was not appropriate for this stream system. R2Cross is used to assess flow requirements in streams where riffles are the critical limiting habitat. The recommended reach of Himes Creek contains almost no riffle habitat, and riffles are not the limiting habitat type. Pools are the limiting habitat in Himes Creek. Pool habitat is the primary habitat available for fish to complete the entire life cycle from spawning and fry to juvenile rearing and adult overwintering.

Dr. Brett Roper, a professor of watershed science at Utah State University and the National Aquatic Monitoring Program Leader for the USFS, authored a paper for Staff of the San Juan National Forest entitled "Himes Creek Cutthroat Trout" (Roper, 2018). In it, he explains that trout select pool habitat because it provides the greatest potential for growth, security from predators, and provides stable habitat during icing conditions. Dr. Roper's paper further supports that pool habitat is the critical limiting habitat in Himes Creek. He also suggests that the absence of this pool habitat would almost certainly eliminate the presence of the Himes Creek cutthroat population and that higher flows are necessary to flush out these pools. Lack of high flows would reduce survival both in times of drought and during periods with high ice coverage. A final point made by Dr. Roper is that maintaining temperatures conducive to these trout is critical because lower temperatures help native species outcompete non-native brook trout. Dr. Roper concludes that the uniqueness of the Himes Creek population of the San Juan lineage trout and its setting provides strong support for maintaining the physical and ecosystem processes in as near a natural condition as possible.

Because pools provide the critical habitat for this unique lineage of San Juan lineage trout, Staff investigated methods to assess the flows necessary to maintain the pools in Himes Creek by preventing sediment from building up and reducing the size and depth of pools. These efforts included contracting with Dr. Ellen Wohl, a professor of Geosciences at Colorado State University who is a prominent scientist in the field of fluvial geomorphology with a significant body of research related to step-pool channels. Dr. Wohl prepared a white paper that provides an overview of step-pool systems and assesses the current state of the science to evaluate flows necessary to scour pools and maintain pool habitat (Wohl, 2018). Dr. Wohl also conducted a site visit to Himes Creek. Based on her analyses to date, Dr. Wohl indicated that existing sediment transport equations in the field of fluvial geomorphology are insufficient to reliably quantify the flow needed for sediment transport within step pool systems. Her primary conclusion is that the use of such equations would likely over-predict sediment transport in the Himes Creek step pool system by a factor of 10 to 100 times, meaning that these equations would predict that sediment transport occurs at much lower flows than what is actually necessary. As a result, the equations would likely result in recommended flow rates that are insufficient to preserve the natural environment of Himes Creek.

While pools are the limiting habitat for this fishery, they are not the only factor. Himes Creek is a complex natural functioning ecosystem that has developed in isolation for thousands of years and these fish have adapted to the unique characteristics of this ecosystem. As a result, the most critical element of this recommendation is the protection of the natural variability of streamflow. The objective of maintaining a naturally variable flow regime is the preservation of a stream that supports natural processes. Specific aspects of the aquatic and terrestrial environments have particular responses to particular points on a continuum of flows. Consequently, if the full range of such responses is to be maintained, then the full spectrum of flows should be protected by the ISF water right.

A literature review prepared by Jay Skinner provides further information about the importance of the natural flow regime (Skinner, 2019). Mr. Skinner is a recently retired CPW fish biologist who spent the majority of his career working on ISF water rights and serving as the CWCB’s biological expert. Mr. Skinner reviewed the applicable scientific literature that address the role of the natural flow regime to overall aquatic ecology, the physical and biological interrelationships between the flowing water environment and the adjacent terrestrial environment, and the contemporary body of knowledge in instream flow science and environmental flow protection. In general, stream ecologists have long recognized, from an energy flow point of view, that energy and nutrients for biological activity flow from the adjacent riparian systems to the flowing water ecosystem throughout the food chain. In addition, aquatic organisms (macroinvertebrates, aquatic insects, and fish) use terrestrial habitats to complete life cycles, for reproduction, for food, and for habitat (physical cover for fish, overhead cover for fish, and water temperature moderation). Riparian habitats have numerous other biologic and hydrologic benefits as well: water quality protection, a water source for stream baseflow during the fall and winter, and overall stream channel stability (sediment dynamics). Mr. Skinner makes the case for protection of the full range of stream flows (the natural flow regime) in isolated circumstances where the biologic community of interest is unique, rare, or is otherwise significant for land, water or fishery managers.

While it may be desirable to use equations and models to determine a specific required flow rate that will preserve the natural environment in Himes Creek to a reasonable degree, CWCB, USFS, and CPW Staff believe such an approach is overly simplistic and is unreliable given the natural environment found in Himes Creek. R2Cross and other models may be reasonable for most streams in Colorado, but they may not be valid or appropriate in cases where a unique species inhabits the natural environment to be preserved. In addition, a specific model based approach is not necessary (or required by statute or the ISF Rules) in order to arrive at a flow determination that: (1) will preserve the natural environment to a reasonable degree, (2) has a sound basis in science, and (3) will have no effect on human needs located in developed areas downstream. As a result, Staff agrees with the USFS recommendation that all of the unappropriated flow in Himes Creek is necessary to preserve the natural environment for the following specific reasons:

1. Himes Creek contains one of the last remnant fish population of the San Juan lineage Colorado River cutthroat trout. This lineage of fish was once thought to be extinct. Protecting this rare fish is a top priority for both the USFS and CPW.

2. The geomorphic nature of Himes Creek results in exceptionally limited habitat due to the small drainage basin size, uncommonly high slope, very large substrate size that forms high steps, and the presence of fine sediment. Any reduction in flow has potential to reduce the amount of habitat available.

3. Himes Creek is physically disconnected from the West Fork of the San Juan River at most times and biologically isolated from any other known populations of this fish lineage. The fish must complete their entire life cycle within the available habitat in Himes Creek and have no opportunity to migrate to other locations or repopulate from other locations.

4. The best available science supports the importance of maintaining the natural hydrologic variability, which has allowed this remnant population to persist to date.

5. Himes Creek is located above all headgates and entirely on public land. This location and the provisions of section 37-92-102(3)(b), C.R.S.(2018), where applicable, both minimize impacts to other water users while fully protecting Himes Creek.

As stated in the USFS recommendation letter, "Any withdrawal of water from Himes Creek may affect the viability of this species by reducing flow, reducing the extent and depth of pools, impacting riparian habitat, and negatively affecting the macroinvertebrate food source this species relies upon." The vulnerability of this population presents a risk in appropriating anything less than that necessary to maintain the physical and ecosystem processes at natural conditions. All of the available flow in Himes Creek is the minimum amount necessary to preserve the natural environment to a reasonable degree.

3. Water Availability and No Injury

Staff conducted an evaluation of water availability for Himes Creek. Since the Himes Creek ISF recommendation is for all of the unappropriated flow, water availability is presented in a manner aimed at identifying the typical range of streamflows that may be protected with this ISF appropriation and to provide some estimate of the magnitude of rare high flow events. Staff analyzed available data, including USGS gage records for nearby gages, diversion records, stream flow measurements, and StreamStats based statistics. Median flow is less than 1 cfs for nearly half of all days based on estimates from the gage data. The peak flow is estimated to be 64 cfs based on the gage data. The two-year recurrence interval flood is estimated at 43.7 cfs based on StreamStats and very rare high flow events such as the 100-year recurrence interval flood are estimated to be 255 cfs. Himes Creek therefore has potential to experience a large range in streamflow from baseflows to snowmelt runoff and monsoonal rain events. However, at most times, flow rates are quite low. Appropriating all unappropriated flow will protect the natural range of flows that are critical to preserve the natural environment. Staff concluded that water is available for appropriation on Himes Creek to preserve the natural environment to a reasonable degree. The location of this ISF recommendation, which is above all headgates and entirely on USFS public lands supports the conclusion that this appropriation can exist without material injury to water rights.

Stakeholder Outreach and Input

Staff provided public notice of the recommendations in both March and November of 2017. Staff met with the Mineral County Commissioners because the subject reach of Himes Creek is located in Mineral County. In addition, Staff worked with both the Southwestern Water Conservation District and the Dolores River Water Conservancy District to discuss ways to address concerns about the recommendation. Other stakeholders have expressed support for the appropriation of ISF water rights for protection of the Himes Creek natural environment and this rare lineage of fish. A letter of support was received from Trout Unlimited and any additional letters of support will be provided to the Board.

Additionally, this ISF appropriation implements the Memorandum of Understanding entered into by the USFS, Colorado Department of Natural Resources (DNR), and CWCB in April 2004, most recently updated in October 2015 (MOU). The MOU's purpose was to establish a framework for the parties to work together in a cooperative manner on issues regarding the management of water and water uses on National Forest lands in Colorado. Among other things, the parties agreed to seek innovative ways to achieve instream flow protection in high priority stream reaches.

Issues

In the course of discussions of this ISF recommendation, the Districts have raised two primary issues. The first issue concerns the Board’s authority to appropriate all of the unappropriated flow as the minimum amount of water necessary for reasonable preservation of the identified natural environment based on the recommendation and supporting analyses. The Districts contend that this ISF recommendation is not based on a proper quantification of the minimum amount of water necessary to preserve the natural environment because a specific hydraulic model such as R2Cross was not used to develop the recommended flow rates. The second issue relates to the perception that this recommended ISF water right could set a precedent for appropriating all available flows on other streams, affecting future water development within the drainage basins of Southwest Colorado. The Districts also have raised federal land management tools, such as a Research Natural Area designation, as an alternative approach to protecting the natural environment of Himes Creek.

1. Board Authority

The General Assembly charged the CWCB with preserving portions of the natural environment for the people of Colorado. § 37-92-102(3), C.R.S. (2018); *Colo. Water Conservation Bd. v. Farmers Water Dev. Co.*, 346 P.3d 52, 58 (Colo. 2015) ("We have consistently recognized that the CWCB acts to protect the environment on behalf of the public."); *Aspen Wilderness Workshop, Inc. v. Colo. Water Conservation Bd.*, 901 P.2d 1251, 1259 (Colo. 1995) (CWCB "acts on behalf of the people of the state of Colorado and is thereby burdened with a fiduciary duty arising out of its unique statutory responsibilities."). To carry out the policy objective of protecting portions of the natural environment in Colorado, the General Assembly vested the CWCB with the "exclusive authority, on behalf of the people of the state of Colorado, to appropriate . . . such waters of natural streams and lakes as the board determines may be required for minimum stream flows . . . to preserve the natural environment to a reasonable degree." § 37–92–102(3), C.R.S. (2018). Whether to make an ISF appropriation is "a policy determination within the discretion of the CWCB." *Farmers Water Dev. Co.*, 346 P.2d at 59. The CWCB is in charge of making these policy decisions because it has specific expertise regarding how to determine the minimum stream flows necessary to preserve the natural environment to a reasonable degree. *Id.; see Aspen Wilderness Workshop, Inc.,* 901 P.2d at 1256 (noting that the CWCB is "a unique entity charged with preserving the natural environment to a reasonable degree for the people of the State of Colorado"); *Colo. River Water Conservation Dist. v. Colo. Water Conservation Bd.*, 594 P.2d 570, 576 (Colo. 1979) ("Factual determinations regarding such questions as which areas are most amenable to preservation and what life forms are presently flourishing or capable of flourishing should be delegated to an administrative agency [CWCB] which may avail itself of expert scientific opinion. This is particularly true, considering that the General Assembly undoubtedly anticipated that the considerations for each locale might vary.") Therefore, based on the facts in each proposed appropriation, the CWCB has broad discretion to determine what minimum stream flows are necessary to preserve the natural environment to a reasonable degree.

The Himes Creek ISF recommendation is based on the expert scientific opinions of CPW, the USFS, and other experts such as Dr. Wohl as to the critical habitat and life forms present on this stream reach and the minimum amount of water needed to preserve the natural environment of this specific stream reach to a reasonable degree. The Board has the discretion to make this policy determination and appropriate this recommended ISF water right based on this site-specific information. Here, the minimum amount needed to ensure the persistence of this rare fish population and to preserve the isolated habitat this fish population needs to survive, is all of the unappropriated flow.

2. Potential for Precedent

The Board approaches each ISF appropriation based on the natural environment, biological needs, and water availability specific to the subject stream, as intended by the General Assembly and confirmed by the Colorado Supreme Court. In rare circumstances, the CWCB has relied on methodologies and science-based approaches that have resulted in minimum flow appropriations up to and including all of the unappropriated flow. Such appropriations demonstrate the Program's flexibility in preserving the natural environment based on site-specific biological needs and policy considerations. What constitutes the "minimum" is going to vary in every appropriation, and there is no rule or statute that binds the CWCB to a certain methodology for quantifying the minimum. In response to stakeholder concerns about the precedent such appropriations could establish, the Board has included non-precedent language in the certain water court decrees stressing the site-specific nature of those ISF water rights. Staff has discussed including similar language in the decree for this ISF water right with the Districts, but has been unsuccessful in developing mutually acceptable language.

3. Use of Federal Land Management Tools

While the USFS can limit land uses in the Himes Creek basin through land management tools, it cannot obtain decrees for instream flow water rights. The CWCB's exclusive authority to hold such decrees ensures the protection of valuable natural resources within the State's priority water rights system, rather than through bypass or other flow requirements imposed by federal agencies. The potential for new water rights on Himes Creek is low, but the future is unknown. The CWCB and federal partners have worked together successfully in other instances to fully protect important resources through a combination of land management and ISF water rights. The most recent example is the Dominguez Canyons Wilderness designation where Big Dominguez and Little Dominguez Creeks are protected by ISF water rights. These collaborative approaches are precisely what the MOU entered into among the USFS, DNR, and CWCB contemplated. Additionally, such an approach can circumvent issues that may arise as a result of unilateral federal actions related to water uses. Based on the foregoing, Staff recommends moving forward with this ISF recommendation as described on page 1 of this memo.

ATTACHMENTS

- Attachment A: Executive Summary
- Attachment B: USFS Recommendation Letter
- Attachment C: Himes Creek Tabulation of ISF Recommendation
- Attachment D: Dr. Ellen Wohl, April 2018, “Himes Creek and Flow Diversions”
- Attachment E: Dr. Brett Roper, April 2018, “Himes Creek Cutthroat Trout”
- Attachment F: Jay Skinner, March 2019, “Literature review on the importance of a natural flow regime to aquatic ecology in rivers and streams”
- Attachment G: CPW Press releases, 2018 – Nature of the San Juan Cutthroat trout discovery
- Attachment H: CPW genetics paper (Rogers et al., 2018)
- Attachment I: CPW and CWCB modified R1R4 Habitat Study (Skinner, 2017)
- Attachment J: CPW Letter of Support
- Attachment K: TU Letter of Support
- Attachment L: Peer Review Letter from Paul Dey and Dave Zafft – Wyoming Game and Fish Department
- Attachment M: Additional Reference Material
- Attachment N: CPW and USFS Fish Survey reports

Attachment A

COLORADO
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Department of Natural Resources

Himes Creek
EXECUTIVE SUMMARY

CWCB STAFF INSTREAM FLOW RECOMMENDATION

UPPER TERMINUS:	headwaters in the vicinity of UTM North: 4144335.05 UTM East: 328210.38
LOWER TERMINUS:	Himes Ditch headgate UTM North: 4143682.20 UTM East: 331098.52
WATER DIVISION:	7
WATER DISTRICT:	29
COUNTY:	Mineral
WATERSHED:	Upper San Juan
CWCB ID:	17/7/A-001
RECOMMENDER:	U.S. Forest Service (USFS)
LENGTH:	2 miles
FLOW RECOMMENDATION:	All unappropriated flow

Himes Creek

Introduction

Colorado's General Assembly created the Instream Flow and Natural Lake Level Program in 1973, recognizing "the need to correlate the activities of mankind with some reasonable preservation of the natural environment" (see 37-92-102 (3), C.R.S.). The statute vests the Colorado Water Conservation Board (CWCB or Board) with the exclusive authority to appropriate and acquire instream flow (ISF) and natural lake level water rights (NLL). Before initiating a water right filing, the Board must determine that: 1) there is a natural environment that can be preserved to a reasonable degree with the Board's water right if granted, 2) the natural environment will be preserved to a reasonable degree by the water available for the appropriation to be made, and 3) such environment can exist without material injury to water rights.

The U.S. Forest Service (USFS) recommended that the CWCB appropriate an ISF water right on a reach of Himes Creek, which is located within Mineral County (See Vicinity Map). Himes Creek originates at an elevation of approximately 11,000 feet in the San Juan Mountains and flows southeast to the confluence with the West Fork San Juan River at an elevation of approximately 7,750 feet. The proposed reach extends from the headwaters downstream to the Himes Ditch headgate. One hundred percent of the land on this 2 mile reach is public land managed by the USFS (See Land Ownership Map). The USFS recommended this reach of Himes Creek because it has a natural environment that can be preserved to a reasonable degree with an ISF water right.

The information contained in this report and the associated supporting data and analyses (located at http://cwcb.state.co.us/environment/instream-flow-program/Pages/2019ProposedISFRecommendations.aspx) form the basis for Staff's ISF recommendation to be considered by the Board. This report provides sufficient information to support the CWCB findings required by ISF Rule 5i on natural environment, water availability, and material injury.

Natural Environment

CWCB Staff relies on the recommending entity to provide information about the natural environment. In addition, Staff reviews information and conducts site visits for each recommended ISF appropriation. This information is used to provide the Board with a basis for determining that a natural environment exists.

The natural environment of Himes Creek is a step-pool system that contains a self-reproducing population of the San Juan lineage of Colorado River cutthroat trout (San Juan lineage trout) that until recently was thought to be extinct. The USFS originally recommended an ISF water right on Himes Creek because it was known to support a Core Conservation population of pure-strain Colorado River cutthroat trout that shows no evidence of interbreeding with rainbow trout or Yellowstone cutthroat trout. During the ISF data collection process, the genetic lineage of the fish was confirmed by Colorado Parks and Wildlife (CPW) researchers (Rogers et al., 2018). This research demonstrated that the Himes Creek fish have the same genetic markers as museum samples of the San Juan lineage trout. The natural environment also consists of water-dependent wildlife habitat, aquatic macroinvertebrates, and healthy riparian vegetation.

Table 1. List of species identified in Himes Creek.

Species Name	Scientific Name	Status
Colorado River cutthroat trout, San Juan lineage	*Oncorhynchus clarkii pleuriticus*	State: Special Concern*

*Colorado River cutthroat trout are designated a state species of special concern, which is not a statutory category.

Himes Creek contains one of only five known distinct populations of the San Juan lineage trout. The total number of San Juan lineage trout in all known populations is estimated to be as few as 1,000. The total number of stream miles that the fish exists in is estimated to be 9.3 miles. Himes Creek contains the longest continuous section of known habitat.

Himes Creek is a small tributary to the West Fork San Juan River located in the San Juan National Forest. The drainage basin is 1.85 square miles and the recommended reach is just 2.0 miles in length. Himes Creek is a step-pool channel characterized by very steep slopes and large size sediment and wood that form steps and plunge pools. Himes Creek is exceptionally steep with channel gradients approaching 18% to 20% in many areas. Himes Creek is also quite small, just five feet wide on average. The sediment is dominated by large cobbles with many large boulders and bedrock throughout, but it also contains fine sediment supplied by eroding hillslopes adjacent to the stream. This creates a large range of sediment sizes throughout the reach. The abundant large wood within the bankfull channel creates channel complexity, entrains sediment, and creates fish habitat (Skinner, 2017). However, the steps created by large boulders and wood within the active channel also pose challenges for fish movement and underscore the importance of pools to provide fish resting areas and sufficient depth for fish to jump over steps. Himes Creek also contains a dense riparian corridor that includes willows and conifers that supply a source of large wood and shade the channel, protecting the thermal regime.

Although Himes Creek is a tributary to the West Fork of the San Juan River, they are rarely connected. The Himes Ditch, located at the proposed lower terminus, is decreed for up to 8 cfs and has the potential to divert the entire flow of the creek. When the ditch is operating, the channel below the diversion is dewatered. In addition, CPW constructed a barrier in 2001 downstream from the Himes Ditch. The purpose of the barrier is "to protect the population from subsequent invasions of nonnative salmonids" (Rogers et al, 2018). Both the ditch and the barrier serve to isolate the Himes Creek fish population from the West Fork San Juan River and to protect them from competition with nonnative fish.

The riparian forest consists mainly of coniferous species, with interspersed stands of cottonwood and aspen trees. The channel is lined with dense willows and alders that shade the stream. Thermal regimes of small streams, such as Himes Creek, are controlled by riparian shading from the forest canopy. Staff measured water temperature in Himes Creek staring in late summer 2018. Water temperature remained cold in Himes Creek during the summer due to abundant streamside vegetation blocking solar inputs, while stable flows during the winter keep pools clear of ice. The maximum water temperature recorded in 2018 was 59 degrees Fahrenheit on August 2, and the maximum seven-day average water temperature was 55 degrees Fahrenheit. Despite very low flows during the summer of 2018, water temperatures remained within the optimal temperature range for cutthroat trout, emphasizing the importance of the riparian community for buffering stressful conditions caused by drought.

Reference streams with a similar ecoregion provide context for the results of a habitat survey conducted by CPW in 2017 (Skinner, 2017). Of nine reference streams with similar habitat types and channel widths, Himes Creek channel gradient is at the upper range (18% slope) compared to slopes between 2-6% for the majority of the reference streams. Two pebble counts conducted in Himes Creek produced an average D50 particle size of 3.4 inches, which refers to the particle size at which 50% of the sample is finer. In comparison, the reference streams had an average D50 of 0.6 inches. Sediment size classes ranged from less than 0.08 inches to greater than 20 inches in Himes Creek, although numerous larger boulders and bedrock were observed outside of the pebble count cross-sections. Large wood (diameter greater than 0.1 feet and longer than 3 feet) is abundant throughout Himes Creek with 18 pieces per 100 feet, compared to an average of four pieces per 100 feet in the reference streams. The large and variable sediment sizes, abundant wood, and steep channel slopes interact to create complex and variable habitat types in Himes Creek that is distinct from many other streams in Colorado.

From an ecological perspective, Himes Creek represents the upper limit of viable trout habitat due to channel gradient, substrate size, and winter conditions. This extreme environment makes the fish population vulnerable to extirpation from catastrophic events, such as wildfire or drought, but is also likely responsible for the survival of the rare San Juan lineage trout. Cutthroat trout exist in fragmented, isolated habitats throughout their range due to habitat loss and nonnative species interactions. The extreme limits of viable trout habitat, such as Himes Creek, represents conditions where native species can out-compete nonnative species due to the unique and stressful conditions in which indigenous fauna have evolved. Himes Creek also represents an important opportunity for native species conservation in that the Himes Ditch, at the lower terminus of this recommendation, precludes the invasion of nonnative species that reside in the West Fork San Juan River.

The Himes Creek fish population size has remained relatively stable since 1994 when population surveys began. The fish population estimates range from 116 fish per mile in 1998 to 264 fish per mile in 2013. The last population survey conducted in 2017 produced an estimate of 244 fish per mile. The fish surveys have also observed a wide range of size classes, indicating that the San Juan lineage trout population is naturally reproducing. Brook trout have been observed within the recommended ISF reach since 2007 and three brook trout were captured in 2017. When encountered, CPW and USFS personnel have removed brook trout to limit establishment of nonnative populations. Nonnative species removal, in conjunction with the fish barrier installed in 2001, have helped reduce impacts to the San Juan lineage trout populations from invasive species.

Basis of the Recommendation

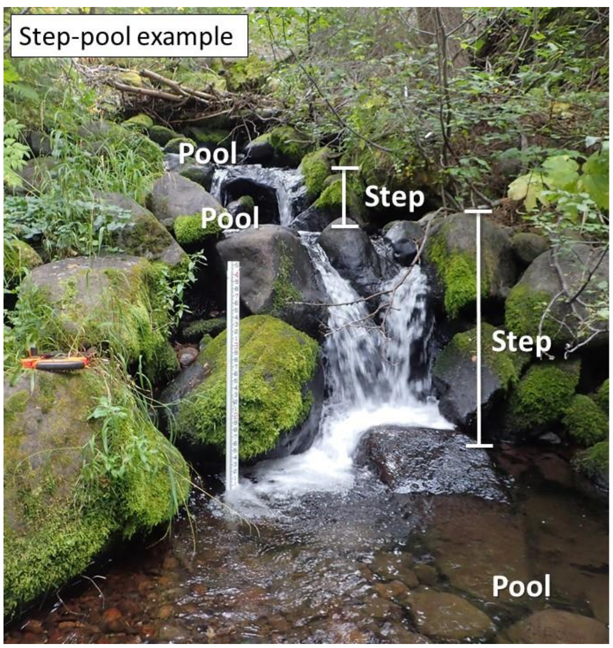
The USFS recommends that all unappropriated flow in Himes Creek is the minimum amount necessary to preserve the natural environment to a reasonable degree. Based on their own investigations and experience, CWCB Staff and CPW confirm and agree with this finding. Further, the recommendation states the importance of maintaining the natural flow regime to preserve the limited available habitat in Himes Creek throughout the year. Baseflows, snowmelt runoff, and short duration high flow events all support different aspects of the natural environment as summarized here:

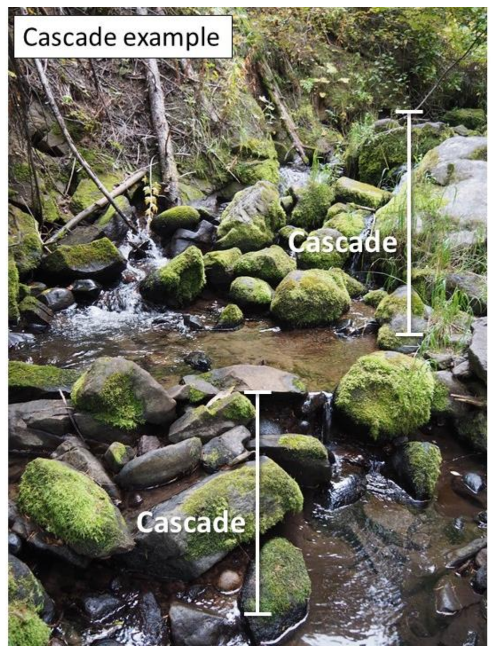
> Baseflows (typically August to March) are required to support macroinvertebrate life cycles, maintain temperature regime during summer, provide juvenile rearing and overwintering habitat, and prevent pools from freezing.
>
> Snowmelt Runoff Flows (typically March through July) are necessary to recharge aquifers to support riparian vegetation, remove fine sediment to maintain pool depth and volume for overwintering, and maintain spawning gravels for successful spawning.
>
> Short Duration Peak Flows (typically July through October) are necessary to entrain large woody debris, scour and form new pools, and maintain the riparian corridor.

The USFS, CWCB Staff, and CPW have conducted a number of studies and assembled a body of evidence and analysis that supports the finding that the natural flow regime is necessary to preserve the natural environment of Himes Creek, and that an ISF water right for all unappropriated flow will protect this flow regime. These investigations and the basis for the recommendation are discussed in further detail below.

The USFS evaluated the R2Cross methodology and determined that it is not an appropriate methodology to quantify the flow rates necessary to preserve the natural environment to a reasonable degree on Himes Creek. R2Cross is used to assess flow requirements in streams where riffles are the critical limiting habitat. The recommended reach of Himes Creek contains almost no riffle habitat, and riffles are not the limiting habitat type. Pools are the limiting habitat in Himes Creek. Pool habitat is the primary habitat available for fish to complete the entire life cycle from spawning and fry to juvenile rearing and adult overwintering.

Both USFS observations and a CPW habitat assessment (Skinner, 2017) confirm that there is little to no riffle habitat within the proposed reach. The primary available habitat type is slow water habitat or pools (52% by area) formed by steps composed of large boulders or woody debris. The physical size of the available pool habitat is very limited; the average stream width is 4.8 feet and average pool depth is 0.4 feet or 4.8 inches. The residual pool depth, or the depth that would remain if water stopped flowing, is 0.8 feet and the maximum measured pool depth is 2 feet. The small pools and inundated portions of the boulders, woody debris, and sediment that form the steps are the primary habitat available for fish to complete their entire life cycle. The remainder of the surveyed habitat is fast water habitat, or cascades. These areas are characterized by steep gradients and large substrate that do not provide many opportunities for fish to spawn, rest, or overwinter. The photos below show the differences between the large steps and pool habitat and the cascades and smaller pocket water features. Fish will migrate through these steep habitat types when high flows inundate side channels or create slow water resting areas on the margins of the cascade. Given that the cascades do not provide sufficient usable habitat, the available pools are the only habitat that can sustain the population of San Juan lineage cutthroat trout in Himes Creek.





The left photo shows a typical step and pool section of Himes Creek. The right photo shows a section of a typical cascade. Pool habitat is the primary usable habitat available to fish on Himes Creek.

Dr. Brett Roper, professor of watershed science at Utah State University and National Aquatic Monitoring Program Leader for the USFS, authored a paper for the San Juan National Forest titled "Himes Creek Cutthroat Trout" (Roper, 2018). This paper describes the Himes Creek fishery as a resident population of San Juan lineage cutthroat trout that has adapted to a survival strategy that involves the population completing all life cycles in the habitat where they were hatched. Although other trout species may use a step-pool environment as migratory corridor, the Himes Creek fishery carries out its entire life cycle within this two-mile reach of isolated stream. Dr. Roper's paper further supports that pool habitat is the critical limiting habitat in Himes Creek. He surmises, "the absence of this pool habitat would almost certainly eliminate the presence of the Himes Creek cutthroat trout population." Further, he maintains that high spring flows are necessary "to flush sediment out of the pools and sort the material in the pool tail-outs." Without these high flows, more fine material would be found in spawning locations and reduce survival both in times of drought and during periods with high ice coverage. A final point made by Dr. Roper is that maintaining temperatures conducive to these cutthroat trout is critical because lower temperatures help native species outcompete nonnative brook trout. After evaluating data on Himes Creek temperatures during the 2012 drought, he concluded that the existing temperatures in the stream appear to be perfect to foster growth within the Himes Creek trout population. Dr. Roper concludes that the uniqueness of this population of Himes Creek San Juan lineage cutthroat trout and its habitat provides strong support for maintaining the physical and ecosystem processes in as near a natural condition as possible.

A primary concern in Himes Creek is loss of pool habitat if sediment settles into the pools. As stated in the USFS recommendation letter, regional geology and local hillslope processes provide a readily available source of fine sediment to the stream. Maintaining pools is necessary to make sure the limited amount of available pool habitat does not decrease. Because pools provide critical habitat for the San Juan lineage trout, Staff investigated what flows maintain the characteristics of pools in Himes Creek, including the pool area and pool depth.

CWCB Staff contracted with Dr. Ellen Wohl, a professor of Geosciences at Colorado State University, to assist in this analysis. Dr. Wohl is a prominent scientist in the field of fluvial geomorphology with a significant body of research related to step-pool channels. Dr. Wohl produced a white paper that provides an overview of step-pool systems and assesses the current state of the science to evaluate flows necessary to scour pools and maintain pool habitat (Wohl, 2018). Dr. Wohl also conducted a site visit to Himes Creek in October 2018 with CWCB and CPW Staff. In the field, Dr. Wohl noted that Himes Creek appeared to have a substantial supply of fine sediment. See photograph demonstrating this point below.

Fine sediment in Himes Creek. Photographed by Ellen Wohl.

Dr. Wohl's report describes the difficulties associated with developing sediment transport equations for step-pool channels due to their high turbulence, significant three-dimensional flow, dissipation or loss of energy on the rough substrate and configuration of the bed and banks (the boundary), and large differences in grain size. She explains that small sediment can be protected from transport when it is shielded by larger sediment like boulders. She notes that "the greater the fluctuations in velocity and turbulence, and the greater the range of grain sizes present on a streambed, the less accurate the equations become" and that step-pool channels have all of these characteristics. The primary conclusion is that “sediment transport equations over-predict sediment transport in step-pool channels by more than 1-2 orders of magnitude, or by more than a factor of 10 to 100 times.” This means that the equations will predict that sediment transport occurs at much lower flows than what is actually necessary. Reliance on these models could significantly under-predict the flows necessary to preserve the natural environment.

Dr. Wohl’s paper goes on to discuss the importance of maintaining the residual pool volume for fish survival. She explains that fish can survive very low flows caused by droughts and freezing conditions during winter if the pools are sufficiently deep. Dr. Wohl ends her paper with discussions of the importance of maintaining natural flow regimes, which she notes includes the magnitude, frequency, duration, timing (seasonality), and rate of change of flow. She states that “natural flow and sediment regimes are critical to channel morphology because they maintain the geometry, and grain-size distribution of a channel, to which stream organisms are adapted.” She concludes that the natural flow regime is “critical to stream organisms because it maintains the habitat, food sources, and thermal and chemical cues on which their life cycles are built.”

A literature review prepared by Jay Skinner provides further information about the importance of the natural flow regime. Mr. Skinner is a recently retired CPW fish biologist who spent the majority of his career working on ISF water rights and serving as the CWCB’s biological expert. Prior to his retirement from CPW, he initiated a written review of applicable scientific literature that addresses the role of the natural flow regime to overall aquatic ecology, the physical and biological interrelationships between the flowing water environment and the adjacent terrestrial environment, and the contemporary body of knowledge in instream flow science and environmental flow protection (Skinner, 2019). In general, stream ecologists have long recognized, from an energy flow point of view, that aquatic and riparian food webs interact as energy and nutrients are transported between terrestrial and fluvial environments. In addition, aquatic organisms (macroinvertebrates, aquatic insects, and fish) use terrestrial habitats to complete life cycles and for reproduction, food, and habitat (physical cover for fish, overhead cover for fish, and water temperature moderation). Riparian habitats have numerous other biologic and hydrologic benefits as well; water quality protection, a water source for stream baseflow during the fall and winter, and overall stream channel stability (sediment dynamics). Mr. Skinner makes the case for protection of the full range of stream flows (the natural flow regime) in isolated circumstances where the biologic community of interest is unique, rare, or is otherwise significant for land, water, or fishery managers.

In addition to the investigations completed by USFS, CPW, and CWCB Staff, CPW asked an outside agency that is not associated with the development of the Himes Creek recommendation to review the USFS’s recommendation. CPW, through its membership in the Instream Flow Council, requested and received a peer review of the USFS’s written flow recommendations; this peer review came from ISF and Colorado River cutthroat trout experts with the Wyoming Game and Fish Department (WGDF). The authors of this review are Paul Dey, WGFD Aquatic Habitat Program Manager, and Dave Zafft, WGFD Fisheries Management Coordinator and Colorado River Cutthroat Trout Conservation Team interagency team leader. The reviewers concluded “we have reviewed the Forest Service’s recommendation for an instream flow water right on Himes Creek and find it makes a strong case for protecting all of the flow in order to preserve a rare population of a genetically unique lineage of Colorado River Cutthroat Trout.”

While it may be desirable to use equations and models to determine a specific required flow rate that will preserve the natural environment of Himes Creek to a reasonable degree, CWCB Staff, USFS, and CPW Staff believe such an approach is overly simplistic and is unreliable given the natural environment found in Himes Creek. R2Cross and other models may be reasonable for most streams in Colorado, but they may not be appropriate or produce valid results in cases where a unique species inhabits the natural environment to be preserved. In addition, a specific model-based approach is not necessary in order to arrive at a flow determination that: (1) will preserve the natural environment to a reasonable degree, (2) has a sound basis in science, and (3) will have no effect on human needs located in developed areas downstream. As a result, Staff agrees with the USFS recommendation that all of the unappropriated flow in Himes Creek is necessary to preserve the natural environment for the following specific reasons:

1. Himes Creek contains one of the last remnant fish population of the San Juan lineage trout. This lineage of fish was once thought to be extinct. Protecting this rare fish is a top priority for both the USFS and CPW.

2. The geomorphic nature of Himes Creek results in exceptionally limited habitat due to the small drainage basin size, uncommonly high slope, very large substrate size that forms high steps, and the presence of fine sediment. Any reduction in flow has potential to reduce the amount of habitat available.

3. Himes Creek is physically disconnected from the West Fork of the San Juan River at most times and biologically isolated from any other known populations of this fish lineage. The fish must complete their entire life cycle within the available habitat in Himes Creek and have no opportunity to migrate to other locations or repopulate from other locations.

4. The best available science supports the importance of maintaining the full range of flows and natural hydrologic variability. Maintaining the natural flow variability preserves the conditions, to the extent possible, that have allowed this remnant population to persist to date.

5. Himes Creek is located above all headgates and entirely on public land. This location and the provisions of section 37-92-102(3)(b), C.R.S., where applicable, minimize impacts to other water users while fully protecting Himes Creek.

Water Availability
CWCB Staff conducts hydrologic analyses for each recommended ISF appropriation to provide the Board with a basis for making the determination that water is available.

Methodology
Each recommended ISF reach has a unique flow regime that depends on variables such as the timing, magnitude, and location of water inputs (such as rain, snow, and snowmelt) and water losses (such as diversions, reservoirs, evaporation and transpiration, groundwater recharge, etc.). Although extensive and time-consuming investigations of all variables may be possible, Staff takes a pragmatic and cost-effective approach to analyzing water availability. This approach focuses on streamflows and the influence of flow alterations, such as diversions, to understand how much water is physically available in the recommended reach.

Staff's hydrologic analysis is data-driven, meaning that Staff gathers and evaluates the best available data and uses the best available analysis method for that data. Whenever possible, long-term stream gage data (period of record 20 or more years) will be used to evaluate streamflow. Other streamflow information such as short-term gages, temporary gages, spot streamflow measurements, diversion records, and StreamStats will be used when long-term gage data is not available. StreamStats, a statistical hydrologic program, uses regression equations developed by the USGS (Capesius and Stephens, 2009) to estimate mean flows for each month based on drainage basin area and average drainage basin precipitation. Diversion records will also be used to evaluate the effect of surface water diversions when necessary. Interviews with water commissioners, landowners, and ditch or reservoir operators can provide additional information. A range of analytical techniques may be employed to extend gage records, estimate streamflow in ungaged locations, and estimate the effects of diversions.

The goal is to obtain the most detailed and reliable estimate of hydrology using the most efficient analysis technique.

The final product of the hydrologic analysis used to determine water availability is a hydrograph, which shows streamflow and the proposed ISF rate over the course of one year. The hydrograph will show median daily values when daily data is available; otherwise, it will present mean-monthly streamflow values. Staff will calculate 95% confidence intervals for the median streamflow if there is sufficient data. Statistically, there is 95% confidence that the true value of the median streamflow is located within the confidence interval.

The water availability analysis for Himes Creek is presented below to provide information about hydrology on Himes Creek and the typical range of streamflows that may be protected with this ISF appropriation. The water availability analysis in this context is not intended to limit or reduce the proposed ISF water right for all the unappropriated flow.

Basin Characteristics

The drainage basin of the proposed ISF on Himes Creek is 1.85 square miles, with an average elevation of 9,940 ft and average annual precipitation of 39.67 inches (See the Hydrologic Features Map). There are no known surface water diversions in the drainage basin tributary to the proposed ISF on Himes Creek. Hydrology in this drainage basin represents natural conditions.

Hydrology throughout the San Juan Mountains demonstrates a snowmelt runoff pattern that is also influenced by monsoon and late season storms. This results in high flow events that can occur between May and early July due to snowmelt and high flow events that can occur between August and October due to rain events. The magnitude of the rain event flows can be comparable to spring runoff flows; for example, the flood of record occurs in fall rather than spring or early summer for several nearby gages.

Available Data

There is not a current or historic streamflow gage on Himes Creek. There are several historic gages in the region near Himes Creek including: West Fork San Juan River above Borns Lake, near Pagosa Springs, CO (USGS 09340500, 1937-1953), Wolf Creek near Pagosa Springs, CO (USGS 09341200, 1968-1975), Wolf Creek at Wolf Creek Campground near Pagosa Springs, CO gage (USGS 09341300 1984-1987 and 1997-1999), and Windy Pass Creek near Pagosa Springs, CO (USGS 09341350, 1984-1987). The two gages on Wolf Creek were identified as most similar to Himes Creek in terms of drainage basin area and annual precipitation, while having a reasonably long period of record to analyze. The Wolf Creek gages also have few diversions; these diversions can be accounted for with available diversion records.

The upstream most gage on Wolf Creek is Wolf Creek near Pagosa Springs, CO (USGS 09341200, 1968-1975), which is approximately 2.0 miles northeast from the proposed lower terminus on Himes Creek. The drainage basin of the Wolf Creek near Pagosa gage is 14.1 square miles with an average elevation of 10,600 ft and average annual precipitation of 47.87 inches. The lower gage, Wolf Creek at Wolf Creek Campground near Pagosa Springs, CO gage (USGS 09341300), was installed approximately 1,800 ft downstream from the upper gage, approximately 1.7 miles northeast from the proposed lower terminus on Himes Creek. The drainage basin of the Wolf Creek at Wolf Creek Campground gage is 17.9 square miles with an average elevation of 10,500 feet and average annual precipitation of 46.29 inches. The lower gage was operated year round from 1984-1987 and seasonally from 1997-1999. A transbasin diversion, with alternate points near Wolf Creek Pass, exports water to Division 3 (Treasure Pass Ditch Division, appropriation date 1922, 8 cfs absolute). This diversion reduces streamflow for both gages on Wolf Creek; however, diversions are recorded by the Treasure Pass Ditch at Wolf Creek Pass gage (USGS 09341000). One other small diversion exists on a tributary to the lower Wolf Creek gage. Bruce Spruce

Ditch (appropriation date 1936, 2.68 cfs) diverts water from Fall Creek and any return flows accrue below the lower gage. No other surface water diversions appear to exist upstream of the gages.

In some cases, diversion records can be used to provide an indication of water availability in a stream reach. The Himes Ditch (appropriation dates 1889 and 1959, 2.5 cfs and 5.5 cfs) is located at the lower terminus on Himes Creek. The Himes Ditch diversion consists of a tarp and sandbags that are used to block Himes Creek and send water down a ditch that has a capacity of about 3 cfs (personal communication, water commissioner Bob Formwalt, May 15, 2018). This structure has the potential to divert nearly the entire flow of Himes Creek during most of the irrigation season and has diversion records from 1963 to 2017.

CWCB Staff made two streamflow measurements on Himes Creek, and the USFS made five streamflow measurements on Himes Creek, as summarized in Table 2.

Table 2. Summary of Streamflow Measurements for Himes Creek.

Visit Date	Flow (cfs)	Collector
6/21/2016	3.18	USFS
6/21/2016	2.92	USFS
9/07/2016	0.62	USFS
9/07/2016	0.57	USFS
8/2/2018	0.19	CWCB
9/25/2018	0.07	USFS
10/16/2018	0.35	CWCB

Data Analysis

Due to the short period of record for the Wolf Creek gages, Staff examined available climate stations and found that the Pagosa Springs climate station (Station USC00056258, downloaded 2/28/2017) is located in vicinity of the Wolf Creek gages and Himes Creek. This station is located 14.5 miles southwest from the Wolf Creek gage locations and roughly 13 miles southwest from the proposed lower terminus on Himes Creek. The station has a relatively long period of record (1906 to 2016), although there are several periods without data. The average annual precipitation at the Pagosa Springs station for the period of record (based on 57 years with 350 or more days of data) was 20.2 inches. During the complete years the Wolf Creek gages operated (1969 to 1975 and 1985 to 1986), the average precipitation was 22.2 inches. Based on the available data, the Wolf Creek gage records may represent slightly above average precipitation conditions.

The Wolf Creek near Pagosa gage (USGS 09341200) was analyzed using the period of record available (1968-1975). Transbasin exports from the Treasure Pass Ditch (USGS 0934100) were added to the gage data to estimate natural streamflow. The adjusted gage record was scaled by 0.11 to the lower terminus on Himes Creek using the area-precipitation method. The area-precipitation method estimates streamflow based on the ratio of the precipitation weighted drainage area at the lower terminus location to that of the gage location. The Wolf Creek at Wolf Creek Campground gage (USGS 09341300) was analyzed using the period of record available (1984-1987 and 1997-1999). Transbasin exports from the Treasure Pass Ditch (USGS 09341000) and in-basin diversions from Bruce Spruce Ditch (WDID 2900548) were added to the gage data to estimate natural streamflow. The adjusted gage record was scaled by 0.09 to the lower terminus on Himes Creek using the area-precipitation method. The scaled data from both gages was combined, resulting in 10 to 13 years of data, depending on the day of the year. Median stream flow was calculated; however, 95% confidence intervals were not calculated due to the short period of record from the combined gage data sets.

There are diversion records during the irrigation season for the Himes Ditch from 1964-2017 based on data available through HydroBase on 5/2/2018. A number of years have a water commissioner comment “water available, but not taken” (1982, 1986, 1987, 1996, 1999). The zero values in the record for these years were not used in the median diversion calculations. The year 2000 has the comment “ditch washed out”; however, the record contained several days with a diversion rate of 0.05 cfs. Records from the year 2000 were used as is. Other than these minor adjustments, the entire diversion record was used to calculate median and maximum diversions.

While the Himes Ditch diversion record can provide an estimate of streamflow, it is not a perfect proxy for streamflow. Diversion rates may be limited by a number of factors that are independent from the amount of water that is physically available. Limiting factors can include the type of structure used to divert water (tarps, pushup dams, etc.), the capacity of the headgate structure, the capacity of the ditch, and in many cases, the decreed flow rate. Diversions are also based on when the ditch owner or operator needs or wants to make diversions and specific to Himes Creek, when the tarp is manually installed. Diversion measurements are based on when a water commissioner can make an observation or when the ditch owner submits self-reported values, and the interval between reported observations can vary. The measured values may miss water that is not captured by the structure or water that leaks from the ditch if the measuring device is not located at the diversion structure. The periodic observations are then typically used to fill in the record until the next observation, which may or may not accurately reflect the actual amount of water diverted during the intervening time. In general, diversion records provide some information, but are likely to miss some water even at low flows, and are especially poor at accurately documenting rare high flow events.

Median Streamflow Estimates

The hydrograph (Complete Hydrograph) shows the median streamflow of the prorated and diversion adjusted data from the Wolf Creek gages. Median streamflow, based on the adjusted and prorated gage data is typically quite low, less than 1 cfs for nearly half of all days. The hydrograph also shows the median and maximum diversions from the Himes Ditch. The median diversion rate is quite low, often near zero due in part to a large number of years with no diversion records. If the zeros are removed, the median diversion rate is typically between 1 and 2 cfs. The maximum recorded diversion rate is 11.42 cfs. This analysis provides estimates about typical low conditions on Himes Creek.

High Flow Estimates

The ISF recommendation is based in part on the importance of rare high flow events that help to maintain pools that are critical habitat for the San Juan lineage trout in Himes Creek. The Maximum Daily Hydrograph shows the maximum daily streamflow based on the Wolf Creek gages. The highest prorated daily streamflow was 43.7 cfs, while the pro-rated peak flow (the maximum instantaneous streamflow) was 64 cfs. The hydrograph also illustrates late season storms, which typically occur during August through October. These peak flows are short in duration, but nearly reach the magnitude of spring runoff flows.

StreamStats also estimates peak flows for a number of different recurrence intervals; the 2-year recurrence interval flow is 43.7 cfs (the exact match to the prorated gage daily value is a coincidence), the 5-year recurrence interval flow is 82.2 cfs, the 10-year recurrence interval flow is 115 cfs, and the 100-year recurrence interval flow is 255 cfs. These estimates suggest that while flow on Himes Creek is usually quite low, rare events can produce more significant streamflow.

Water Availability Summary
The hydrographs presented below together with recurrence intervals from StreamStats provide an estimate of the range of streamflow conditions on Himes Creek. Staff has concluded that water is available for appropriation.

Material Injury
Because the proposed ISF on Himes Creek is a new junior water right, the ISF can exist without material injury to other water rights. Under the provisions of section 37-92-102(3) (b), C.R.S. (2018), the CWCB will recognize any uses or exchanges of water in existence on the date this ISF water right is appropriated.

Citations

Capesius, J.P. and V.C. Stephens, 2009, Regional regression equations for estimation of natural streamflow statistics in Colorado, Scientific Investigations Report 2009-5136.

Rogers, K.B, White, J, and M. Japhet, 2018, Rediscovery of a lost Cutthroat Trout lineage in the San Juan Mountains of southwest Colorado. Colorado Parks and Wildlife, p 1-33.

Roper, B., 2018, Himes Creek Cutthroat Trout. Utah State University, p 1-7.

Skinner, J., 2019, Literature review on the importance of a natural flow regime to aquatic ecology in rivers and streams, p 1-13

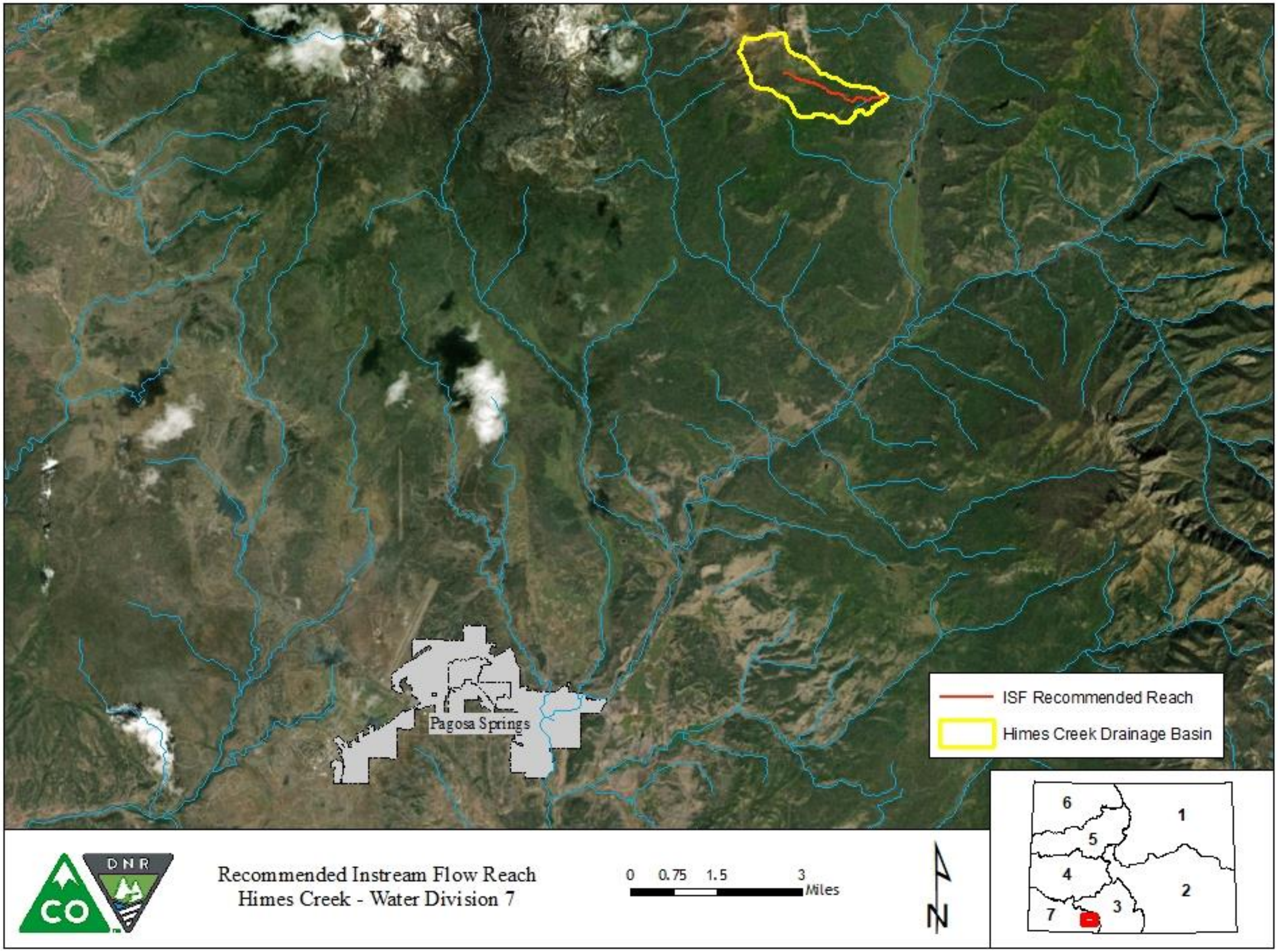
Skinner, J., 2017, Himes Creek Habitat Survey and Inventory Report. Colorado Parks and Wildlife, p 1-17.

Wohl, E., 2018, Himes Creek Flow Diversions. Colorado State University, p 1-14.

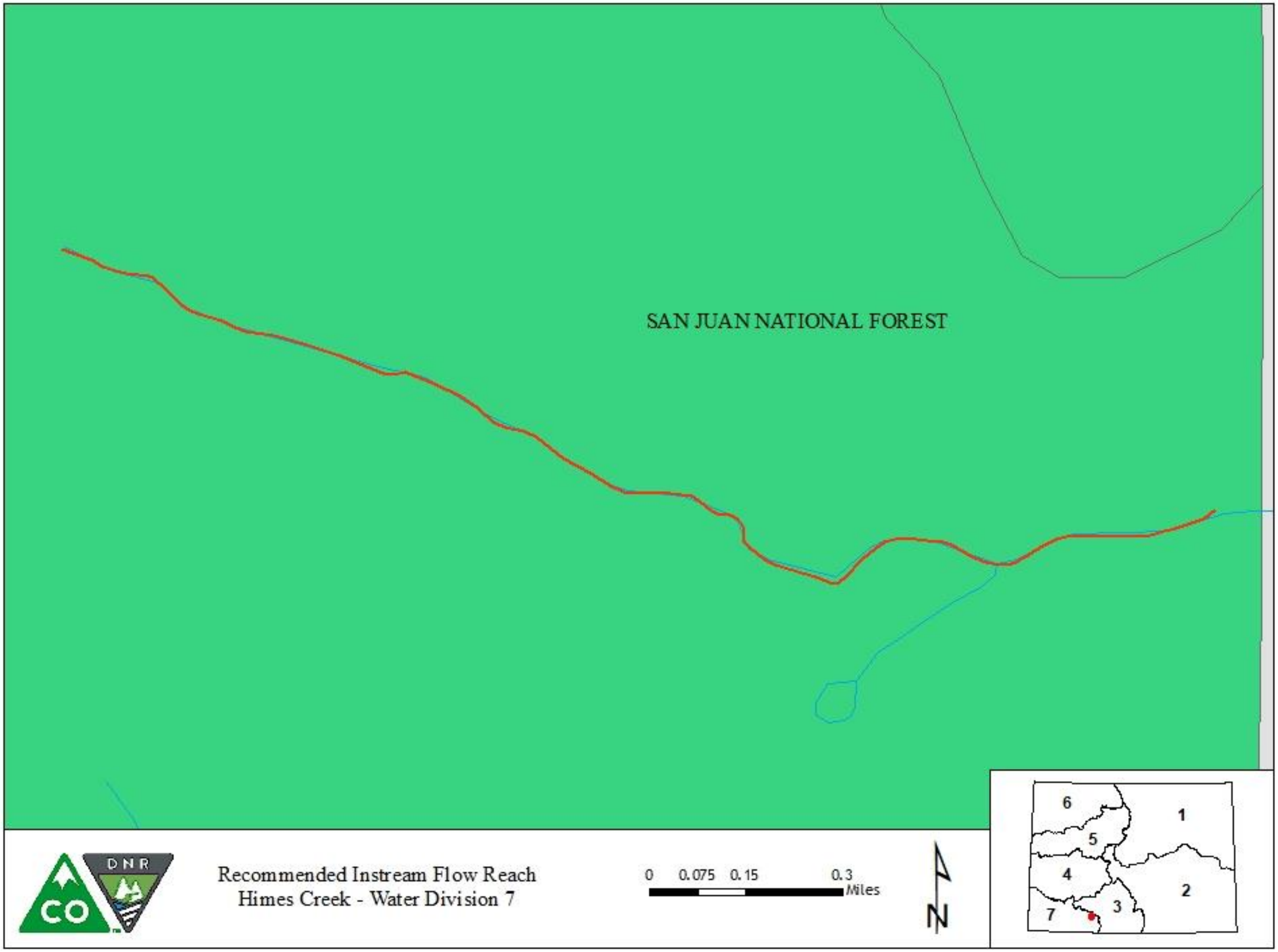
Metadata Descriptions
The UTM locations for the upstream and downstream termini were derived from CWCB GIS using the National Hydrography Dataset (NHD).

Projected Coordinate System: NAD 1983 UTM Zone 13N.

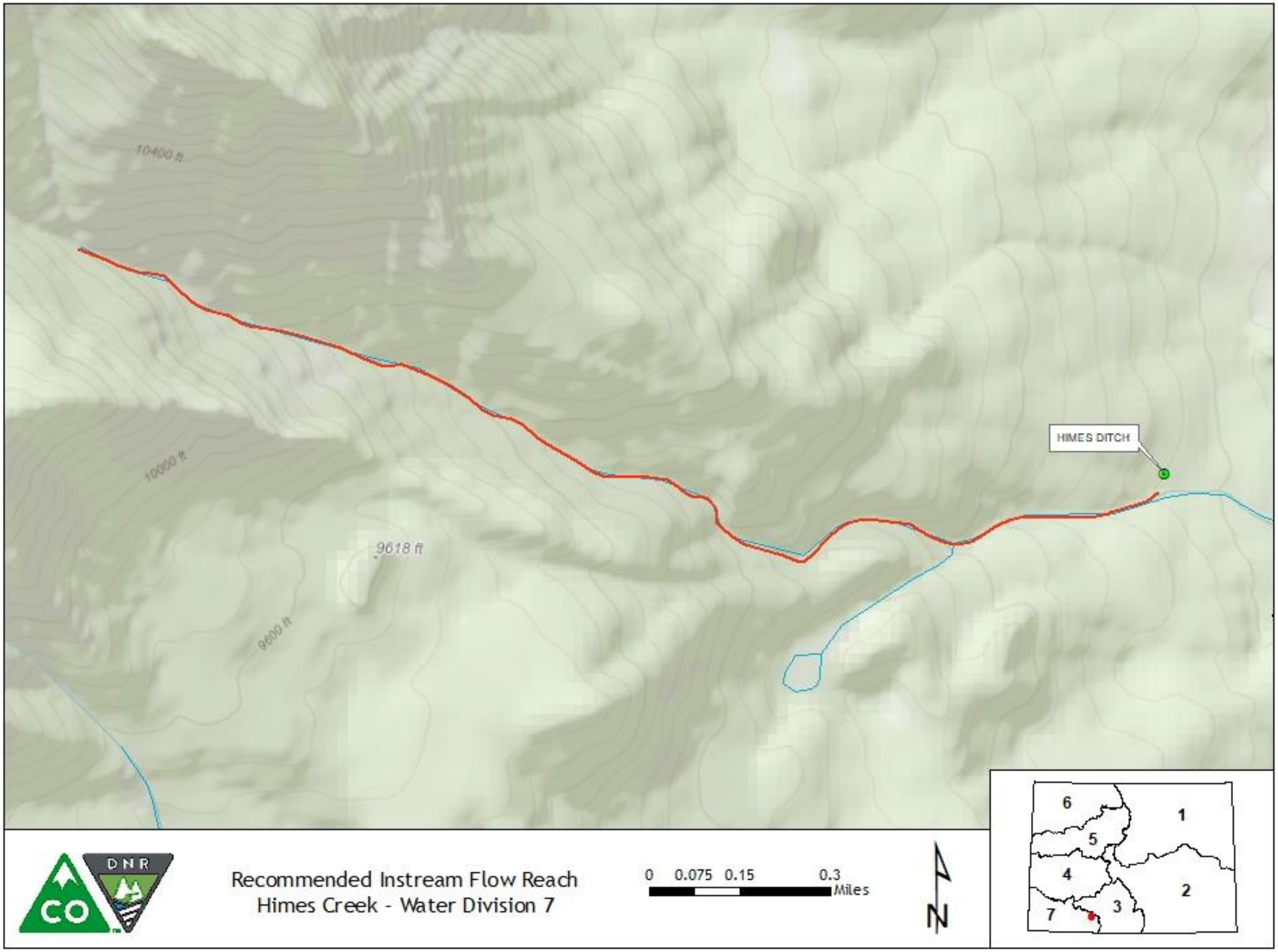
VICINITY MAP



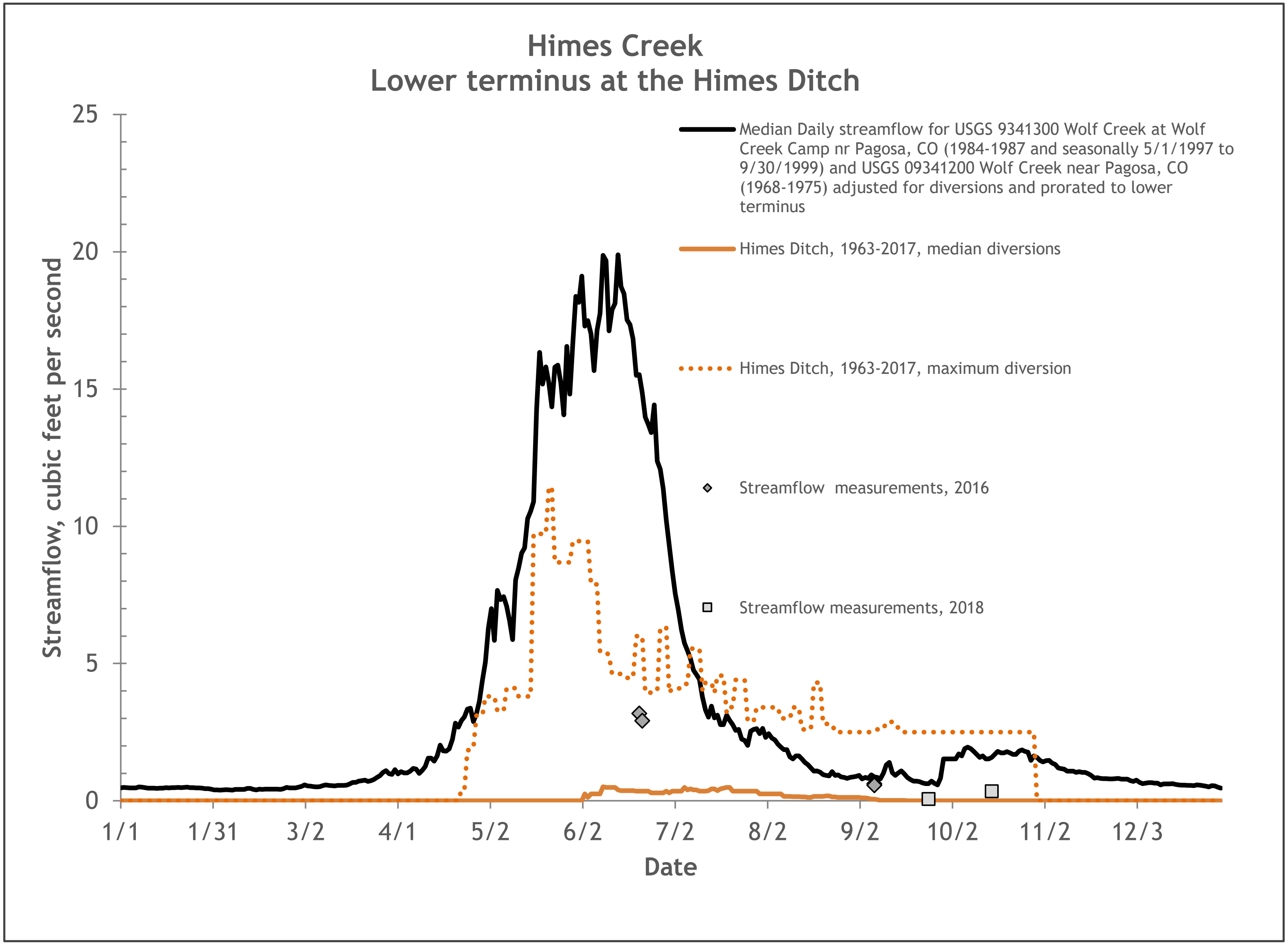
LAND OWNERSHIP MAP



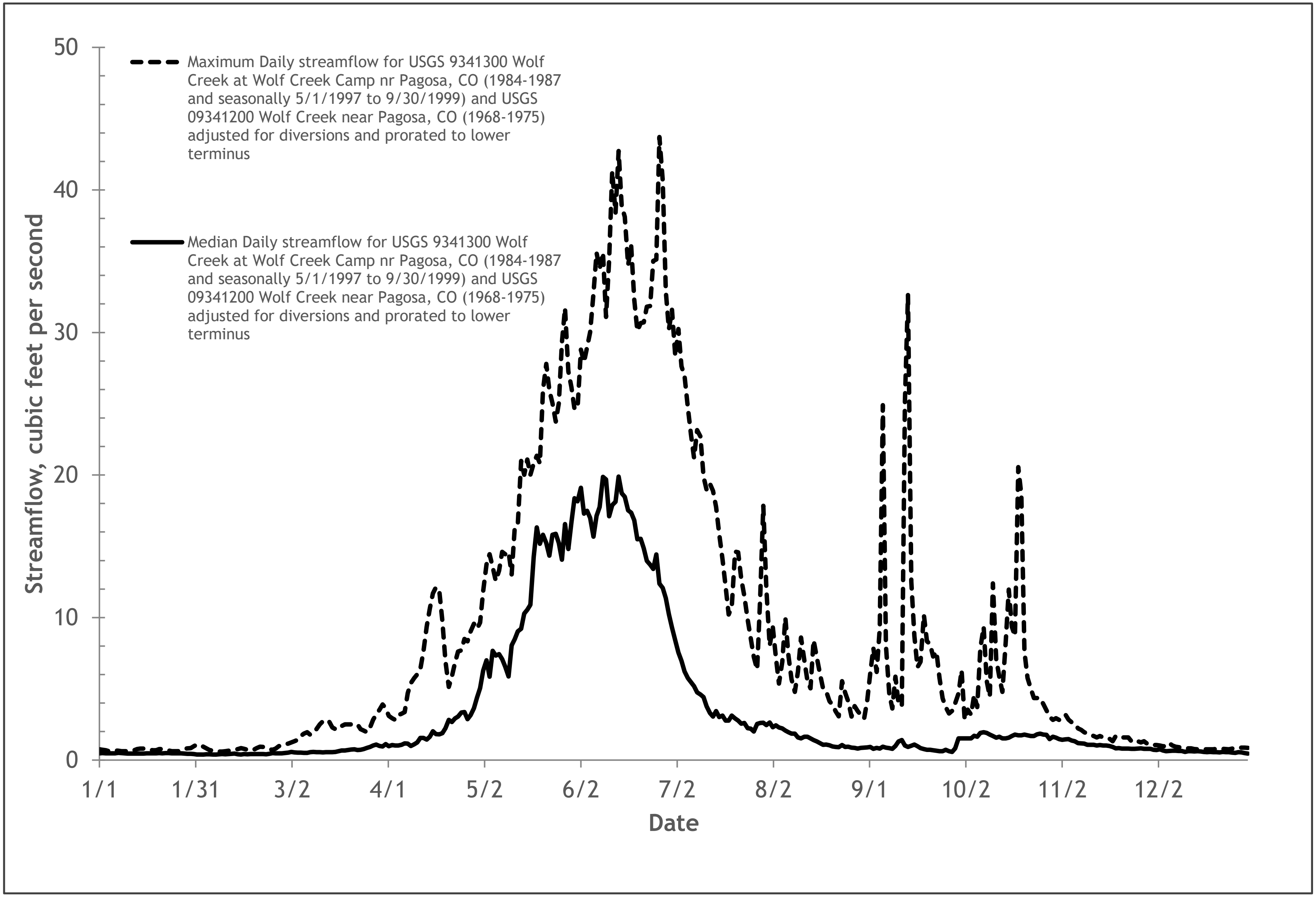
HYDROLOGIC FEATURES MAP



COMPLETE HYDROGRAPH



MAXIMUM DAILY HYDROGRAPH



SELECT PHOTOS

Unusually large step and pool.

Tarp being used to divert flow to the Himes Ditch.

Small pool that demonstrates a mix of sediment sizes.

Eroding hillslope adjacent to the channel.

San Juan lineage trout

SELECT PHOTOS

Himes Creek Fall 2018

Himes Creek Winter 2019

Attachment B

USDA United States Department of Agriculture | Forest Service | San Juan National Forest

15 Burnett Court
Durango, CO 81301
(970) 247-4874
Fax: (970) 375-2319

File Code: 2500
Date: November 30, 2017

Linda Bassi
Section Chief
Colorado Water Conservation Board
1313 Sherman Street, Room 721
Denver, CO 80203

Dear Ms. Bassi:

The U.S.D.A. Forest Service ("Forest Service") is writing this letter to formally communicate its recommendation for an instream flow water right on Himes Creek pursuant to the rules of the Colorado Instream Flow and Natural Lake Level Program. The stream is located in Colorado Water Division 7.

Natural Environment: The natural environment of Himes Creek consists of a Core Conservation population of pure-strain Colorado River cutthroat trout as defined in the Conservation Agreement and Strategy for Colorado River Cutthroat Trout in the States of Colorado, Utah, and Wyoming[1]. The native fish in Himes Creek have not hybridized with rainbow trout. The recommended reach is important to the San Juan National Forest and the State of Colorado because it contains a fish population that shares a number of genetic markers with the San Juan lineage Colorado River cutthroat trout, a subspecies of Colorado River cutthroat trout that was thought to be extinct[2].

In the Upper San Juan River Basin there are hundreds of fish-bearing streams, yet Himes Creek is one of only five streams known to contain fish with the same genetic markers as museum specimens of San Juan lineage Colorado River cutthroat trout. In one of the five streams, only one fish was found. Since Himes Creek is very isolated and in near-pristine condition, it is important refugia habitat for this rare fish species. The natural environment also consists of water dependent wildlife habitat, aquatic macroinvertebrates, and healthy riparian vegetation.

Location and Land Status: Himes Creek is a small tributary to the West Fork San Juan River located about 11.5 miles northeast of Pagosa Springs, Colorado. The recommended reach is approximately 2 miles in length and is entirely located on lands managed by the San Juan National Forest.

Segment: The recommended reach begins at the headwaters and extends to immediately above the point of diversion of the Himes Ditch. The entire proposed reach is located on public lands above all headgates and known water diversions.

[1] CRCT Task Force. 2001. Conservation agreement and strategy for Colorado River cutthroat trout (Oncorhynchus clarkii pleuriticus) in the States of Colorado, Utah, and Wyoming. Colorado Division of Wildlife, Fort Collins. 87p.
[2] Metcalf et al., 2012. Historical stocking data and 19th century DNA reveal human-induced changes to native diversity and distribution of cutthroat trout. Molecular Ecology (2012) 21, 5194-5207.

Upper Terminus Headwaters in the vicinity of:
Latitude: N37° 25' 47.67" Longitude: W106° 56' 29.86"
Lower Terminus at Himes Ditch Headgate:
Latitude: N37° 25' 28.42" Longitude: W106° 54' 31.87"

Biological Summary:
Stream Habitat Himes Creek is a cold-water, high gradient step-pool mountain stream. The watershed is largely unmanaged, undeveloped, and stream condition is excellent. The recommended reach is a predominately confined channel with large-sized cobble and boulder substrate (50th percentile bed material is 86.3 mm). Aquatic habitat is dominated by cascades and pools and negligible riffle habitat is present. The predominant pool habitat in the segment consists of pools that are very small; the typical Himes Creek pool is only approximately 2 feet wide and 3.5 feet long. Average pool depth is only 0.4 feet, and the maximum residual depth of the pools is approximately 0.8 feet. The riparian corridor has variable width and has many different plant species throughout the reach. The riparian overstory is mixed conifer forest and the primary understory brush species are Rocky Mountain maple, red-osier dogwood, and alder.

Critical Habitat The importance of pool habitat for Colorado River cutthroat trout in small to medium sized mountain streams has long been recognized[3]. For Himes Creek, pools are the critical habitat feature for overwintering fish. High quality residual pools are also very important for refuge habitat during drought and during the low flows that occur in late summer, fall, and early winter.

The Himes Creek watershed is located on lands managed by the Forest Service and is by and large free of management activities such as roads and vegetation manipulation. The local geology and soils are a non-anthropogenic source of sediment for the channel. The upper Himes watershed is situated in volcanic geology comprised of ash flows, tuff, and andesite. The lower watershed is within Quaternary landslide deposits and modern alluvium[4]. All of these geologic formations are potential sources of sediment which could fill pools in Himes Creek. In fact, surveys conducted by the Forest Service and Colorado Parks and Wildlife ("CPW") in 2016 and 2017 found that eroding upland side-slopes and adjacent eroding stream banks are a ready source of fine sediment into Himes Creek in several places. Typical stream channel geomorphic processes, including minor channel adjustments and flood events can also be sources of finer sediment.

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[3] Young, Michael K., 2008. Colorado River Cutthroat Trout (Oncorhynchus clarkii pleuriticus) A technical Conservation Assessment. United States Department of Agriculture, Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-207-WWW, 122 pp.
[4] Twedo, Ogden, 1979. Geologic Map of Colorado. U.S, Geological Survey, Federal Center, Denver, Colorado.

Since pool habitat is critical to the survival of this fish population, sedimentation of pools can be a significant limiting factor on the survival of the fish population. To maintain the step-pool channel morphology and pool dimensions necessary to support critical fish habitat, it is the opinion of the Forest Service that flows greater than typical R2Cross minimum flows are necessary. Peak flows generate the turbulence and shearing necessary to control step-pool channel topography by moving sediment[5]. For Himes Creek, peak flows are associated with snowmelt runoff typically occurring March through July, and from large rainstorm events which typically occur July through October.

Fish Surveys Fish surveys were conducted by the Colorado Division of Wildlife ("CDOW") and/or the Forest Service in 1994, 1998, 2007, 2013, 2016, and 2017. The standard taxonomic analysis indicated genetically pure Colorado River cutthroat trout (*Oncorhynchus clarkii pleuriticus*). A small population of brook trout (*Salvelinus fontinalis*) also exists, but efforts to remove the species are ongoing due to concerns about habitat competition with the native cutthroat trout. In the late 1980's, CDOW and downstream landowner cooperatively constructed a fish barrier on private land to help isolate the Himes Creek fish population.

Since 1994, CDOW and Forest Service personnel have been monitoring this fish population. In 2002, stream flows in the San Juan River basin near Pagosa Springs, Colorado reached record low levels at numerous locations. CDOW and USFS fish biologists feared that the Himes Creek cutthroats might have been lost due to low stream flows and high water temperatures. In 2003, biologists conducted an assessment of the fishery and found that a number of individual fish survived the drought. A comprehensive population survey of the fishery was not conducted at the time so as not to exert any undue stress on the remaining fish. The 2012 drought was not as severe and Himes Creek was rigorously sampled in 2013. Figure 1 illustrates the status of the Himes Creek cutthroat trout population over time. Despite the two droughts, the Himes Creek fish population persists ranging from an estimated 116 fish/mile sampled in 1998 to 264 fish/mile in 2013. The survey data also shows that since 2013, the population appears to be stable and contains several age classes of fish: this indicates that natural reproduction is occurring. As a part of this on-going monitoring effort, some fish tissue samples were collected from trout in Himes Creek in 2016.

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[5] Wohl, Ellen and Douglas Thompson, 2000. Velocity Characteristics along a Small Step-Pool Channel. Earth Surf. Landforms **25**, 353-367; Comiti, Francesco, A. Andreoli, M. Lenzi, 2005. Morphological Effects of Local Scouring in Step-Pool Streams. Earth Surf. Processes and Landforms **30**, 1567-1581.

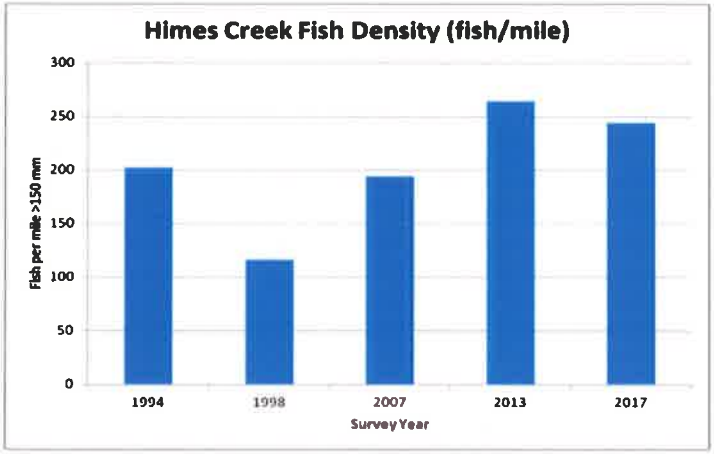


Figure 1. Estimated adult Cutthroat Trout density in Himes Creek, Mineral County, Colorado.

DNA Analysis Over the last decade or so, advanced DNA characterization technologies have provided fish biologists and managers additional information about cutthroat trout taxonomy. These scientific advancements have added both complexity and in some cases, clarity, to the job of managing and conserving these rare native fish. At this point in time, there are six known subspecies of Colorado River cutthroat trout in Colorado (two of which were thought to be extinct, including the San Juan River lineage). Though there are visual characteristics that distinguish these lineages, it is more efficient to categorize them based on the DNA profiles of individual fish and their similarity to historic samples and museum specimens. Mitochondrial DNA is passed from mother to daughter virtually unchanged, thus analysis of mitochondrial DNA is used to evaluate familial relationships, ancestry, and lineage.

Tissue samples collected from the Himes Creek fish population in 2016 were analyzed by comparing the mitochondrial DNA (genetic markers) to museum specimens collected in the 1880s from the San Juan River near Pagosa Springs. These museum specimens were the San Juan lineage cutthroat which were believed extinct. Interestingly, the Himes Creek fish shared the same mitochondrial haplotype (genetic markers) as the museum specimens, indicating the Himes Creek fish shared a close ancestry with museum specimens. No other museum specimens of San Juan lineage fish are known to exist.

At this point, the genetic analysis, which is the best available science, show a shared lineage between the Himes Creek cutthroat trout and the San Juan native, indicating that the Himes Creek population is likely a relict population of San Juan native. Due to the age of the existing museum specimens, the ability to complete a comprehensive DNA profile for those fish has not been possible. Genetic testing of fish populations in four other streams in the San Juan River basin also found genetic markers present in these fish that are consistent with markers present in the museum specimens of San Juan lineage Colorado River cutthroat trout.

Species Management and Threats The Colorado Division of Wildlife (now Colorado Parks and Wildlife or CPW) and federal land management agencies (Forest Service and BLM) as well as other state fish and wildlife management agencies in the intermountain west have been actively managing and conserving cutthroat trout populations for several decades. Cutthroat trout sub-species range from New Mexico north to Alaska and fall in various management categories ranging from "species of greatest conservation need" to "threatened or endangered" status under the Endangered Species Act. Colorado River cutthroat trout are not listed under the Endangered Species Act. They are designated by the Forest Service and State of Colorado as a Sensitive Species. Forest Service Manual (FSM) 2670.5 defines sensitive species as "those plants and animals identified by a Regional Forester for which population viability is a concern as evidenced by: a) Significant current or predicted downward trends in population numbers or density, b) Significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution." Further, FSM 2672.1 directs "Sensitive species of native plant and animal species must receive special management emphasis to ensure their viability and to preclude trends toward endangerment that would result in the need for Federal listing."

A 1998 CDOW habitat survey noted that Himes Creek is a very small, isolated stream, and stated specific concerns for the resident native Colorado River cutthroat trout "Long-term, this small, isolated population is vulnerable and could be lost if measures are not taken to preserve this genetic strain". The Himes Creek population of fish is at a higher risk of extirpation because Himes Creek is isolated and has no connectivity to any other source populations of potential San Juan lineage cutthroat trout. The stream characteristics (limited reach length, small pool size, etc.) also make it vulnerable to disturbance such as fire or drought. Should the fish population decline significantly or be extirpated due to some type of disturbance or prolonged drought conditions, the Forest Service would no longer have a viable population in Himes Creek. This is significant because of the extremely limited distribution of the San Juan lineage fish and lack of connectivity to other streams from which re-colonization might occur.

The Himes Creek fish are unique and are therefore very valuable in terms of what they represent for the genetic biodiversity of native cutthroat trout in the Rocky Mountain west. Protection of the Himes Creek population is therefore a top priority for the State of Colorado (CPW) and the Forest Service. Protective land management combined with securing all the available water through a CWCB instream flow water right are two immediate steps that should be taken to help ensure that this population can persist into the future.

R2Cross Analysis: R2Cross is one of the standard methods used to quantify minimum flows necessary to preserve the natural environment to a reasonable degree. R2Cross was not an appropriate method to quantify minimum flows in Himes Creek for several reasons. First, Forest Service stream surveys conducted in 2016 document that low gradient riffles are negligible in Himes Creek. R2Cross data is collected in riffle habitat and Himes Creek does not have sufficient riffles to make appropriate measurements. In addition, the R2Cross method assumes that riffles are the most critical or limiting habitat within a reach. In Himes Creek, this is not the case because it is a high gradient step-pool system and pools are the most critical habitat to protect.

Photos 1 and 2. Himes Creek typical step-pool habitat. Photo courtesy of CWCB.

The critical habitat feature in Himes Creek are pools that the fish need for overwintering habitat and to survive the low flow conditions present in the late summer, fall, early winter, and during drought. Critical pool habitat is already limited in Himes Creek because the reach length is only 2 miles and, as stated above, the pools are small. The importance of pool habitat has been observed in Himes Creek by Mike Japhet, CDOW Aquatic Biologist, and the Forest Service while performing stream reconnaissance during drought conditions. The biologists found that water deep enough to hold fish was available almost exclusively in the pool habitat (Dave Gerhardt, retired Forest Service Fisheries Biologist, personal communication). A primary assumption for the R2Cross model is that low gradient riffles are the limiting and critical habitat feature for fish in most streams. This is not the case for Himes Creek. We make this conclusion because low gradient riffles are rare or absent in Himes Creek and the fish must hold in pools during the most stressful conditions of the year. This rare native San Juan genetic lineage of Colorado River cutthroat has been able to persist thousands of years in Himes Creek, perhaps since at the last glacial period in the San Juan Mountains. It is the existence of pool habitat and natural fluvial geomorphic processes that have provided and maintained the pool habitat over time that has allowed these fish to persist and survive.

Photo 3. Native cutthroat trout from Himes Creek, 2016 Forest Service fish survey.

The species likely survived the 2002 and 2012 droughts due in part to the natural hydrograph, unaffected by anthropogenic changes that supported natural fluvial geomorphic processes such as pool scouring, which in turn provided sufficient pool depth and refugia for the fish. However, it is important to note that the entire natural hydrograph is important to support all life stages of this rare and unique species as the reduction of flows at other periods of time could also be limiting and jeopardize their survival. The following table summarizes the various flow periods and their importance to this unique fishery.

Flow Period	Ecological / Fishery Function
Base Flows (typically check August to March)	Support macro-invertebrate life cycles, maintenance of temperature regime, juvenile rearing habitat, overwintering adult and juvenile habitat, prevention of pools from freezing.
Snow Melt Runoff Flows (typically March through July)	Recharge of aquifer for support of riparian vegetation; cutthroat spawning; removal of fine sediment, maintenance of pool depth and volume, and deposition and maintenance of spawning gravels.
Short Duration Peak Flows (Storm-driven events typically July through October)	Entrainment of large woody debris, scouring and formation of new pools, maintenance of riparian corridor and floodplain areas.

Forest Service Instream Flow Recommendation:
Based upon currently available data and information, the Forest Service has determined that all the unappropriated flow in Himes Creek is the minimum amount needed for fish population survival and to preserve the natural environment (described above) to a reasonable degree in the subject reach of Himes Creek.

The value of this fish population in terms of genetic biodiversity cannot be understated. There are only five known populations of fish with genetic markers that indicate a lineage to the San Juan River cutthroat trout, once thought to be extinct. None of these five populations have connectivity with the other populations, making recolonization impossible should one of these populations be lost due to disturbance or environmental factors. Any withdrawal of water from Himes Creek may affect the viability of this species by reducing flow, reducing the extent and depth of pools, impacting riparian habitat, and negatively affecting the macroinvertebrate food source this species relies upon. Management actions that affect the viability of a Forest Service sensitive species is precluded by the laws, regulations, and policy that direct the Forest Service. An instream flow water right for all the unappropriated flow in Himes Creek would assist the USFS in this management responsibility and protect this critical fish population.

Water Availability: All water rights on Himes Creek are located downstream of the recommended reach. There are no water rights on Himes Creek within or upstream of the recommended reach. The Himes Ditch is located on Forest Service lands but is below the recommended reach.

Himes Creek is a very small stream with no gage record. Available water can be estimated by extrapolating the records from nearby similar stream gages and from the USGS StreamStats model. StreamStats estimates the mean monthly flows during base flow periods could be 1 cfs or less. The mean monthly flows during runoff periods are up to 11 cfs. It should be noted that all the unappropriated flow in the Himes Creek watershed represents modest flows at most times.

Relationship to Land Management Plans: Forest Service watershed and aquatic habitat conservation is based on several key federal laws that set a consistent land-and-water stewardship vision (see Appendix). These Laws direct Forest Service actions to protect watersheds and aquatic habitat through sound management. In addition, the San Juan Forest Plan calls for Himes Creek to be managed to provide ecological conditions sufficient to support native fish species and other aquatic biota in the long-term. Specifically, the Forest Service Land Management Plan strategy for Colorado River cutthroat trout is to 1) stabilize and maintain existing populations, and 2) expand the distribution and overall abundance of this species to a point where long-term viability is no longer a concern. It also directs that the management of riparian areas restore the composition, structure, and function of these ecosystems. In addition, aquatic habitat should support well-distributed populations of vertebrate and invertebrate species.

Establishing an instream flow water right for all the unappropriated flow on Himes Creek pursuant to the Colorado Instream Flow and Natural Lake Level Program would assist in meeting the Forest Service management obligations and Forest Plan direction summarized above. Thank you for considering the Forest Service recommendation for Himes Creek, a stream with many important resource values including a rare native fish species, water dependent wildlife habitat, aquatic macroinvertebrates, and healthy riparian vegetation.

If you have any questions regarding our instream flow recommendation, please feel free to contact me or Forest Hydrologist Kelly Palmer at (970) 385-1232 or via email at kapalmer@fs.fed.us.

Sincerely,

Kara L Chadwick

KARA L. CHADWICK
Forest Supervisor

Appendix

LAWS, REGULATION, AND POLICY GUIDING U.S. FOREST SERVICE AQUATIC RESOURCE MANAGEMENT

Forest Service watershed and aquatic habitat conservation is based on several key federal laws (listed below in chronological order) that set a consistent land-and-water stewardship vision. These laws direct Forest Service actions to protect watersheds and aquatic habitat through sound management. Brief summaries of these laws and their direction for management related to watersheds and aquatic habitat are included below. Federal regulations contain the current interpretations and direction specific to these laws.

1. **Organic Administration Act of 1897 (16 U.S.C. 475).** This law defines original National Forest purposes to improve and protect the forest, secure favorable conditions of water flows, and furnish a continuous supply of timber. Years of concern about watershed damage led to creation of the National Forest System. Watersheds must be cared for to sustain their hydrologic function as "sponge-and-filter" systems that absorb and store water and naturally regulate runoff. The goals are good vegetation and ground cover, streams in dynamic equilibrium with their channels and flood plains, and natural conveyance of water and sediment.

2. **Multiple Use-Sustained Yield Act of 1960 (16 U.S.C. 528).** This law expands National Forest purposes to include watershed, wildlife and fish, outdoor recreation, range, and timber and to sustain native ecosystems. Renewable surface resources are to be managed for multiple use and sustained yield of the several products and services that they provide. The principles of multiple use and sustained yield include the provision that the productivity of the land shall not be impaired.

3. **Endangered Species Act of 1973 (16 U.S.C. 1531-1536, 1538-1540).** This law conserves endangered and threatened species of wildlife, fish, and plants and the ecosystems on which they depend. Federal agencies must conserve endangered and threatened species and cooperate with State and local agencies to resolve resource issues (Section 2). Each Federal agency shall, with the consultation and help of the Secretary of Interior, ensure that any action authorized, funded, or done by the agency is unlikely to jeopardize the continued existence of any endangered or threatened species or result in adverse modification of their critical habitat (Section 7).

4. **National Forest Management Act of 1976 (16 U.S.C. 1600-1602, 1604, 1606, 1608-1614).** The Forest Service must be a leader in conserving natural resources (Section 2). Programs must protect and, where appropriate, improve the quality of soil and water (Section 5). The overall goal of managing the National Forest System is to sustain the multiple uses of its renewable resources in perpetuity while maintaining the long-term productivity of the land. Maintaining or restoring the health of the land enables the National Forest System to provide a sustainable flow of uses, benefits, products, services and visitor opportunities (36 CFR 219.1 (2005)). The overall goal of the ecological element of sustainability is to provide a framework to

contribute to sustaining native ecological systems by providing ecological conditions to support a diversity of native plant and animal species (36 CFR 219.10 (2005)).

Ecological conditions are the components of the biological and physical environment that can affect diversity of plant and animal communities and the productive capacity of ecological systems. These components could include the abundance and distribution of aquatic and terrestrial habitats, roads and other structural developments, human uses, and invasive, exotic species (36 CFR 219.16 (2005)).

5. **Federal Land Policy and Management Act of 1976 (43 U.S.C. 1752).** Rights-of-way for water diversion, storage, and/or distribution systems, and other uses must include terms and conditions to protect the environment and otherwise comply with the requirements of Section 505, including section (a) (ii): "minimize damage to scenic and esthetic values and fish and wildlife habitat and otherwise protect the environment".

6. **Clean Water Act of 1977 (33 U.S.C. 1251, 1254, 1323, 1324, 1329, 1342, 1344).** This series of laws was written to restore and maintain the chemical, physical, and biological integrity of the Nation's waters (Section 101). Congress sought to sustain the integrity of water quality and aquatic habitat so that waters of the United States will support diverse, productive, stable aquatic ecosystems with a balanced range of aquatic habitats. All issues are framed by the intent of Congress to improve and preserve the quality of the Nation's waters (540 F2.d 1023; 543 F2.d 1198; 612 F2.d 1231; 97 S.Ct 1340; 97 S.Ct 1672).

Waters of the United States include perennial and intermittent streams, lakes, wetlands, and their tributaries. Aquatic ecosystems are waters of the United States that serve as habitat for interrelated and interacting communities and populations of plants and animals (40 CFR 230.3). Impacts to flow patterns, temperature, dissolved oxygen, sediment, and pollutant levels must be controlled (33 U.S.C. 1311 and 1314; 843 F2.d 1194; 753 F2.d 759). Physical features needed to support existing uses for anti-degradation include substrate, cover, flow, depth, pools, and riffles (40 CFR 131.10, 230.10, and 230.11).

7. **Forest Plans.** The purpose of the San Juan National Forest Land and Resource Management Plan (Forest Plan) is to provide strategic guidance for future management of all National Forest System lands managed by the San Juan National Forest. It provides a framework for informed decision making, while guiding resource management programs, practices, uses, and projects.

To ensure the long-term sustainability of ecosystems, humans must manage within the physical and biological capabilities of the land, maintain all of the ecological components and processes, and not irreversibly alter ecosystem integrity and resilience. The concept of sustainability is a fundamental component of the Forest Plan and is guided by the Multiple-Use Sustained-Yield Act (MUSY) and the Federal Land Policy and Management Act (FLPMA). Ecological sustainability is intended to provide the ecological conditions that maintain or restore the diversity of native ecosystems and natural disturbance processes. This in turn will maintain suitable habitats for a wide range of plant and animal species and provide for the diversity and viability of plant and animal species, populations and communities.

For lands managed by the USFS, the Planning Rule in 36 CFR 219.19 specifically requires that "[f]ish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area," and "[f]or planning purposes, a viable population shall be regarded as one which has the estimated numbers and distribution of reproductive individuals to insure [sic] its continued existence is well distributed in the planning area." Regulation 36 CFR 219.26 requires that "[f]orest planning shall provide for diversity of plant and animal communities and tree species consistent with the overall multiple-use objectives of the planning area. Such diversity shall be considered throughout the planning process." In addition, the FLPMA specifies that special uses granted by the Secretary of Agriculture are subject to terms and conditions that "minimize damage to fish and wildlife habitat and otherwise protect the environment." Agency actions should avoid or minimize impacts to species whose viability has been identified as a concern. USFS actions must not result in loss of population viability or create significant trends toward federal listing (FSM 2670.32).

For riparian area and wetland ecosystems, aquatic ecosystems, and terrestrial ecosystems, specific management direction has been developed that is intended to address the legal, regulatory, and policy requirements for species diversity and population viability. The process applied was to identify a range of key ecosystem elements, determine the importance of those elements to maintaining species diversity and population viability (e.g. limiting factors), define desired future conditions and land management objectives for those elements, and ensure that appropriate management standards and guidelines are in place that address the ecological needs of species and populations. In general, management standards have been developed for those elements determined to have an overriding influence on species diversity or long-term population viability, while other elements that have less influence are typically addressed through the application of guidelines.

Attachment C

Colorado Water Conservation Board
Instream Flow Tabulation - Streams
Water Division 7

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Water Court Div.	Case Number	Stream	Watershed	County	Upper Terminus (UTM)	Lower Terminus (UTM)	Length (miles)	Amount (dates)	Approp Date
7	17/7/A-001	Himes Creek	Upper San Juan	Mineral	headwaters in the vicinity of E: 328210.38 N: 4144335.05	Himes Ditch hdgt at E: 331098.52 N: 4143682.20	2.0	all unappropriated flow (1/1-12/31)	

Totals for Water Division 7

Total # Appropriations = 1
Total # Appropriation Stream Miles = 2

April 2018

Himes Creek and Flow Diversions

Ellen Wohl, Department of Geosciences, Colorado State University

Introduction

Stream channels steeper than about 2% typically have sequential vertical down-steps composed of boulders, bedrock, or large wood, separated by plunge pools[3]. Together, these step-pool sequences create a staircase-like longitudinal profile in steep streams. Step-pool sequences are a type of bedform. Bedforms are downstream undulations in the streambed that result from sediment transport: other examples include pools and riffles. The height and downstream spacing of steps and pools, as well as the size of sediment in the streambed, reflect the prevailing balance between water and sediment supplied to the stream. When supplies of water and sediment change, the channel configuration also changes.

During the past two centuries, hydraulic engineers and fluvial geomorphologists have developed equations to describe the interactions among water, sediment, and channel configuration in order to quantitatively predict how channel configuration will change in response to altered volumes of water and sediment. Until the past decade, the most widely applied versions of these equations assumed *steady, uniform, one-dimensional flow*[24]. These assumptions, although not strictly accurate for natural channels, are adequate for describing flow in lower *gradient* channels with smoother boundaries. The equations do not adequately describe flow and sediment movement, however, in steep, *rough boundary* step-pool channels[23]. This means that we cannot accurately predict basic parameters such as velocity, *shear stress*, and sediment movement in step-pool channels and we cannot predict how channel configuration will change except in broad terms.

Flow in step-pool channels is highly *turbulent* and *three-dimensional*, with significant cross-stream and vertical forces, as well as downstream forces[22]. Much of the flow energy is dissipated in overcoming *external or boundary resistance* and *internal resistance*, rather than being directed toward picking up and transporting sediment. Boundary resistance derives from the fact that a natural channel does not have a smooth bed or banks. The degree to which individual boulders or pieces of wood protrude above the bed or out from the banks governs boundary resistance: resistance increases as the channel boundaries become more irregular. Internal resistance results from the fact that individual water particles do not move in perfectly parallel flow paths or at the same velocity. Water flowing beside the channel bed and banks experiences more external frictional resistance and thus moves more slowly and in more irregular flow paths, which creates internal frictional resistance with water particles in the central portion of the channel, which are typically moving faster. This internal frictional resistance is expressed in turbulence, during which portions of the flow can be directed upward away from the bed, downward toward the bed, or toward or away from the banks, as well as being directed downstream.

Even the flow energy not dissipated in overcoming frictional resistance and thus available to carry sediment may not actually result in sediment movement because the wide range of grain sizes typical of step-pool channels allows large boulders to shield smaller sediment from the flow. Consequently, we do not have equations that allow us to predict exactly how a step-pool channel will respond to increases or decreases in the supply of water or sediment.

The objective of this report is to summarize existing knowledge of step-pool channels, particularly within the context of the potential effects of changes in flow. The report focuses on step-pool channels but brings in knowledge from other types of river channels where appropriate. References are cited where relevant and a glossary of italicized words is provided to further explain technical terms used in the report.

Channel Morphology and Habitat in Step-Pool Channels

Step-pool channels have steps that span the channel and intervening plunge pools. Steps can be formed of boulders, logs, bedrock, or some combination of these materials. Steps formed of boulders result from the interlocking of large, keystone boulders under conditions of limited sediment supply, leading to a jammed state in which the boulders limit downstream movement of logs and smaller cobbles[29,30]. Steps formed of wood can consist of individual logs that are ramped, with one end resting above high-flow level on the bank, or logs that are wedged across the channel. These relatively immobile logs can block downstream movement of cobbles and boulders, creating a wedge of sediment that forms a step[17,21]. A logjam can also effectively trap sediment and create a step[27].

A step consists of the relatively flat step tread and the step lip (Figure 1). A logjam-step can create an upstream backwater and a distinct threshold over which flow must pass to continue downstream, whereas the irregular lip of a boulder-step is likely to readily pass flow at lower discharges (Figure 2). The step lip is likely to be formed by the largest grain sizes of sediment present in the channel.

Flow dropping over the step lip creates a plunge pool by scouring the streambed. The highly turbulent, aerated flow in the plunge pool dissipates significant energy in overcoming internal resistance, and *finer sediment* and particles of organic matter carried into the pool tend to settle along the pool margins. The elevation of the streambed reaches a low point in the pool and then rises again slightly to the tread of the next step downstream, creating a short zone of reverse bed gradient.

Lower discharges in step-pool channels can create interstitial flow, with water primarily passing through gaps between the step-forming boulders and much of the energy used to overcome external resistance (Figure 3). With increasing discharge, free falls over steps create nappe or weir flow, in which flow plunges vertically over the step lip and then forms a standing wave at the downstream end of the pool. Much of the energy dissipated during nappe flow goes into overcoming internal resistance associated with turbulence. At the highest discharges, the vertically plunging flow and standing wave disappear. A skimming flow regime develops in which the water flows as a coherent stream with a recirculating vortex at the base of each step. The rate of flow energy dissipation increases from interstitial to nappe flow and then decreases significantly at the transition to skimming flow[4]. This means that skimming flow has high velocity and the ability to transport more sediment.

Step-pool sequences can abruptly change to braided or plane-bed channels during extremely large discharges that mobilize the entire bed and greatly enhance the supply of sediment available for transport. The frequency of such mobilization varies enormously between channels. In channels with high rates of sediment supply associated with frequent debris flows from nearby hillslopes, as well as high seasonal and interannual variability in flow, steps and pools can be destroyed and re-formed annually[19]. In other channels with less variability in flow regime (e.g., snowmelt flows) and more stable hillslopes, steps and pools can be mobilized and re-formed only once every few decades[23]. Mobilization and destruction of steps and pools occurs only during the highest discharges in a channel, which typically leaves a planar bed as flow recedes. Subsequent smaller flows mobilize the finer sediment exposed at the surface, gradually winnowing the streambed to a larger average grain size in which steps and pools form once again[8,9]. Understanding this sequence through time is critical, because steps and pools are commonly interpreted to form in response to a limited supply of sediment finer in size than the step-forming boulders[13].

The substantial variations in grain size, bed gradient, flow depth, and velocity create diverse habitat for stream organisms. Some forms of bottom-dwelling insects are adapted to clinging to the surface of logs and boulders in the swiftest current. These insects graze algae growing on the streambed. Other insect species collect fine organic matter accumulating on the margins of pools or filter organic matter suspended in the water. Fish inhabiting step-pool channels commonly rely on pool habitat, although the details of habitat use change with flow level and age or size of the fish. Fish may spend more time in the pool center during base flow and move to the pool margins during high flow, for example, as well as seasonally using spawning gravels on the step tread.

Sediment Dynamics in Step-Pool Channels

Entrainment refers to the initiation of motion of a sediment particle. Fundamentally, a particle will move if the forces promoting motion exceed the forces resisting motion. This idea is typically represented with a force balance diagram (Figure 4). Quantifying the forces acting on a sediment particle is relatively simple if the depth and velocity of flow and the size and density of the particle are known. The uncertainties in predicting when a sediment particle will actually move in a real channel arise from site-specific variations in the forces on the particle. Although drag force is commonly computed based on average velocity, for example, numerous flume experiments indicate that the turbulent fluctuations in a flow and the associated momentary increases in velocity actually result in most entrainment[6]. These turbulent fluctuations are much less predictable than average velocity. Similarly, a force balance diagram assumes the particle is completely exposed to the flow rather than shielded by adjacent, larger particles or tightly packed among particles of similar size. A pebble an inch in diameter that sits on a patch of sand will move at much lower threshold values of velocity and shear stress than a pebble of the same size packed in among other pebbles. Consequently, equations designed to estimate the threshold flow at which sediment begins to move on a streambed can at best describe median conditions – the average velocity or shear stress at which the average sediment size present on the streambed will begin to move. The greater the fluctuations in velocity and turbulence, and the greater the range of grain sizes present on a streambed, the less accurate the equations become.

The position of a particle within the range of grain sizes is also important to entrainment. This position is commonly described as D_x, where *x* refers to percentile within a cumulative frequency distribution. D_{50} is the median grain size, for example, whereas 84% of the grains are smaller in size than the D_{84}. In a streambed with mixed grain sizes, particles smaller than D_{50} tend to be shielded by larger grains and thus require more energy to move than would be predicted based solely on their size and mass. Conversely, grains larger than D_{50} may move at lower than predicted values of velocity or shear stress because they are fully exposed to the flow. The wider the range of grain sizes, the more important the effects of shielding and packing become. Because step-pool channels commonly have a large range of grain sizes, the accuracy of prediction of sediment entrainment is usually low.

Sediment transport equations predict the volume of sediment moved as a function of flow energy and sediment grain size. More than a dozen sediment transport equations exist to predict sediment carried suspended within the flow (suspended sediment), sediment moving downstream in contact with the bed (bedload), and the combined suspended and bedload transport[23]. Some equations focus on sand-bed channels, others were developed for gravel- or boulder-bed channels. All of these equations assume that the amount of sediment transported is limited primarily by the flow energy available. In steep channels with *coarse sediment*, however, the largest grains can shield the smallest grains from entrainment, so that sediment transport is commonly limited primarily by sediment supply[28]. In addition, much of the flow energy is used to overcome external resistance rather than to transport sediment. Consequently, sediment transport equations routinely over-predict sediment transport in step-pool channels by more than 1-2 orders of magnitude, or by more than a factor of 10 to 100 times[28]. Even when equations are specifically modified to fit the conditions of step-pool channels, they are only accurate to within an order of magnitude of measured values of sediment transport[28].

Some of the particles within the finer half of the grain size distribution in a step-pool channel can be transported during high flows even though most of the streambed remains stable. Particles in pools are preferentially entrained and are transported longer distances[20]. Field experiments using tracer clasts suggest that particles finer than or equal to D_{40} of the bed surface all move similar distances during floods, whereas particles larger than the bed surface D_{84} move very little[9]. These observations suggest that periodic high flows are needed to keep removing finer sediment that continually enters step-pool channels from hillslopes, floodplains, and channel banks.

Both the magnitude and duration of high flows are important with respect to sediment transport. Because of the shielding effect of boulders, very high flows may be needed to initiate motion of even the smaller grain sizes present on the bed of a step-pool channel[10]. Field measurements of sediment transport in step-pool channels indicate that longer duration of flows above a threshold for sediment movement results in greater sediment transport during the course of the snowmelt hydrograph[10,18]. In other words, if it is important to maintain pool volume and spawning gravels for fish habitat, then both magnitude and duration of peak flows must be preserved.

Flow Regimes & Channel Stability

As noted earlier, the frequency with which steps and pools are mobilized varies significantly among channels. In the snowmelt-dominated flow regimes characteristic of Colorado mountains, step-pool sequences tend to be very stable, with several decades between floods capable of mobilizing the entire bed. Sediment moves into and through these channels every year[18], but this is typically the finer half of the bed grain size distribution. Mobilization of portions of the bed can result from step failure, particularly where the step is formed around a logjam or a single log. If the wood is dislodged or breaks, much of the sediment stored around it can be mobilized and move at least a short distance downstream[1], although the sediment commonly only moves for a few minutes to hours before again becoming stable on the bed. More significant sediment movement and channel instability can result from a large input of sediment to the channel, such as when a debris flow or landslide from an adjacent hillslope enters the channel. A very large flood – in the San Juan Mountains, typically associated with summer thunderstorm rainfall or a dissipating tropical storm in autumn – can also mobilize the entire streambed and reconfigure the steps and pools.

As a result of this general stability, step-pool channels have been described as transport reaches of a stream because they are relatively insensitive to changes in water and sediment supply[13,16,26]. In contrast, pool-riffle channels are response reaches that are more likely to change with alterations in water and sediment supply. The relative stability of step-pool channels reflects the combined effects of hydraulically rough boundaries that create external resistance and effectively dissipate flow energy as discharge increases, as well as large, relatively interlocked boulders in steps that require substantial flow energy to mobilize. However, this does not mean that step-pool channels are completely unresponsive to changes in water and sediment supply. Because the issue under consideration in Himes Creek is changes in flow regime, the rest of this discussion focuses on potential responses of step-pool channels to altered flow.

Step-Pool Resistance and Resilience to Changes in Flow

Resistance refers to the degree to which changes in flow create changes in channel morphology – width, depth, bedforms, bed gradient, and grain size distribution. A resistant channel exhibits very little change in response to changes in flow. Resilience describes how quickly the channel returns to pre-flood conditions following a flood. A resilient channel quickly recovers its pre-flood configuration. Step-pool channels are resistant up to threshold discharges that can mobilize the entire streambed. Beyond that, step-pool channels change dramatically and can require several years to completely recover. Consequently, they are resistant but not resilient to increased flow. An increase in flow that is not capable of fully mobilizing the bed of a step-pool channel can result in progressive channel widening because the finer sediment of the channel banks is easier to erode than the coarse sediment of the bed. This scenario has been documented for step-pool channels in Colorado that serve as the receiving channel for water diverted from another catchment[5,26]. The bed of these receiving channels can also coarsen, with all finer sediment completely removed from the bed surface.

Where flow is reduced, typically by diversion out of the channel, the primary physical effect is likely to be fining of the streambed as smaller sediment that would normally remain mobile gradually accumulates on the bed. This can eventually result in clogging of interstitial spawning gravels and loss of pool volume. The effects are likely to be greatest in sites with unstable hillslopes that episodically introduce substantial quantities of finer sediment into the channel via debris flows or landslides. Physical characteristics such as bed grain-size distribution and pool volume may be maintained by an annual "flushing flow" (a high flow of similar magnitude but shorter duration than the natural snowmelt peak flow), but the low predictive ability of existing equations makes it difficult to quantify the exact magnitude and duration of flow necessary to adequately flush stored fines from a channel.

In other words, step-pool channels are physically resistant and resilient to decreased flows, but there is a limit to this resistance and resilience, and the limit cannot be readily predicted. Likely of more importance in the context of flow reduction are the potential biological effects of changes in channel morphology. As portions of the channel that preferentially accumulate sediment during lower flows[5,11], pools in a channel with reduced flow can lose residual pool volume. Residual pool volume refers to the volume of water in the pool if flow in the channel ceased. Think of a pool as a bowl sunk to its rim in the streambed, with water normally flowing by above the rim of the bowl. If flow ceased, the pool would only contain the volume of water held by the bowl up to the rim. Residual pool volume can govern fish survival during conditions of very low flow, such as dry summers or the coldest portion of the winter. Pools with insufficient residual volume can have warm water low in dissolved oxygen that limits fish survival during summer, or they can go completely dry. During winter, small pools can freeze to the bottom and limit fish survival. Reduced flow can limit the ability of stream organisms to move between habitat patches, essentially creating longitudinally disconnected patches that limit organism dispersal and survival[7].

Finally, reduced flow can change stream food webs. Organisms in forested step-pool channels rely on dead plant material falling into the channel from overhanging riparian trees. Microbes and stream insects ingest this plant material and in turn become food for other insects, fish, stream birds such as ouzels, and spiders, bats, and birds that feed on insects emerging from the stream. Reduced flow levels can limit the habitat abundance and quality for the organisms that first ingest plant material, as well as the duration of time the organisms are active. This in turn can reduce food supplies for fish and riparian predators such as spiders and birds.

Summary

One of the most influential papers in river science describes the importance of the natural flow regime for maintaining river processes and morphology[14]. The natural flow regime – described in terms of the magnitude, frequency, duration, timing (seasonality), and rate of change of flow present in a channel with no dams or diversions – is critical to stream organisms because it maintains the habitat, food sources, and thermal and chemical cues on which their lifecycles are built. The natural flow and sediment regimes[25] are critical to channel morphology because they maintain the geometry and grain-size distribution of a channel, to which stream organisms are adapted. A few studies document changes in step-pool channel configuration and the species composition or abundance of stream organisms following changes in flow regime[2,12,15]. These changes are relatively straightforward to characterize once they have occurred, but very difficult to quantitatively predict ahead of time.

To recap the key points in this report: Stream channels steeper than about 2% typically have sequential vertical down-steps composed of boulders, bedrock, or large wood, separated by plunge pools. Together, these step-pool sequences create a staircase-like longitudinal profile in steep streams. Existing hydraulic and sediment equations do not adequately describe flow and sediment movement in step-pool channels. We cannot accurately predict basic parameters such as velocity and sediment movement in step-pool channels and we cannot predict how channel configuration will change except in broad terms. Sediment transport equations routinely over-predict sediment transport in step-pool channels by more than 1-2 orders of magnitude, or by more than a factor of 10 to 100 times. Consequently, we do not have equations that allow us to predict exactly how a step-pool channel will respond to increases or decreases in the supply of water or sediment. Existing studies suggest that periodic high flows are needed to keep removing finer sediment that continually enters step-pool channels from hillslopes, floodplains, and channel banks. Both the magnitude and duration of high flows are important with respect to sediment transport and channel morphology. Mobilization and destruction of steps and pools occurs only during the highest discharges in a channel. The substantial variations in grain size, bed gradient, flow depth, and velocity within step-pool channels create diverse habitat for stream organisms, and both base and peak flows fulfill important functions in maintaining habitat. Reductions in flow can allow smaller sizes of sediment to accumulate on the stream bed; reduce the volume of pools; reduce the ability of aquatic insects and fish to move along the channel; and change stream food webs.

References

1. Adenlof, K.A. & E.E. Wohl. 1994. Controls on bedload movement in a subalpine stream of the Colorado Rocky Mountains, USA. *Arctic and Alpine Research* 26: 77-85.
2. Baker, D.W., B.P. Bledsoe, C.M. Albano, & N.L. Poff. 2011. Downstream effects of diversion dams on sediment and hydraulic conditions of Rocky Mountain streams. *River Research and Applications* 27: 388-401.

3. Chin, A. & E. Wohl. 2005. Toward a theory for step pools in stream channels. *Progress in Physical Geography* 29: 275-296.
4. Comiti, F., D. Cadol & E. Wohl. 2009. Flow regimes, bed morphology, and flow resistance in self-formed step-pool channels. *Water Resources Research* 45: W04424. DOI: 10.1029/2008WR007259.
5. David, G.C.L., B.P. Bledsoe, D.M. Merritt & E. Wohl. 2009. The impacts of ski slope development on stream channel morphology in the White River National Forest, Colorado, USA. *Geomorphology* 103: 375-388.
6. Diplas, P., C.L. Dancey, A.O. Celik, M. Valyrakis, K. Greer & T. Akar. 2008. The role of impulse on the initiation of particle movement under turbulent flow conditions. *Science* 322: 717-720.
7. Falke, J.A., K.R. Bestgen, & K.D. Fausch. 2010. Streamflow reductions and habitat drying affect growth, survival, and recruitment of brassy minnow across a Great Plains riverscape. *Transactions of the American Fisheries Society* 139: 1566-1583.
8. Lenzi, M.A. 2001. Step-pool evolution in the Rio Cordon, northeastern Italy. *Earth Surface Processes and Landforms* 26: 991-1008.
9. Lenzi, M.A. 2004. Displacement and transport of marked pebbles, cobbles and boulders during floods in a steep mountain stream. *Hydrological Processes* 18: 1899-1914.
10. Lenzi, M.A., V. D'Agostino, & P. Billi. 1999. Bedload transport in the instrumented catchment of the Rio Cordon. Part I. Analysis of bedload records, conditions and threshold of bedload entrainment. *Catena* 36: 171-190.
11. Madsen, S.W. 1995. *Channel Response Associated with Predicted Water and Sediment Yield Increases in Northwestern Montana*. Unpublished MS thesis, Colorado State University, Fort Collins, 230 pp.
12. McCarthy, J.M. 2008. *Factors Influencing Ecological Recovery Downstream of Diversion Dams in Southern Rocky Mountain Streams*. Unpublished MS thesis, Colorado State University, Fort Collins, 114 pp.
13. Montgomery, D.R. & J.M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. *Geological Society of America Bulletin* 109: 596-611.
14. Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, & J.C. Stromberg. 1997. The natural flow regime. *BioScience* 47: 769-784.
15. Rader, R.B. & T.A. Belish. 1999. Influence of mild to severe flow alterations on invertebrates in three mountain streams. *River Research and Applications* 15: 353-363.
16. Ryan, S.E. 1997. Morphologic response of subalpine streams to transbasin flow diversion. *Journal of the American Water Resources Association* 33: 839-854.
17. Ryan, S.E., E.L. Bishop & J.M. Daniels. 2014. Influence of large wood on channel morphology and sediment storage in headwater mountain streams, Fraser Experimental Forest, Colorado. *Geomorphology* 217: 73-88.
18. Ryan, S.E., L.S. Porth & C.A. Troendle. 2005. Coarse sediment transport in mountain streams in Colorado and Wyoming, USA. *Earth Surface Processes and Landforms* 30: 269-288.

19. Sawada, T., K. Ashida & T. Takahashi. 1983. Relationship between channel pattern and sediment transport in a steep gravel bed river. *Zeitschrift fur Geomorphologie* 46: 55-66.
20. Schmidt, K.-H. & P. Ergenzinger. 1992. Bedload entrainment, travel lengths, step lengths, rest periods – studied with passive (iron, magnetic) and active (radio) tracer techniques. *Earth Surface Processes and Landforms* 17: 147-165.
21. Scott, D.N., D.R. Montgomery, & E.E. Wohl. 2014. Log step and clast interactions in mountain streams in the central Cascade Range of Washington State, USA. *Geomorphology* 216: 180-186.
22. Wilcox, A.C., E.E. Wohl, F. Comiti, & L. Mao. 2011. Hydraulics, morphology, and energy dissipation in an alpine step-pool channel. *Water Resources Research* 47: W07514, doi:10.1029/2010WR010192.
23. Wohl, E. 2010. *Mountain Rivers Revisited*. American Geophysical Union Press, Washington, DC, 573 pp.
24. Wohl, E. 2014. *Rivers in the Landscape: Science and Management*. Wiley Blackwell, Chichester, UK, 318 pp.
25. Wohl, E., B.P. Bledsoe, R.B. Jacobson, N.L. Poff, S.L. Rathburn, D.M. Walters & A.C. Wilcox. 2015. The natural sediment regime in rivers: broadening the foundation for ecosystem management. *BioScience* 65: 358-371.
26. Wohl, E. & D. Dust. 2012. Geomorphic response of a headwater channel to augmented flow. *Geomorphology* 138: 329-338.
27. Wohl, E. & D.N. Scott. 2017. Wood and sediment storage and dynamics in river corridors. *Earth Surface Processes and Landforms* 42: 5-23.
28. Yager, E.M., W.E. Dietrich, J.W. Kirchner, & B.W. McArdell. 2012. Prediction of sediment transport in step-pool channels. *Water Resources Research* 48: 10.1029/2011WR010829.
29. Zimmermann, A. & M. Church. 2001. Channel morphology, gradient profiles and bed stresses during flood in a step-pool channel. *Geomorphology* 40: 311-327.
30. Zimmermann, A., M. Church, & M.A. Hassan. 2010. Step-pool stability: testing the jammed state hypothesis. *Journal of Geophysical Research* 115: F02008, doi:10.1029/2009JF001365.

Glossary

channel or bed gradient: the average downstream slope of the channel, typically measured at either the channel bed or the water surface, and expressed in % or vertical foot per horizontal foot (e.g., 2% or 0.02 ft/ft)

coarse sediment: large grain sizes

external or boundary resistance: frictional resistance to the movement of water as the water passes along the channel boundaries

fine sediment: smaller grain sizes

internal resistance: frictional resistance to the movement of water associated with overcoming viscous shear and turbulence within the flow

one-dimensional flow: focuses solely on the downstream component of flow in a channel; flow actually has 3 components (cross-stream, vertical, and downstream)

rough boundary: a channel with large external frictional resistance

shear stress: the force exerted against the channel boundaries, including sediment particles, by flowing water; typically calculated as the product of the specific weight of the water, the depth of flow, and the channel gradient

steady flow: velocity is constant with time (in contrast, velocity varies with time where unsteady flow is present)

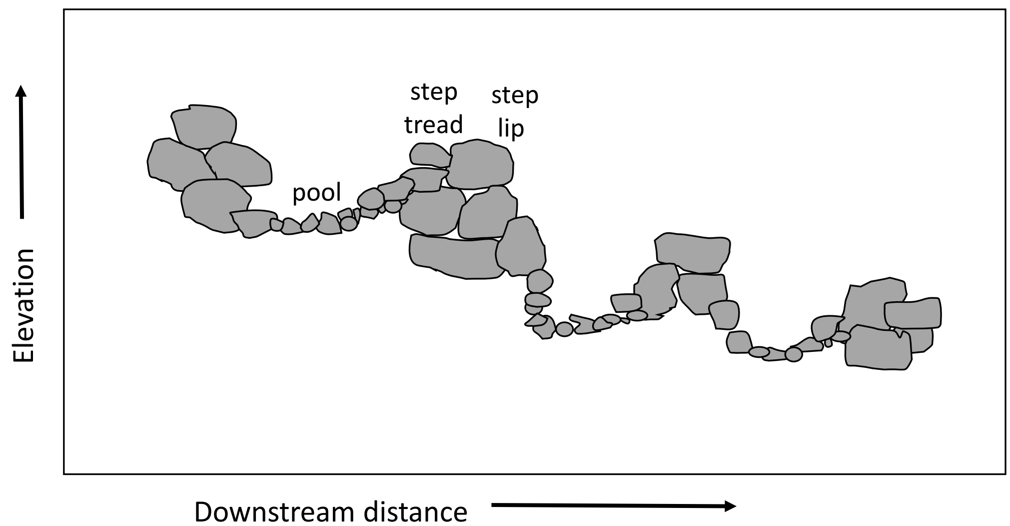
three-dimensional flow: all flow is three-dimensional, but referring to highly three-dimensional flow indicates that the cross-stream and vertical components of velocity are significant relative to the downstream component

turbulent flow: fluid elements follow irregular paths and mixing occurs; the presence of turbulent flow can be mathematically described as occurring when the Reynolds number exceeds 2500 – the Reynolds number is the ratio of the product of velocity, flow depth, and water density to the dynamic viscosity of the water

uniform flow: velocity is constant with position (in contrast, velocity varies with position in varied flow)

Figures

1. Schematic longitudinal view of steps and pools.

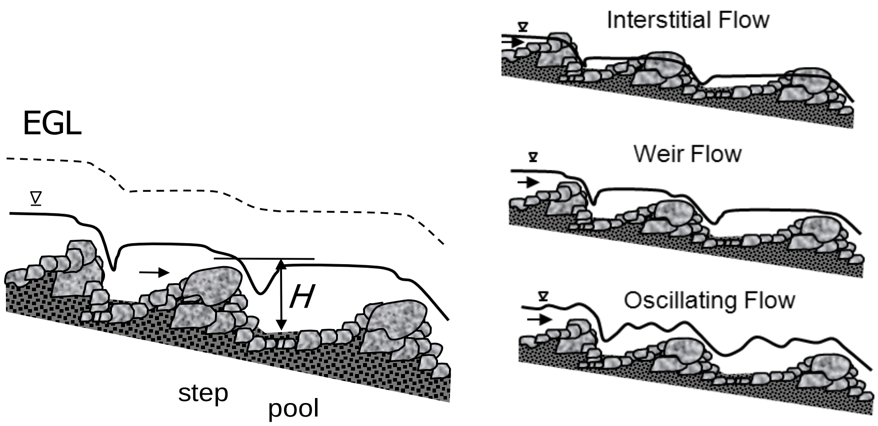


2. A log-formed step (A) on which most flow passes over the step lip formed by the log and a clast-formed step (B) that includes substantial interstitial flow at lower discharges.

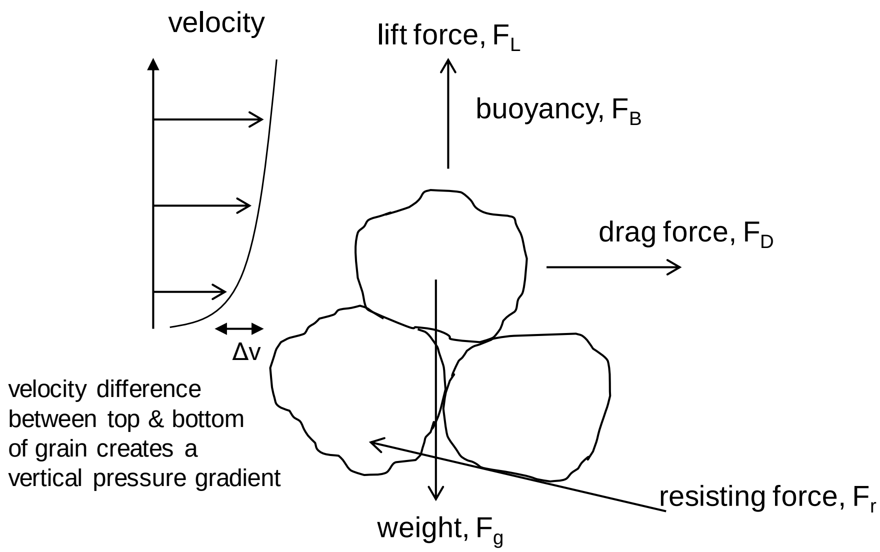
A

B

3. Longitudinal (side) view of the components and hydraulics associated with step-pool bedforms. *H* is bedform amplitude: here, the step height. Solid line above the bed indicates the water surface. The dashed line or EGL is the energy grade line, which is a theoretical representation of the rate at which energy is expended as water flows downstream in the channel. Interstitial, weir and oscillating flow represent flow regimes under progressively increasing discharge. Flow is from left to right.



4. Schematic illustration of the forces acting on a noncohesive grain under steady uniform flow on a nearly horizontal surface. The velocity difference between the top and bottom of a grain creates a vertical pressure gradient that results in lift force.



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Himes Creek Cutthroat Trout

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Background

Cutthroat Trout (*Oncorhynchus clarkii*) are the most wide spread trout species in western North America and are the only trout native to Colorado. The varied aquatic and geomorphic conditions under which this species has evolved has led to great diversity in the habitats and ecological communities in which they occur. Along the Pacific coast this species was found in sympatry with as many as five salmonid species while throughout much of their inland distribution Cutthroat Trout were often the only native salmonid species present. As these fish occupy a number of major basins throughout the west it has long been recognized that there is great diversity within this species.

For the last half century the classification of Cutthroat Trout has been guided by the work done by Colorado State University's Robert Behnke (1979). Currently there are 14 recognized subspecies. With the advent of improved genetic tools, however, this historic classification system is being reappraised in a manner that suggests greater diversity persists within Cutthroat Trout. One of the populations of fish receiving additional attention are those that occupy Himes Creek. Questions still remain on the exact relationships among populations of Cutthroat Trout within the 293,900 square kilometer upper Colorado River Basin (O. c. pleuriticus; Hirsch et al. 2006; Metcalf et al. 2012). The Colorado River Basin falls within portions of five states to include Colorado, Utah, Wyoming, Arizona and New Mexico. Within this basin there are 361 Colorado River Cutthroat Trout conservation populations that occupy 3,403 km of stream habitat; this is only 11% of the estimated historic range (Hirsch et al. 2013). One of the conservation populations occurs within Himes Creek. The fish within Himes Creek are one of the six streams known to have genetic markers indicative of the native San Juan lineage of Colorado River Cutthroat Trout (Metcalf et al. 2012). This lineage is a unit of diversity worthy of additional protection (Funk et al. 2012, Rogers et al. 2014).

Cutthroat Trout of the inland west exhibit several adaptive movement strategies including staying in the stream reach where they hatched (resident), moving from smaller streams where they were born to larger streams where they feed (fluvial), and spawning in streams but rearing in lakes (adfluvial). The distribution of these fish has contracted as many fluvial and adfluvial populations have been lost. The loss of these fish at lower elevations and in bigger streams has been driven by streamflow modification (e.g. diversions and dams), habitat degradation and/or hybridization with Rainbow Trout (*O. mykiss*). In high elevation, smaller streams these fish are at risk as they are often outcompeted by Brook Trout (*Salvelinus fontinalis;* Roberts et al. 2017). In all areas these fish are susceptible to the negative effects of whirling disease (Arye et al. 2014) These stressors in combination will continue to put many populations of Cutthroat Trout at risk throughout their range.

Some populations of resident Cutthroat Trout are at higher risk because they occupy short sections of headwater streams. The length of Himes Creek occupied by Cutthroat Trout is limited to less than two miles which means the numbers of individuals that can mature in this river are small (demographic stochasticity) and/or a single ecological challenge such as fire or drought (environmental stochasticity) could eliminate the population (Hilderbrand and Kershner 2000). These site specific risks are heightened because many high elevation small streams face synchronous threats of increasing water temperatures due to a changing climate (Isaak et al. 2015). Furthermore increasing stream temperatures could increase the likelihood of negative interaction with Brook Trout. Colorado River Cutthroat Trout and Brook Trout have been shown to be equal competitors at 10°C (50°F) but Brook Trout dominate when water temperatures are 20°C (68°F; De Staso and Rahel 1994). The result is young-of-the-year Cutthroat Trout at elevations between 8200 to 8900 feet have 13 times greater survival when allopatric rather than sympatric with Brook trout (Peterson et al. 2004). As water temperature warm to exceed 11°C the probability of hybridization with Rainbow Trout increases dramatically as these fish have higher metabolic requirements. (Gunnell et al. 2008, Rasumssen et al. 2012). Given the proximity of thermal boundaries between Cutthroat Trout and these two introduced species, current distributions of Cutthroat Trout are likely defined by the cold water temperatures within the occupied watersheds (Peterson et al. 2004) or by the presence of barriers that prevent upstream movement of Brook and Rainbow Trout.

Colorado River Cutthroat Trout and related lineages of this species in the Colorado River Basin will continue to occupy small to medium sized rivers in relatively steep regions of the Basin. In these rivers Cutthroat Trout favor pool habitat over riffles (Young 1996, Young 2008). Their choice of pool habitat is because these areas provide the greatest potential for growth as fish feed on macroinvertebrates dislodged from upstream riffles (Rosenfeld and Boss 2001, Gowan and Fausch 2002). In mid-winter deep pools in small streams provide areas for fish to minimize energy expenditure and may be slightly warmer than surrounding habitats because of groundwater inputs (Chisholm et al. 1987, Brown et al. 1994, Jakober et al. 1998, Lindstrom and Hubert 2004). Pool habitats provide fish security from predators and are the most stable habitat type under varying ice conditions, such as when frazil and anchor ice form (Brown et al. 2011). In winter, reduced pool area occupied by ice can reduce survival of trout using these habitats. Given Himes Creek is a step pool morphology rather than the classic pool riffle or forced pool morphology found in many other small streams occupied by Cutthroat Trout, pools are even more important. The absence of pool habitat in this small high gradient stream would almost certainly eliminate the presence of Cutthroat Trout as both summer and winter survival of these fish would decline.

A step–pool stream reach morphology is one where stream velocities, turbulence, and habitat types reoccur in an alternating manner (Montgomery & Buffington, 1997, Wohl 2018). Step–pool stream reaches are generally found in high-gradient (>3%) valley's where pools alternate with shallow high velocities riffles, often referred to as steps. These steps are seldom occupied by fish. The presence of large boulders and wood in such streams provide resistance that dissipates stream energy which would otherwise quickly erode and degrade a stream channels ability to provide trout habitat.

For this stream type to be maintained is it necessary for high spring flows to occur and flush sediment out of the pools and sort the material in the pool tail-outs. These flushing flows result in deeper water with large cobble material remaining in areas with the highest flow velocities and patches of finer material at the back and edges of pools. Without flushing flows, pool habitat would become shallower as they filled with substrate. To achieve flows capable of scouring pocket pools in steeper mountainous systems, is necessary to have discharges that greatly exceed baseflow. While the R2Cross (Tennant 1976, Nehring 1979) is primarily used to determine summer time instream flows necessary for fish, this paper (Tennant 1976) does recognize that high flows are needed to maintain habitats in some stream types. Without flushing flows it is likely pool habitats would become shallower and that more fine material would be found in spawning locations. Both outcomes would reduce survival of Cutthroat Trout especially in times of drought and high ice coverage.

The hydraulic conditions and physical habitat formed in step-pool stream reaches affect the biological communities found in these stream types. The high turbulence and velocities of the water found in these stream types alter the macroinvertebrates communities and the outcomes of species interactions. Macroinvertebrates found in step pools are more stream-lined and have adapted methods to maintain attachment to the stream bottom (O'Dowd and Chin 2016). Similarly fish that occupy these types of stream reaches must have a hydrodynamic shape (torpedo like).

Step-pool stream types are generally seen as migratory corridors for trout rather than as primary habitat for resident species (Walter et al. 2016). Cutthroat trout in Himes Creek are unlike many other trout taxa as these fish must carry out their entire life cycle in an environment that is harsh and precludes large scale movement. Many other populations of Cutthroat Trout can maximize growth and survival by moving among different geomorphic and hydraulic units depending upon the season. Himes Creek Cutthroat Trout must be able to live, grow, and reproduce in a series of small turbulent pools.

Given sufficient pool habitat and forage exist within Himes Creek to sustain a Cutthroat Trout population, it becomes important to understand the role water temperatures have in allowing Cutthroat Trout to spawn and carry out their life cycle. Three measures of temperature are helpful in understanding thermal conditions necessary to sustain Cutthroat Trout populations; summer maximum temperatures, winter minimum temperature, and the cumulative thermal units during spring and summer. Based on stream temperature data collected in Himes Creek during 2012, temperatures are suitable for Cutthroat Trout growth (Hickman an Raleigh 1982) from mid-May until October (Figure 1). During the summer there were over 70 days that had a daily mean temperatures between 12 and 15 – optimal for summer growth for these fish (Bell 1973, Dwyer and Kramer 1975) but not so high as to benefit either Rainbow Trout or Brook Trout. At no time during the summer did temperatures approach thermal maximum for Cutthroat Trout (≈ 22°C (72°F)). One concern with stream temperatures within this creek is that if summer maximum temperatures increased by several degrees this would increase the likelihood that Cutthroat Trout could be out competed by Brook Trout.

A second measure of thermal quality is the amount of warmth it takes for eggs to develop. This stream temperature metric is usually measured in degree days. In general it takes approximately 570-600 degree-days for a Cutthroat Trout egg to develop into a small fish (Coleman and Fausch 2007a). While this seems like a complex concept, degree days (DD) is simply a measure of the warmth of the water after the initiation of spawning activities in the spring, which occurs for these fish as water temperatures exceed 5° C. Total degree days is determined by summing up the thermal units on days when temperatures are exceed 5° C using the following equation;

$$DD = \sum_{t=1}^{n} (D_t > 5) - 5$$

where D_t is the mean daily temperature on days that exceed 5°, t are the days over 5° from the beginning (t=1) to the last day (t=n). Based on a temperature device placed in Himes Creek in 2012 there were 809 degrees days, more than warm enough for eggs to develop. The stream temperature observed in Himes Creek would allow for the devolvement of juvenile Cutthroat Trout by late August to early October (Young 1995, Coleman and Fausch 2007b).

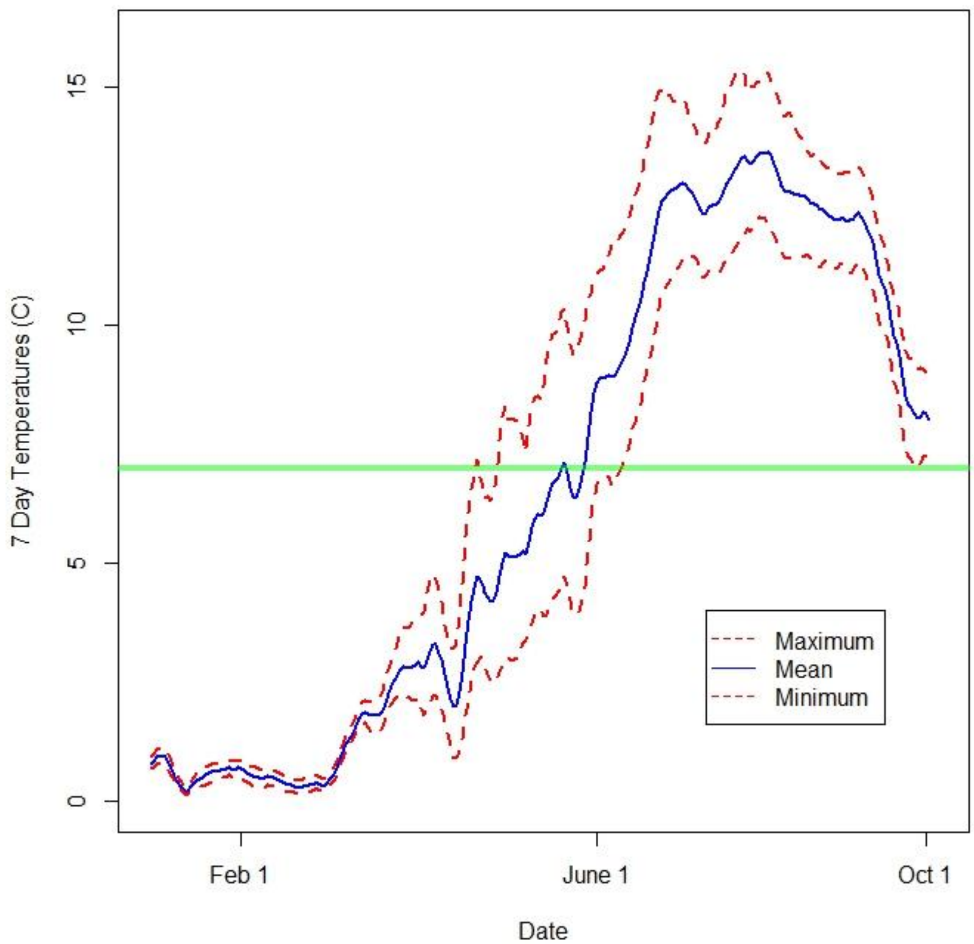

Figure 1. Stream temperatures measured within Himes Creek during 2012. The red and blue line represent the seven day moving average for the maximum, mean, and minimum stream temperatures. All recorded temperature that are above the green lines are good for the growth of Cutthroat Trout.

Based on 36 temperature devices randomly placed in Colorado River Cutthroat Trout conservation populations in 2011/2012, the metrics for stream temperature in Himes Creek were near the middle of the values recorded (Olsen 2013). Many other conservation populations of Colorado River Cutthroat Trout had stream temperatures that were too warm or too cold to consistently foster fish growth. Himes Creek seemed to meet the Goldilocks criteria of being neither too hot nor too cold for Cutthroat Trout. Another important thermal finding was stream temperatures were consistently above 1 degree during the winter. This pattern suggest that either a snow bridge was formed over the stream channel or groundwater inputs were keeping frazil ice from forming.

Conclusions

Cutthroat Trout in Himes Creek provide an important legacy component of the Cutthroat Trout genome. This fish lives in a tenuous environment that is prone to be negatively affected by demographic and environmental perturbations. Given these challenges these fish have been sustained in and around this watershed for hundreds if not thousands of years. The Cutthroat Trout in this creek have shown an ability to be a sustainable population even though they are subject to high stream flows and minimal connection with larger rivers downstream. The uniqueness of this population and its setting provides strong support for maintaining the physical and ecosystem processes in as near a natural condition as possible so as to maximize the chance that this population of Cutthroat Trout will be maintained into the future.

References

Ayre, K.K., C.A. Caldwell, J. Stinson, and W.G. Landis. 2014. Analysis of regional scale risk of whirling disease in populations of Colorado and Rio Grande cutthroat trout using a Bayesian belief network model. Risk Analysis 34:1589-1605.

Behnke, R. J. 1979. Monograph of the native trouts of the genus Salmo of western North America. Rep. prepared for U.S. Fish and Wildlife Service, Region 6, Denver, Colo. 215 pp.

Bell, M. C. 1973. Fisheries handbook of engineering requirements and biological criteria. U.S. Army Corps Eng., North Pacific Div., Contract DACW57-68-C-0086. 92 pp.

Brown, R. S., S.S. Stanislawski, and W.C. Mackay. 1994. Effects of frazil ice on fish. In Workshop on environmental aspects of river ice. Environment Canada, National Hydrology Research Institute, Symposium (Vol. 12, pp. 261-277).

Brown, R. S., W.A. Hubert, and S.F. Daly. 2011. A primer on winter, ice, and fish: what fisheries biologists should know about winter ice processes and stream-dwelling fish. Fisheries, 36(1): 8-26.

Chisholm, I.M., W.A. Hubert, and T. A. Wesche. 1987. Winter stream conditions and use of habitat by brook trout in high-elevation Wyoming streams. Transactions of the American Fisheries Society 116: 176-184.

Coleman, M.A. and K.D. Fausch. 2007a. Cold Summer Temperature Limits Recruitment of Age-0 Cutthroat Trout in High-Elevation Colorado Streams. Transactions of the American Fisheries Society, 136:1231-1244.

Coleman, M.A. and Fausch, K.D., 2007b. Cold summer temperature regimes cause a recruitment bottleneck in age-0 Colorado River cutthroat trout reared in laboratory streams. Transactions of the American Fisheries Society, 136:639-654.

De Staso III, J., and F.J. Rahel. 1994. Influence of water temperature on interactions between juvenile Colorado River cutthroat trout and brook trout in a laboratory stream. Transactions of the American Fisheries Society 123: 289-297.

Dwyer, P. D., and R. H. Kramer. 1975. The influence of temperature on scope for activity in cutthroat trout, Salmo clarki. Trans. Am. Fish. Soc. 104:552-554.

Funk, W. C., J. K. McKay, P. A. Hohenlohe, and F. W. Allendorf. 2012. Harnessing genomics for delineating conservation units. Trends in Ecology and Evolution 27:489-496.

Gowan, C. and K.D. Fausch, 2002. Why do foraging stream salmonids move during summer? In *Ecology, behaviour and conservation of the charrs, genus Salvelinus* (pp. 139-153). Springer, Dordrecht.

Gunnell, K., M.K. Tada, F.A. Hawthorne, E.R. Keeley, and M.B. Ptacek. 2008. Geographic patterns of introgressive hybridization between native Yellowstone cutthroat trout (Oncorhynchus clarkii bouvieri) and introduced rainbow trout (O. mykiss) in the South Fork of the Snake River watershed, Idaho. Conservation Genetics, 9:49-64.

Hickman, T., and R. F. Raleigh. 1982. Habitat suitability index models: Cutthroat trout. U.S.D.I. Fish and Wildlife Service. FWS/OBS-82/10.5. 38 pp

Hilderbrand, R.H. and J.L. Kershner. 2000. Movement patterns of stream-resident Cutthroat Trout in Beaver Creek, Idaho–Utah. Transactions of the American Fisheries Society, 129:1160-1170.

Hirsch, C. L., S. L. Albeke, and T. P. Nesler. 2006. Range-wide status of Colorado River cutthroat trout (*Oncorhynchus clarkii pleuriticus*): 2005. Colorado River Cutthroat Trout Conservation Team Report, Colorado Division of Wildlife, Fort Collins, Colorado.

Hirsch, C. L., M. R. Dare, and S. E. Albeke. 2013. Range-wide status of Colorado River cutthroat trout (Oncorhynchus clarkii pleuriticus): 2010. Colorado River Cutthroat Trout Conservation Team Report. Colorado Parks and Wildlife, Fort Collins. Available: http://cpw.state.co.us/ Documents/Research/Aquatic/CutthroatTrout/ CRCTRangewideAssessment-08.04.2013.pdf

Jakober, M. J., T. E. McMahon, R. F. Thurow, and C.G. Clancy. 1998. Role of stream ice on fall and winter movements and habitat use by bull trout and cutthroat trout in Montana headwater streams." Transactions of the American Fisheries Society 127: 223-235.

Lindstrom, J.W. and W.A. Hubert. 2004. Ice processes affect habitat use and movements of adult cutthroat trout and brook trout in a Wyoming foothills stream. North American Journal of Fisheries Management, 24:1341-1352.

Metcalf, J. L., V. L. Pritchard, S. M. Silvestri, J. B. Jenkins, J. S. Wood, D. E. Cowley, R. P. Evans, D. K. Shiozawa, and A. P. Martin. 2007. Across the great divide: genetic forensics reveals misidentification of endangered cutthroat trout populations. Molecular Ecology 16:4445-4454.

Metcalf, J. L., S. L. Stowell, C. M. Kennedy, K. B. Rogers, D. McDonald, J. Epp, K. Keepers, A. Cooper, J. J. Austin, and A. P. Martin. 2012. Historical stocking data and 19th century DNA reveal human-induced changes to native diversity and distribution of cutthroat trout. Molecular Ecology 21:5194-5207.

Montgomery, D.R. and J.M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin, 109:596-611.

Nehring, R.B., 1979. Evaluation of instream flow methods and determination of water quantity needs for streams in the state of Colorado. Colorado Division of Wildlife.

O'Dowd, A.P. and A. Chin. 2016. Do bio-physical attributes of steps and pools differ in high-gradient mountain streams? Hydrobiologia, 776:67-83.

Olsen, K. 2013. Colorado River cutthroat habitat resistance and resilience to climate change. Utah State University Theses and Dissertations. 1965. https://digitalcommons.usu.edu/etd/1965

Peterson, D.P., K.D. Fausch, and G.C. White. 2004. Population ecology of an invasion: effects of brook trout on native cutthroat trout. Ecological Applications, 14:754-772.

Rasmussen, J. B., Robinson, M. D., Hontela, A., & Heath, D. D. 2012. Metabolic traits of westslope cutthroat trout, introduced rainbow trout and their hybrids in an ecotonal hybrid zone along an elevation gradient. Biological Journal of the Linnean Society, 105, 56–72.

Roberts, J.J., K. D. Fausch, M.B. Hooten, and D. P. Peterson. 2017. Nonnative trout invasions combined with climate change threaten persistence of isolated cutthroat trout populations in the southern Rocky Mountains. North American Journal of Fisheries Management 37:314-325.

Rogers, K. B., K. R. Bestgen, and J. Epp. 2014. Using genetic diversity to inform conservation efforts for native Cutthroat Trout of the southern Rocky Mountains. Pages 218-228 in R. F. Carline and C. LoSapio, editors. Wild Trout XI: Looking back and moving forward. Wild Trout Symposium, West Yellowstone, Montana. Available online at http://www.wildtroutsymposium.com/proceedings.php.

Rosenfeld, J.S. and S. Boss. 2001. Fitness consequences of habitat use for juvenile cutthroat trout: energetic costs and benefits in pools and riffles. Canadian Journal of Fisheries and Aquatic Sciences, 58:585-593.

Tennant, D.L. 1976. Instream flow regimens for fish, wildlife, recreation and related environmental resources. Fisheries 1: 6-10.

Young, M.K., 1996. Summer movements and habitat use by Colorado River cutthroat trout (Oncorhynchus clarki pleuriticus) in small, montane streams. Canadian Journal of Fisheries and Aquatic Sciences, 53:1403-1408.

Young, M.K. 2008. **Colorado River cutthroat trout: a technical conservation assessment.** General Technical Report. RMRS-GTR-207-WWW. Fort Collins, CO: USDA Forest Service, Rocky Mountain Station. 123 p. Available: http://www.fs.fed.us/rm/pubs/rmrs_GTR-207-WWW.pdf [March 2008].

Wohl, E. 2018. White Paper on Himes Creek and Flow Diversions.

Wolter, C., A.D. Buijse, and P. Parasiewicz. 2016. Temporal and spatial patterns of fish response to hydromorphological processes. River Research and Applications, *32:*190-201.

Attachment F

Literature Review on the Importance of a Natural Flow Regime to Aquatic Ecology in Rivers and Streams

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March 1, 2019

INTRODUCTION

The purpose of this paper is to explore the scientific literature for support of the notion that there are instances where the protection of the natural flow regime in rivers and streams is necessary and appropriate. The natural flow regime, as a concept, includes the full range of flows both seasonally and annually in frequency and duration. Typical instream flow protection strategies do not go to this extent in that they typically provide flows needed to maintain the biologic riverine components while counting on the natural variability of stream systems that occur. There are circumstances where water, land and river managers need to be more proactive in their flow protection actions; instances where the natural environment is so special or unique that they require preservation of the entire flow regime to maintain these unique characteristics. Examples of this situation may include threatened or endangered species conservation, protection of wild and scenic rivers, protection of outstanding water quality characteristics, streams in wilderness areas or national parks/monuments, or streams where the entire riparian corridor (not just fish or aquatic macroinvertebrates) is the biologic community that the managers are seeking to protect.

This paper documents a review of scientific literature that spans nearly five decades of international work by aquatic ecologists, geomorphologists, fishery managers, water resource managers, and instream flow experts. I intend to start with some of the classic work in aquatic ecology, H. B. N. Hynes' *The Ecology of Running Waters* (1970) and end with contemporary instream flow and environmental flow protection standards such as the Instream Flow Council's book *Instream Flows for Riverine Resource Stewardship* (2002), N. LeRoy Poff *et al*'s 1997 Natural flow Regime paper, and Angela Arthington's book *Environmental Flows: Saving Rivers in the Third Millenium* (2012). This review will also include examination of several other references to provide information to support the above contention that there are valid ecological reasons that the full range of flows should, in certain isolated circumstances, be protected in streams and rivers that may have unique biological characteristics.

General Aquatic Ecology

Nearly all aquatic ecology text books have sections or diagrams that discuss and/or illustrate the connection between the flowing river or stream component and the adjacent land components. The consistent point of these writings and diagrams is that energy and nutrients flow from the terrestrial environment to the aquatic environment and, in the case of many aquatic macroinvertebrates, there is a terrestrial component to their reproductive strategies and life cycles. In general, the key ecological concept is that energy from the sun is converted by terrestrial and aquatic plants to energy utilized down the food chain by microorganisms, aquatic insects and other macroinvertebrates, fish, etc. Hynes (1970), Barnes and Mann (1980), and Allen (1995), and Windell (1992) (below) all have similar diagrams, flow charts and illustrations showing these interrelationships between the aquatic and adjacent terrestrial environment (See Below). It is also important to understand that the interactions between the terrestrial environment and the aquatic environment occurs at many different places in time and space within the stream ecosystem – it is not just primary production (sun energy to plants) but the importance of leaf litter habitats, the use of overhanging vegetation by adult life stages of aquatic insects to complete reproductive cycles, the importance of vegetative shade to regulate water temperatures, and the manner by which fish use terrestrial vegetation for habitat and cover (overhead cover, undercut banks and root wads).

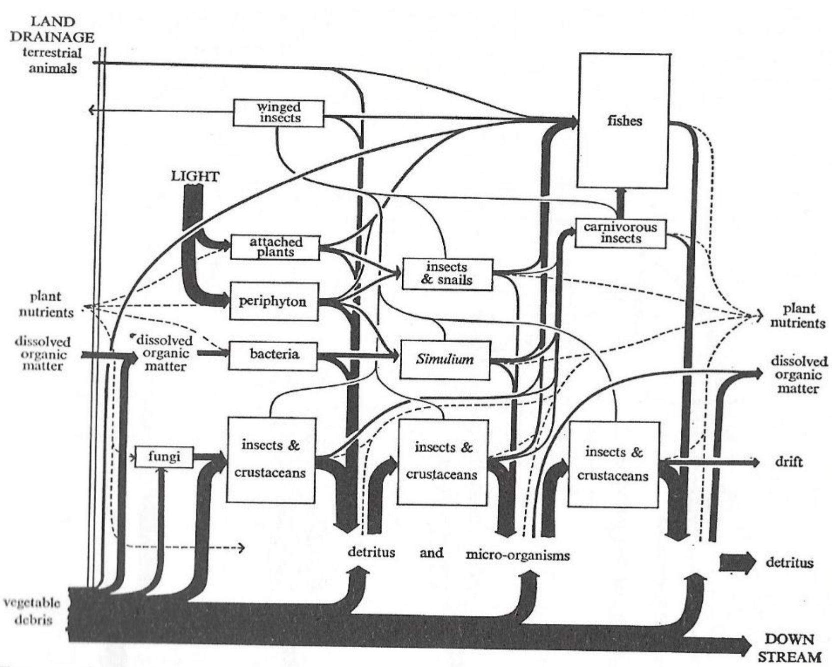

FIG. XXII, 1. A diagrammatic representation of the trophic relationships of the ecosystem in the rhithron. The relative sizes of the boxes are an indication of the biomass and the width of the arrows is proportional to the supposed relative importance of the energy pathways. Dotted lines represent salts in solution.

(From Hynes, H. B. N., *Ecology of Running Waters*, 1970)

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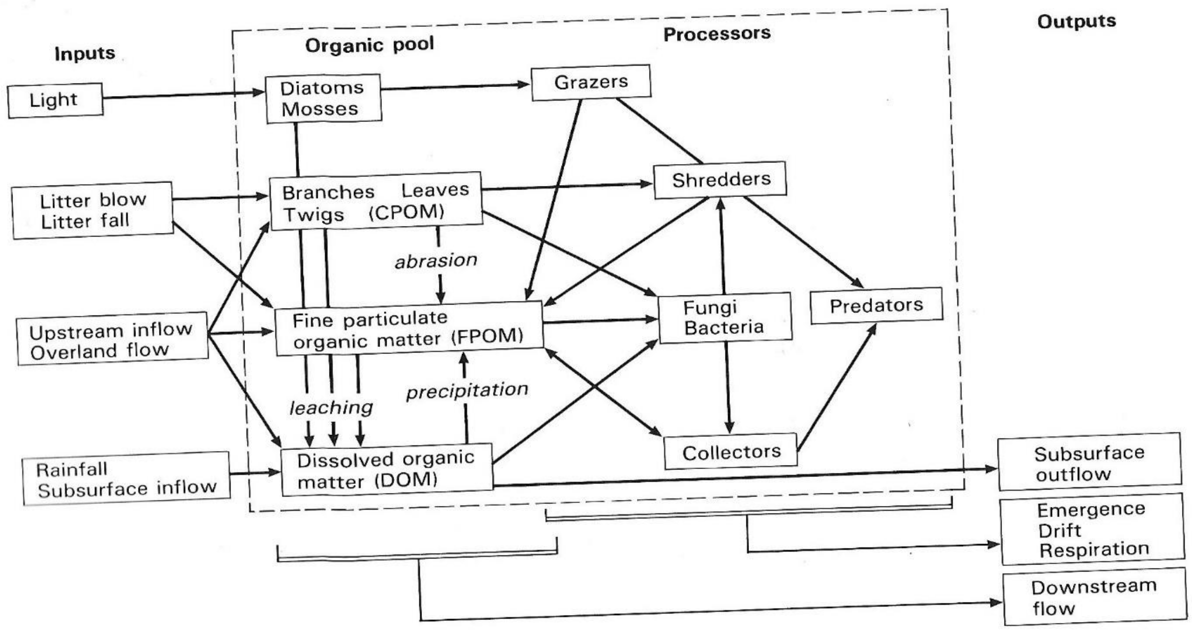
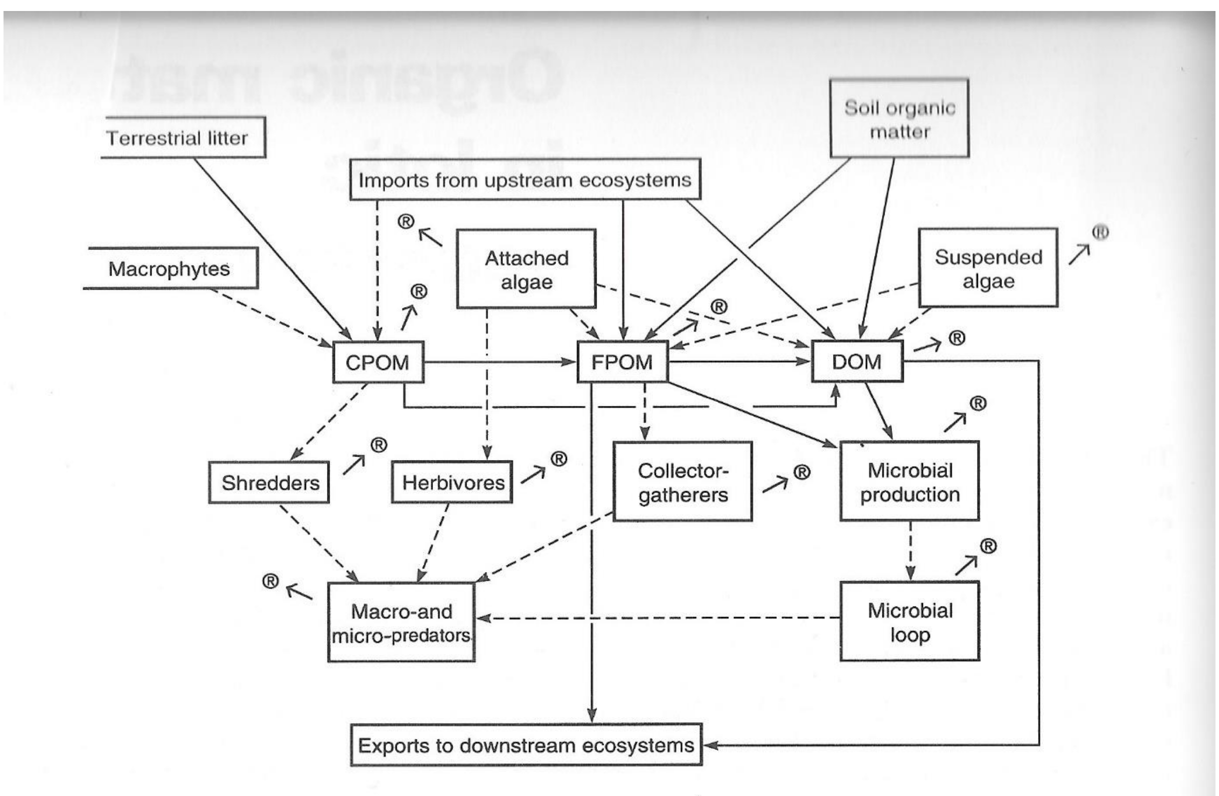


Fig. 12.1 Simplified model of a forest-stream ecosystem showing the principal biological components, energy sources and material pathways. The relative importance of the pathways will differ from stream to stream.

(From Barnes, R. S. K. and Mann, KH., *Fundamentals of Aquatic Ecology*, 1980)



(From Allan, J. D., *Stream Ecology: Structure and Function of Running Waters*, 1995)

Nutrient dynamics

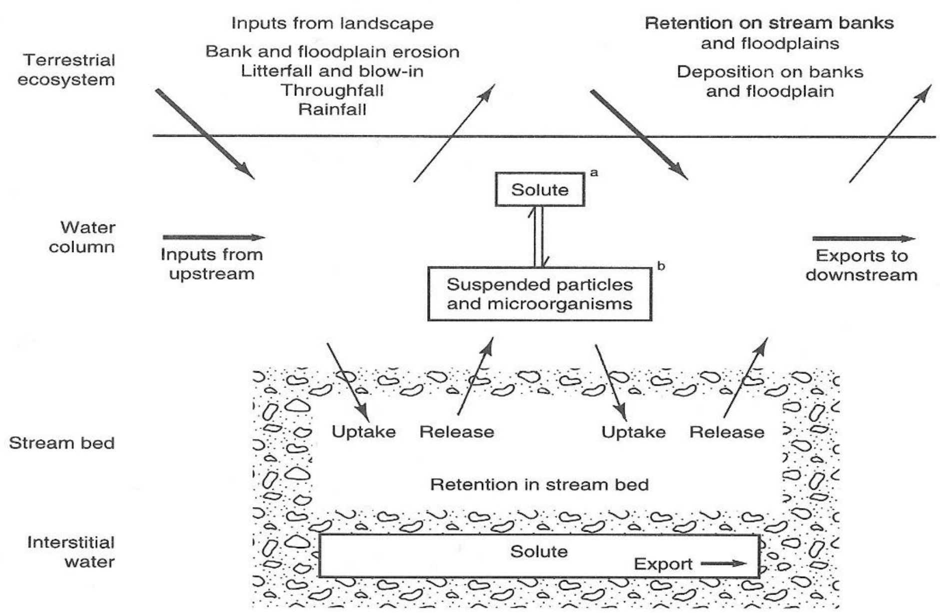


FIGURE 13.1 Conceptual diagram of solute processes in streams. Arrow widths are intended to approximate magnitude of process. Most materials are transported in dissolved form (a), but phosphorus, trace metals, and hydrophobic organics are transported mainly as particulates (b). (Modified from Stream Solute Workshop, 1990.)

(From Allan, J. D., *Stream Ecology: Structure and Function of Running Waters*, 1995)

It is important to note that the left-hand side of all of the first three of these figures represent the inputs and energy pathways from the adjacent terrestrial environment – the riparian corridor, tributaries, and the floodplain to the stream that lies at the center. Barnes and Mann notes that "much of the energy flow through small, forest-stream ecosystems is supported by materials of terrestrial origin." Allen notes that carbon inputs to streams is highest during times of higher stream discharge (snowmelt runoff and storm events). The second figure from Allen illustrates that energy (carbon) and nutrient pathways (nitrogen, phosphorous, trace metals, and other organics) follow similar routes to and from the terrestrial ecosystem. The common theme to all these resources is that they illustrate the importance of a healthy and connected riparian and floodplain ecosystem; the inescapable conclusion is that connectivity and ecosystem health depend upon the full range of stream flows.

In the 1970s and 80s, *The River Continuum Concept* gained notoriety in stream ecology. This concept takes much of the above ecologic information and applies it to river systems from first order headwater streams down to higher order mainstem rivers – that rivers follow a predictable metabolic trend longitudinally. River continuum also stresses the interconnectivity between the flowing water system and the vegetated riparian canopy. Windell (1992) has an excellent section on the river continuum and has the following illustration showing the importance of riparian influences.

Riparian Ecosystems

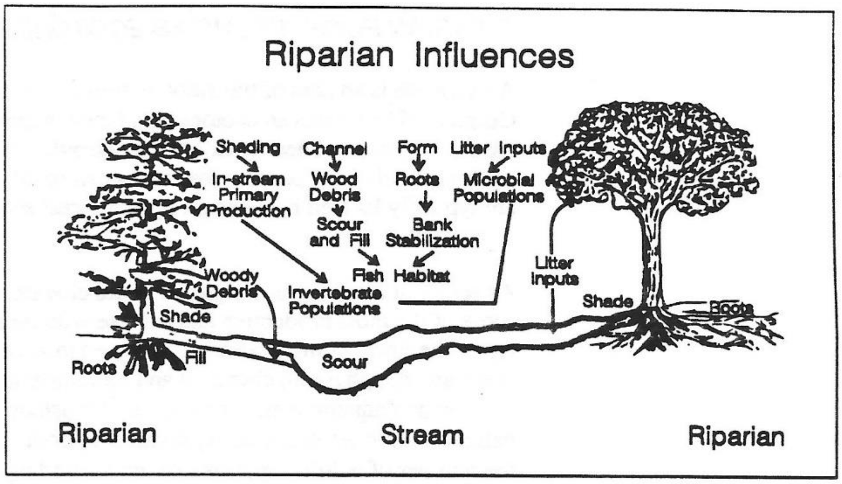


Figure 4.1 Riparian zones are identified by the presence of vegetation that requires large amounts of free or unbound water.

(From Windell, J. T., *Stream Riparian and Wetland Ecology*, 1992)

Focused Aquatic Ecology Reference Review

I also reviewed several in-depth technical references (ecological research papers and research text books) on the general topics described here. These reference materials provide supporting data and scientific/statistical conclusions consistent with the above general discussion. *Bioenergetic considerations in the analysis of stream ecosystems* (Benke et al, North American Benthological Society, 1988), chapter 6 of *The Biology of Streams and Rivers* (Giller, P. and Malmqvist, B., 1998), and chapters 27, 30 and 31 of *Methods in Stream Ecology – Second Edition* (Hauer, F. R. and Lamberti, G. A., 2007) were all reviewed in support of this paper. Benke's list of co-authors includes many prominent river ecologists including Jack Stanford and J. V. Ward, among others. Benke examines and recommends additional research into the important role of dissolved organic matter into our understanding of stream bioenergetics. Giller and Malmqvist's chapter on Energy and Nutrients is a fairly rigorous examination of food sources and energy flow in lotic systems. They describe the importance of leaf litter breakdown and the nutrient processing in rivers and streams highlighting the importance of connectivity to the riparian community for this important source of food for aquatic macroinvertebrates (the primary food source for fish). This chapter also has an excellent discussion of the River Continuum Concept in its discussion of longitudinal nutrient cycling. Hauer and Lamberti has three excellent chapters on Stream Food Webs, Decomposition of Leaf Material, and Riparian Processes and Interactions. As the title of this book suggests, the chapters concentrate on research methods and study design considerations in stream ecology. The food web section discusses the trophic levels in streams – primary producers, macroinvertebrates (aquatic insects), vertebrates (fish), predators, and detritivores but reinforces the above described foundation of stream energetics – riparian and aquatic plants. The leaf litter chapter highlights the importance of this component to the overall food chain. Leaf litter serves as habitat for microorganisms who process the nutrients contained in the leaf material. The microbial community is the nutritious “peanut butter” on the otherwise low nutrition “cracker” that is the leaf material itself (Ward, J. V., unpublished classroom lecture materials). The overall importance of leaf litter cannot be understated, especially in high elevation small streams with relatively pure water quality (the water is low in dissolved solids, therefore low in nutrients). Finally, the chapter on Riparian Processes discusses the unique role of the riparian zone as the ecotone (transition) between the stream and the upland terrestrial environment. While Windell (1992) wrote about the species diversity that exists in the ecotone (the incredible number of species that inhabit or depend upon the riparian zone for all or part of their lifecycles), Chapter 31 in *Methods* describes in detail the principal pathways and interfaces that occur in the riparian zone – solar input, precipitation throughfall and surface runoff, plant uptake, leaf litter, shade, hyporheic communities, and infiltration and shallow groundwater processes (linkage to base flows).

The final important topic in the relationship between streams and riparian and floodplain habitats is the relative importance of woody debris to stream ecosystems. Woody debris is somewhat like leaf litter in that it is an important source of carbon and nutrients to the stream system, but it has additional benefits in terms of habitat creation and maintenance as well as stream stability. Coarse woody debris is a very important component in some steep, plunge pool streams in that wood (along with large rocks) form the hydraulic controls (the plunges) that are key to the stability of the pools in these stream types. It goes without saying where the woody debris in these stream systems comes from – it has origins in the adjacent riparian zone and floodplain.

The Natural Flow Regime, Riverine Resource Stewardship and Environmental Flows

In this section, I will look at three contemporary sources of information that focus on river conservation and restoration, instream flow protection strategies, and environmental flows. The 1997 paper published in the journal BioScience, *The Natural Flow Regime: A paradigm for river conservation and restoration* is yet another paper that has a list of contributing authors that include well known contemporary of aquatic ecologists, such as LeRoy Poff, J. David Allen, Mark Bain and Brian Richter just to name a few. The Instream Flow Council is a 20-year-old professional organization of state and provincial instream flow professionals in North America; their 2002 book, *Instream Flows for Riverine Resource Stewardship*, is the first and only book devoted to the topic of instream flow protection strategies. Angela Arthington’s 2012 book, *Environmental Flows – Saving Rivers in the Third Millennium*, is an ecological resource that describes the timing, quality and quantity of water needed to sustain aquatic ecosystems with attention given to competing human needs as well.

Poff *et a*l’s 1997 paper on the Natural Flow Regime is a widely cited reference on the topic. The paper starts with the premise that rivers are used and abused throughout the world to the point that they no longer can support native species or sustain healthy ecosystem services. Society needs to recognize that “the integrity of flowing water systems depends largely on their natural dynamic character" and that this fundamental scientific principle is key to riverine resource conservation. The natural flow regime includes flow magnitude, frequency, duration, timing, and rate of change. In many cases, practically speaking, restoration of a natural flow regime addressing all of these components is, often times, difficult or impossible. There are places in Colorado where the natural flow regime is currently intact; it is probably not reasonable to think that all of these locations should receive full flow protection, As stated above in the opening paragraph of this paper, it is reasonable to think that there are places where the flow regime is currently unaltered and where unique, rare or special biologic factors are worthy of the full range of flow protection. Most resource managers realize that this is not true or achievable everywhere, but it is reasonable to believe that it can be done without causing human water use problems in the future. Proactive flow protection is much easier to accomplish in these situations than flow restoration and/or endangered species recovery ever is. One take-away message from Poff's paper might be – seek to protect the best examples of unique aquatic ecosystems and natural flow regimes and seek to restore the rest.

The Instream Flow Council's 2002 book was written by a team of 16 state and provincial fishery and water managers who serve as their state's or their Canadian province's instream flow specialist. The IFC's approach is that instream flow prescriptions need to address the five riverine components – Hydrology, Geomorphology, Biology, Water Quality, and Connectivity. All five of these components have a linkage to the premise of this literature review – that there are sound ecological reasons to, under certain circumstances, provide the full range of flow protection.

- Hydrology: riparian resource values and flood plain maintenance
- Geomorphology: channel form and sediment transport
- Biology: life history cues and hydraulic habitat
- Water Quality: temperature and fine sediment
- Connectivity: nutrient cycling, energy pathways, habitat fragmentation

The IFC book devotes many of its pages to what constitutes a good instream flow protection program. One can take an alternative view to this goal of the book and find wisdom that relates to reach-specific flow protection strategies. Strategies that seek comprehensive ecologically-based instream flow protection with flexibility to apply site-specific instream flow protection objectives that reflect agency missions or native species management objectives. Good flow protection programs allow for flexibility and creativity while addressing the five riverine components.

Arthington's 2012 book on Environmental Flows is the newest printed resource available. This book has an international flavor which draws on examples from throughout the world to address the global balancing act between environmental conservation and the human need for water. While much of the book is dedicated to human activities – alteration of watersheds, channel geometry, dam operations, flood control activities, water quality issues, general habitat degradation, and declining biodiversity; Arthington has an excellent chapter on river ecology, the natural flow regime paradigm, and hydro-ecological principles. The following tables from Arthington (2012) contain a considerable amount of information relating to the Facets of Flow Regime's Ecological Functions (Tables 8-12). They are quite self-explanatory and provide back-up information to support many of the points regarding base flows, high flows, floods, flow frequency, flow duration, seasonal timing, and rates of change made earlier in this paper.

TABLE 8 *Facets of the flow regime*

Low- and high-flow magnitude and their ecological functions

Flow facets	*Ecological functions*
Low (base) flows	Normal level
	Maintain suitable water temperatures, dissolved oxygen, and water chemistry
	Provide adequate habitat space for aquatic organisms
	Keep fish and amphibian eggs suspended
	Enable fish to move to feeding and spawning areas
	Maintain water table levels in riverbanks and floodplain, soil moisture for plants
	Support hyporheic organisms (living in saturated sediments)
	Provide drinking water for terrestrial animals
	Drought level
	Provide refuge habitat in pools after riffles and runs dry out
	Concentrate prey into limited areas to benefit predators
	Enable recruitment of certain floodplain plants
	Enable limited invertebrate and fish recruitment
	Purge invasive, introduced species from aquatic and riparian communities
High flows within channel	Shape physical character of river channel, including pools, riffles, runs
	Determine size of streambed substrates (sand, gravel, cobble)
	Prevent riparian vegetation from encroaching into channel
	Restore normal water-quality conditions after prolonged low flows, flushing away waste products and pollutants
	Aerate eggs in spawning gravels, prevent siltation
	Provide suitable habitats for invertebrates and fish
	Maintain suitable salinity conditions in estuaries
Large floods	Shape physical habitats in channels and on floodplain (e.g., lateral channels, oxbow lakes)
	Provide migration and spawning cues for fish, trigger invertebrate life-history phases
	Enable fish to spawn on floodplain, provide nursery habitat for juvenile fish
	Provide new feeding opportunities for fish, amphibians, waterbirds
	Distribute life stages of fish and invertebrates among channel habitats
	Create sites for recruitment of colonizing plants
	Provide plant seedlings with prolonged access to soil moisture

(continued)

TABLE 8 *(continued)*

Flow facets	*Ecological functions*
Large floods *(continued)*	Maintain diversity in floodplain plant and forest types through differential inundation
	Disburse seeds and fruits of riparian plants
	Flush organic materials (food) and woody debris (habitat structures) into channel
	Purge invasive, introduced species from aquatic and riparian communities
	Maintain suitable salinity conditions in estuaries
	Provide nutrients and organic matter to estuaries
	Stimulate spawning of estuarine biota and support recruitment

SOURCE: Adapted from Postel and Richter 2003 and references therein

TABLE 9 *Facets of the flow regime*

Ecological significance of the frequency of flows

Flow facets	*Ecological functions*
Frequency of flows	The timing, or predictability, of flow events is critical ecologically because the life cycles of many aquatic and riparian species are timed to either avoid or exploit flows of variable magnitudes
	Natural timing of high or low stream flows provides environmental cues for initiating life-cycle transitions in fish, e.g., spawning, egg hatching, rearing, movement onto the floodplain for feeding or reproduction, or migration upstream or downstream
	Match of reproductive period and floodplain or wetland access explains some of the yearly variation in stream fish community composition
	Many riparian plants have life cycles that are adapted to the seasonal timing components of natural flow regimes through their "emergence phenologies"—the seasonal sequence of flowering, seed dispersal, germination, and seedling growth
	Interaction of emergence phenologies with temporally varying environmental stress from flooding or drought helps to maintain high species diversity in floodplain forests
	Productivity of riparian forests is influenced by flow timing and can increase when short-duration flooding occurs in the growing season

SOURCE: Adapted from Poff et al. 1997 and references therein

TABLE 10 *Facets of the flow regime*

Ecological significance of the duration of flows

Flow facets	*Ecological functions*
Duration of flows	The duration of a specific flow condition often determines its ecological significance
	Differences in tolerance to prolonged flooding in riparian plants and to prolonged low flow in aquatic invertebrates and fish allow these species to persist in locations from which they might otherwise be displaced by dominant, but less tolerant, species
	Seasonal access to floodplain wetlands is essential for the recruitment of certain river fishes; the duration of floodplain inundation can influence the growth potential and recruitment of fish and other biota that need to use floodplain habitats and food resources
	Duration of dry periods in arid-zone rivers can influence the survival of fish to the point that isolated water bodies may lose their entire fish assemblage unless replenished by flow

SOURCE: Adapted from Poff et al. 1997 and references therein

TABLE 11 *Facets of the flow regime*

Ecological significance of the seasonal timing of flows

Flow facets	*Ecological functions*
Seasonal timing of flows	Natural timing of high or low stream flows provides environmental cues for initiating life-cycle transitions in fish, e.g., spawning, egg hatching, rearing, movement onto the floodplain for feeding or reproduction, or migration upstream or downstream
	Match of reproductive period and floodplain or wetland access explains some of the yearly variation in stream fish community composition
	Many riparian plants have life cycles that are adapted to the seasonal timing components of natural flow regimes through their "emergence phenologies"—the seasonal sequence of flowering, seed dispersal, germination, and seedling growth
	Interaction of emergence phenologies with temporally varying environmental stress from flooding or drought helps to maintain high species diversity in floodplain forests
	Productivity of riparian forests is influenced by flow timing and can increase when short-duration flooding occurs in the growing season
	Natural seasonal variation in flow conditions can prevent the successful establishment of nonnative species with flow-dependent spawning and egg incubation requirements, such as striped bass *(Morone saxatilis)* and brown trout *(Salmo trutta)*

SOURCE: Adapted from Poff et al. 1997 and references therein

TABLE 12 *Facets of the flow regime*

Ecological significance of the rate of change in flow conditions

Flow facets	*Ecological functions*
Rate of change in flow conditions	The rate of change, or flashiness, in flow conditions due to heavy storms can influence species persistence and coexistence
	Rapid flow increases in streams of the central and southwestern United States serve as spawning cues for native minnow species, whose rapidly developing eggs are either broadcast into the water column or attached to submerged structures as floodwaters recede
	More gradual, seasonal rates of change in flow conditions regulate the persistence of many aquatic and riparian species
	Cottonwoods (*Populus* spp.) are disturbance species that establish after winter–spring flood flows, during a narrow "window of opportunity" when competition-free alluvial substrates and wet soils are available for germination
	A certain rate of floodwater recession is critical to cottonwood seedling germination because seedling roots must remain connected to a receding water table as they grow downward
	Nonnative fish generally lack the behavioral adaptations to avoid being displaced downstream by sudden flood, e.g., the introduced predatory mosquitofish *(Gambusia affinis)* can extirpate the native Gila topminnow *(Poeciliopsis occidentalis)* in locations where natural flash floods are regulated by upstream dams, but the native species persists in naturally flashy stream

SOURCE: Adapted from Poff et al. 1997 and references therein

(Tables 8 – 12 from Arthington, A. H., *Environmental Flows – Saving Rivers in the Third Millennium*, 2012)

Summary and Conclusions

There is ample information in the scientific literature to support the notion that there are connections between the hydrograph of a given stream and the health of the aquatic and riparian ecosystem. From an instream flow protection standpoint in Colorado, I believe that there are circumstances where an instream flow water right for all of the unappropriated flow is appropriate; I also believe that the scientific literature supports me in this. Himes Creek in southwest Colorado is one of those unique circumstances where such an appropriation of water is both necessary and appropriate to preserve the natural environment to a reasonable degree. The natural environment of Himes Creek is well documented – it is one of only few streams in the San Juan River drainage where a previously thought to be extinct lineage of Colorado river cutthroat trout exists. As such, there is no room for error when it comes to flow protection for these fish and the Himes Creek watershed is so small and so isolated, and there is likely a minimal level risk to future water development potential if the state proceeds with this instream flow appropriation.

The literature review that was conducted and documented in this paper provides the CWCB with information that confirms that there is a biological and ecological rationale for the need to protect streamflows up to all of the available (unappropriated) flows. The scientific literature is clear in its conclusions that, from a stream energetics standpoint, there is a connection between bankfull and overbank flows and riparian health and that the full range of flows (amount, timing and duration) are needed to ensure the health of streams like Himes Creek. A healthy and connected riparian floodplain is a critical component to the long-term health of the Himes Creek fishery, fish habitat, and food web. Anything less than "all of the unappropriated flow" would, in our opinion, constitute an unacceptable and unnecessary risk to this high value fish population. Further, I am of the opinion that this action will not result in any risk to Colorado water users. It is important that the CWCB be able to continue to use its discretion and evaluate each instream flow recommendation on its own merit – that there be an opportunity for a case-by-case analysis of each recommendation. This approach will be applied sparingly in only those unique and isolated circumstance; this has been the case up until this point in history and should the CWCB proceed with the Himes Creek proposal, that will likely continue to be the case.

References (listed in chronological order)

The Ecology of Running Waters, 1970, Hynes, H. B. N., University of Toronto Press

Fundamental of Aquatic Ecology, 1980, Barnes, R. S. K. And Mann, K. H., Blackwell Scientific Publications

Bioenergetic considerations in the Analysis of Stream Ecosystems, 1988, Benke, A. C., Hall, C. A. S., Hawkins, C. P., Lowe-Mcconnell, R. H., Stanford, J. A., Suberkrupp, K., Ward, J. V., Journal of North American Benthological Society

Stream, Riparian and Wetland Ecology, 1992, Windell, J. T., University of Colorado Press

Stream Ecology: Structure and Function of Running Waters, 1995, Allan, J. D., Chapman and Hall

The Natural Flow Regime – A paradigm for river conservation and restoration, 1997, Poff, N. L., Allan, J. D., Bain, M. B., Karr, J. R., Prestegaard, K. L., Richter, B. D., Sparks, R. E., Stromberg, J. C., BioScience

The Biology of Streams and Rivers, 1998, Giller, P. S., Malmqvist, B., Oxford University Press

Mountain Rivers, 2000, Wohl, E., American Geophysical Union

Instream Flows for Riverine Resource Stewardship – Revised Edition, 2002, Instream Flow Council

The Ecological Significance of High Flows, A Seminar on the Linkage of Hydrometric-Geomorphic-Ecological Dynamics on alluvial Rivers and Streams, 2006, DVD Produced by the Washington State Department of Fish and Wildlife

Methods in Stream Ecology – Second Edition, 2007, Hauer, F. R., Lamberti, G. A., Elsevier Academic Press

Environmental Flows – Saving Rivers in the Third Millennium, 2012, Arthington, A. H., Freshwater Ecology Series, Stephen Bechtel Fund, University of California Press

Attachment G

COLORADO PARKS & WILDLIFE

CPW News Release

9/4/2018

Colorado Parks and Wildlife announces discovery of unique cutthroat trout in southwest Colorado

FOR IMMEDIATE RELEASE

Joe Lewandowski
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970-375-6708

Colorado Parks and Wildlife has found cutthroat trout that are unique to the San Juan River Basin in southwest Colorado. The photo below is of a museum specimen found in the Smithsonian.

Colorado Parks and Wildlife announces discovery of unique cutthroat trout in southwest Colorado

DURANGO, Colo. – Colorado Parks and Wildlife biologists have discovered a unique genetic lineage of the Colorado River cutthroat trout in southwest Colorado that was thought to be extinct. The agency will continue to evaluate the findings and collaborate with agency partners to protect and manage populations of this native trout.

The discovery was officially recognized earlier this year thanks to advanced genetic testing techniques that can look into the basic components of an organism’s DNA, the building blocks of life. This exciting find demonstrates the value of applying state-of-the-art genetic science to decades of native cutthroat conservation management and understanding.

“Anyone who just looked at these fish would have a difficult time telling them apart from any other cutthroat; but this is a significant find,” said Jim White, aquatic biologist for CPW in Durango. “Now we will work to determine if we can propagate these fish in our hatcheries and reintroduce them into the wild in their historic habitat. It’s a great conservation effort and a great conservation story.”

Eight small populations of these trout have been found in streams of the San Juan River Basin within the San Juan National Forest and on private property. The populations are in isolated habitats and sustained through natural reproduction. U.S. Forest Service staff and landowners have been cooperative in CPW’s efforts; they will also be instrumental in further cutthroat conservation efforts.

In August, north of Durango, crews from CPW and the U.S. Forest Service hiked into two small, remote creeks affected by the 416 Fire and removed 58 fish. Ash flows from the fire could have severely impacted these small populations.

Cutthroat trout originated in the Pacific Ocean and are one of the most diverse fish species in North America with 14 different subspecies. Three related subspecies are found in Colorado: Colorado River cutthroat trout found west of the Continental Divide; Greenback cutthroat trout in the South Platte River Basin; and the Rio Grande cutthroat trout in the San Luis Valley. A fourth, the yellowfin cutthroat trout native to the Arkansas River Basin, went extinct in the early 1900s. Cutthroats from each of these areas have specific and distinctive genetic markers. CPW propagates the three remaining subspecies, and actively manages their conservation and recovery throughout the state.

White and other biologists – including Kevin Rogers, a CPW cutthroat researcher based in Steamboat Springs, and Mike Japhet, a retired Durango CPW aquatic biologist – have been surveying remote creeks in southwest Colorado for more than 30 years looking for isolated populations of cutthroat trout. They found some populations in remote locations long before advanced genetic testing was available. The biologists understood that isolated populations might carry unique genetic traits and adaptations, so they made sure to preserve collected samples for genetic testing later. Significant advances in genetic testing technology over the last 10 years were instrumental in finding the distinct genetic markers that identify the San Juan lineage trout as being unique.

In 1874, naturalist Charles E. Aiken collected and preserved samples of fish found in the San Juan River near Pagosa Springs. Two trout were deposited in the Smithsonian National Museum of Natural History in Washington, D.C. These samples were forgotten until 2012 when a team of researchers from the University of Colorado was hired by the Greenback Trout Recovery Team to study old trout specimens housed in the nation’s oldest museums. When the researchers tested tissue from those two specimens they found genetic markers unique to the San Juan River Basin. Armed with the knowledge of these genetic “fingerprints”, CPW researchers and biologists set out to test all the cutthroat trout populations they could find in the basin in search of any relic populations.

“We always ask ourselves, ‘What if we could go back to the days before pioneer settlement and wide-spread non-native fish stocking to see what we had here?’” White said. “Careful work over the years by biologists, finding those old specimens in the museum and the genetic testing gave us the chance, essentially, to go back in time. Now we have the opportunity to conserve this native trout in southwest Colorado.”

Developing a brood stock of these trout so that they can be reintroduced into San Juan River headwaters streams will be a key conservation strategy for increasing their distribution into suitable habitat and help their long-term stability. Protecting the fish from disease, other non-native fish, habitat loss and over-harvest are important factors that will be considered in a conservation plan that will be developed over the next few years. While that might seem like a long time, the discovery of this fish goes back more than 100 years.

Over the decades, CPW has worked with many partners throughout the state to find and conserve distinct cutthroat populations. Many of these efforts were conducted with assistance from the U.S. Forest Service, conservation groups and private property owners. CPW also works on projects with both the Colorado

River Cutthroat Trout and Rio Grande Cutthroat Trout conservation teams.

All native cutthroats have been adversely affected by a variety of issues, including reduced stream flows, competition with other trout species, changes in water quality and other riparian-habitat alterations. Consequently, the various types of native cutthroats are only found in isolated headwaters streams. To ensure continued conservation of Colorado's cutthroats, CPW stocks only the native species in high lakes and headwater streams. That stocking practice started in the mid-1990s.

CPW has also conserved cutthroats in headwaters streams by working with the U.S. Forest Service to build barriers to prevent upstream migration of non-native trout, removing non-native trout and subsequently stocking them with native trout. The conservation group, Trout Unlimited, has provided valuable assistance with many of these projects.

John Alves, Durango-based senior aquatic biologist for CPW's Southwest Region, said the discovery shows the dedication of CPW aquatic biologists.

"These fish were discovered because of our curiosity and our concern for native species," Alves said. "We're driven by scientific inquiry that's based on hard work and diligence. This is a major discovery for Colorado and it shows the critical importance of continuing our research and conservation work."

###

CPW is an enterprise agency, relying primarily on license sales, state parks fees and registration fees to support its operations, including: 41 state parks and more than 350 wildlife areas covering approximately 900,000 acres, management of fishing and hunting, wildlife watching, camping, motorized and non-motorized trails, boating and outdoor education. CPW's work contributes approximately $6 billion in total economic impact annually throughout Colorado.

COLORADO
Parks and Wildlife
Department of Natural Resources

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Attachment H

Rediscovery of a lost Cutthroat Trout lineage in the San Juan Mountains of southwest Colorado.

January 30, 2018

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Abstract

The discovery of a distinct lineage of Cutthroat Trout in museum specimens collected from the San Juan basin precipitated an intensive search for any remaining extant populations across the putative native range of this fish. Tissue samples from every known Cutthroat Trout population in the basin were assembled and analyzed with molecular methods. Of these, eight waters harbored Cutthroat Trout with mitochondrial DNA markers that placed them in the San Juan clade (a monophyletic lineage closely aligned with another Colorado River Cutthroat Trout lineage native to the headwaters of the Colorado, Dolores, and Gunnison rivers). Analysis of nuclear DNA amplified fragment length polymorphism markers also suggested they were distinct, with no evidence of introgressive hybridization with Rainbow Trout or Yellowstone Cutthroat Trout. We recommend that morphological studies be conducted on these same fish to evaluate if they can be distinguished with morpho-meristic traits as well. In this report we discuss support for considering these fish as a distinct unit of biodiversity worthy of conservation, as well as the current status of these eight populations.

Introduction

A recent study exploring mitochondrial DNA sequence data acquired from museum specimens of Cutthroat Trout collected in the late 19th century showed that six major monophyletic lineages (clades) occupied the state of Colorado prior to European settlement (Metcalf et al. 2012; Rogers 2012) rather than just three subspecies as previously thought (Behnke 1992, 2002). These clades aligned with major drainage basins that were not linked by coldwater confluences (Figure 1). That study and one that followed examining morphological features (Bestgen et al. 2013) suggested that four clades could still be found on the landscape today. Two are found west of the Continental Divide in what is currently Colorado River Cutthroat Trout (CRCT) habitat in the Green, White, and Yampa River drainages (blue lineage), or the headwaters of the Colorado, Gunnison, and Dolores Rivers (green lineage). The remaining two extant clades are found east of the Divide in the South Platte and Rio Grande River drainages. The Yellowfin Cutthroat Trout that historically occupied the headwaters of the Arkansas River appears to have gone extinct by 1903 just 17 short years after its discovery (Juday 1906). A sixth clade was detected by Metcalf et al. (2012) from a pair of specimens collected by C. E. Aiken from the San Juan River near Pagosa Springs in 1874. Mitochondrial sequence data did not match any of the extant populations examined, and was therefore also presumed extinct by the authors.

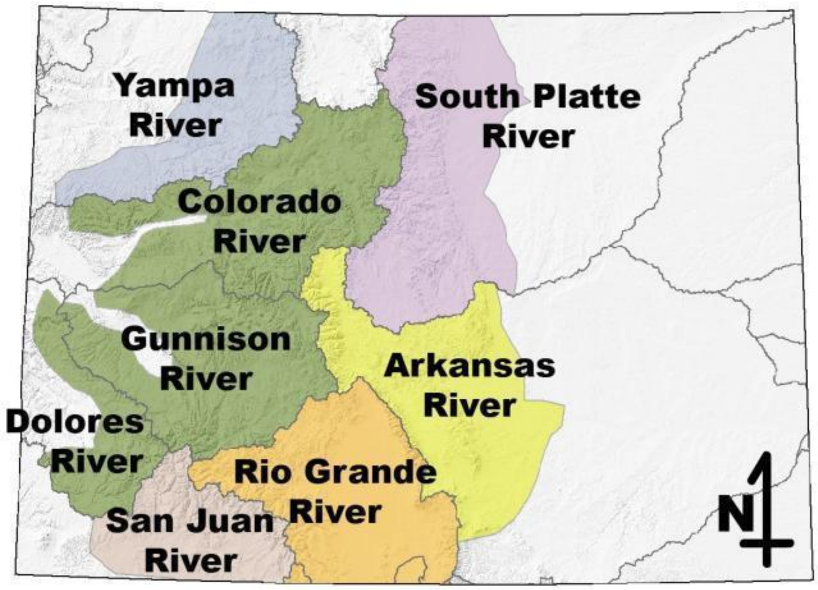

Figure 1: Historical range of six major Cutthroat Trout clades native to Colorado are organized by major drainage basins that do not share coldwater confluences.

An intensive survey effort was launched to confirm that this clade was no longer present on the landscape. Isolated DNA was gathered either from earlier collections in the basin or from new tissue samples (fin clips). Mitochondrial DNA sequence data were obtained, and compared to Aiken's specimens for evidence of haplotypes that would place them in the San Juan clade. Here we report on populations that do share mitochondrial NADH dehydrogenase subunit 2 (ND2) locus haplotypes with Aiken's fish and should therefore be considered for further study. With new samples to examine, we explore the evidence that supports recognizing the San Juan clade as a discrete taxonomic entity worthy of conservation focus, and discuss population characteristics that will help inform management actions designed to secure these remaining small fragmented populations.

Methods

Molecular testing

A survey of Cutthroat Trout conservation waters in the San Juan basin (Hirsch et al. 2013) revealed 20 candidate populations from which fin clips or previously isolated DNAs were obtained. Cutthroat Trout DNA was extracted from fin clips using a proteinase K tissue lysis and spin-column purification protocol following the manufacturers specifications (Qiagen DNeasy, Hilden, Germany). An aliquot of each sample DNA was amplified using primers specific to a region of the ND2 mitochondrial gene in Cutthroat Trout, generating a 648 bp fragment that falls within the same fragment examined in previous studies (Metcalf et al. 2007; Rogers et al. 2011; Loxterman and Keeley 2012; Metcalf et al. 2012). After amplification, residual primers and deoxynucleotides were removed or inactivated. Fluorescently-labeled DNA sequences in the forward and reverse direction for each sample were generated. After sequencing reactions were completed, unincorporated fluorescently labeled nucleotides were removed according to the manufacturer's instructions (Rogers et al. 2011). Samples were run on a capillary sequencer (3130 Genetic Analyzer, Applied Biosystems, Foster City, California). Sequence reads generated from the forward and reverse strands of each sample DNA were assembled using the Contig Express program (Vector NTI 11, Invitrogen, Carlsbad, Caliornia). The assembled contiguous sequence chromatograms were examined for sequence quality and accuracy, and the primer sequences removed from the ends of the fragments. Sequences were aligned in MUSCLE (Edgar 2004) and compared to the suite of genetic diversity found in the NCBI database (Metcalf et al. 2007, 2012; Pritchard et al. 2009; Loxterman and Keeley 2012) and elsewhere (Rogers et al. 2011; Bestgen et al. 2013; Rogers et al. 2014) using MEGA7 (Kumar et al. 2016).

Examination of the nuclear genome was explored with Amplified Fragment Length Polymorphisms (AFLPs; Rogers 2008a; Rogers 2012). AFLP marker fragments were generated using restriction digested DNA (EcoR1 and MseI) and a single pair of +3 PCR primers (ACT for the FAM-labeled forward primer; CAG for the reverse primer). Fragments were separated and sized on an ABI 3130 DNA sequencer (Applied Biosystems, Foster City, California). Using the program Genemapper 4.0 (Applied Biosystems), a genetic fingerprint was produced for each individual by scoring for the presence or absence of a standardized set of 119 markers between 50 and 450 base pairs in size generated from reference Cutthroat Trout populations (Table 1; Rogers 2008a, 2012). The genetic signature of individuals in the test population were compared to those found in the reference populations using a Bayesian approach for identifying population clusters (Pritchard et al. 2000). Reference populations were selected and grouped by their mtDNA lineage (Metcalf et al. 2007), and not necessarily by geographic or historic subspecies classifications. The similarity or dissimilarity was scored as the admixture proportion, or the probability that each test individual shares a genetic background with each of the cutthroat subspecies reference population groups with the program STRUCTURE 2.3.4 (Falush et al. 2007; Pritchard et al. 2007) and expressed as q values for each subspecies. Average q values from the run with the highest log likelihood (Pritchard et al. 2007) were used to generate the admixture proportions for the unknown population, with confidence intervals generated in program QSTRAP (Rogers 2008b).

Table 1.— Amplified fragment length polymorphisms were used with Program STRUCTURE to assess relatedness and purity of Cutthroat Trout populations in the San Juan basin, Colorado. Reference populations included both lineages of Colorado River Cutthroat Trout (CRCT, blue and green), Rio Grande Cutthroat Trout (RGCT), Yellowstone Cutthroat Trout (YSCT), and Rainbow Trout

Trout lineages	**Water**	**County**	**Water Code**	**Collection Date**	**Sample Size**
CRCT - Blue	Williamson Lake (#3)	Inyo	NA	07/31/06	22
	Piedra, E Fk	Hinsdale	42096	02/07/06	20
	Slater Crk, S Fk	Routt	23286	NA	14
	Parachute Crk, E Fk	Garfield	21460	NA	10
CRCT - Green	Severy Creek	El Paso	31312	NA	10
	Antelope Crk, W	Gunnison	48016	02/21/03[e]	21
	Bobtail Creek	Grand	23026	09/03/03	19
RGCT	Canones Creek	Rio Arriba	329	03/29/06	19
	Columbine Creek	Taos	1026	09/17/02	20
	Osier Creek	Conejos	44444	09/22/04	11
	Cuates Creek	Costilla	38141	07/25/05	10
YSCT	Dog Creek	Teton	813220	06/28/01	20

	Willow Creek	Teton	813350	10/26/02	14
	Yellowstone River	Park	TenSleep	03/01/05	12
Rainbow Trout	Colorado River	Grand	21298	NA	10
	Bellaire	Garfield	RifleFalls	03/06/08	9
	Eagle Lake	Garfield	RifleFalls	03/06/08	9
	Erwin	Garfield	RifleFalls	03/06/08	9
	Fish Lake	Garfield	RifleFalls	03/06/08	9
	Kamloops	Garfield	RifleFalls	03/06/08	9
	Tasmanian	Garfield	RifleFalls	01/12/08	9

At this time, the San Juan lineage is defined only from a pair of museum samples whose DNA is so degraded that they cannot serve as a reference population for our standard AFLP test. Instead, we explored AFLP markers from extant candidate populations in program STRUCTURE compared to the reference Cutthroat Trout without using prior population information (no reference populations). We used a burn-in of 10,000 and a MCMC of 20,000, while allowing K to increment from 3 to 7 over 10 iterations each to help isolate genetic structure where it exists. Again, the run with the highest log likelihood was used for subsequent analysis and plotting. The same 119 AFLP loci were examined further with principal coordinate analysis as implemented in GenAlEx 6.502 (Peakall and Smouse 2012) so that major patterns within the multivariate data could be explored. A pairwise Nei's genetic distance matrix was calculated from binary (diploid) allele calls as is appropriate for dominant markers like AFLPs. The resulting table was then plotted over principal coordinate space and the amount of variation explained by the plotted axes was recorded.

Results

We recovered mitochondrial (ND2) haplotypes that matched museum specimens collected by C. E. Aiken from the Pagosa River in 1874 from eight waters in the San Juan River basin (Figure 2; Table 2). Only San Juan clade haplotypes (Figure 3) were recovered from these populations (no evidence of nonnative salmonid admixture in the mitochondrial DNA). Seven of the eight populations shared the same haplotype while the last also harbored a single base pair variant. These haplotypes suggest that the San

Juan lineage is most closely related to the green lineage CRCT (Figure 3), with half the genetic distance between the San Juan and green lineage CRCT as compared to the blue lineage CRCT and the Greenback Cutthroat Trout of the South Platte River basin (Table 3).

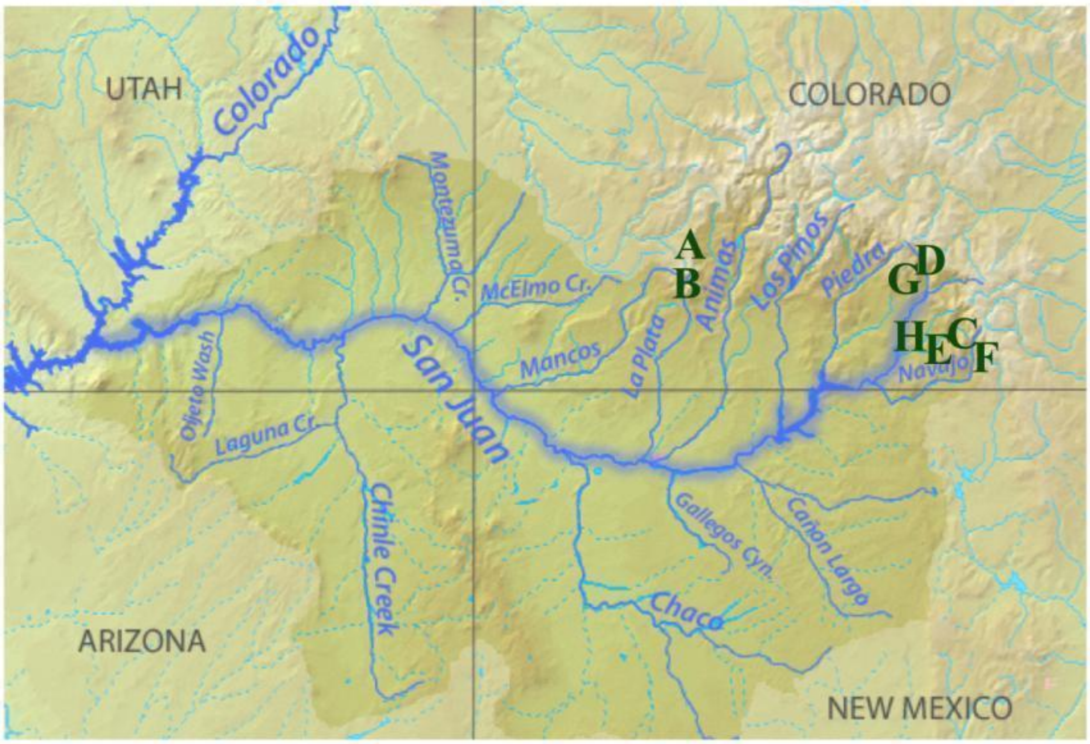

Figure 2: Eight populations of Cutthroat Trout in the San Juan River basin harbor haplotypes characteristic of San Juan basin native. Letters correspond to populations identified in Table 2 below.

Table 2: Eight populations of Cutthroat Trout in the San Juan River basin harbor haplotypes characteristic of San Juan basin native. Elevation (m), of fin collection locations and associated latitude and longitude (decimal degrees) are provided. .

Water	**Legend**	**Water Code**	**Elevation**	**Latitude**	**Longitude**
Big Bend Creek	A	47325	2733	37.6	-108.0
Clear Creek*	B	47565	2643	37.5	-107.9
Cutthroat Creek	C	39415	2560	37.1	-106.7
Fall Creek	D	38117	2493	37.4	-106.9
Grayhackle Lake	E	96457	2796	37.1	-106.7
Headache Creek	F	39491	2466	37.1	-106.7
Himes Creek	G	39502	2437	37.4	-106.9
Rio Blanco River	H	38439	2605	37.3	-106.7

*Founded from Big Bend population in 1989

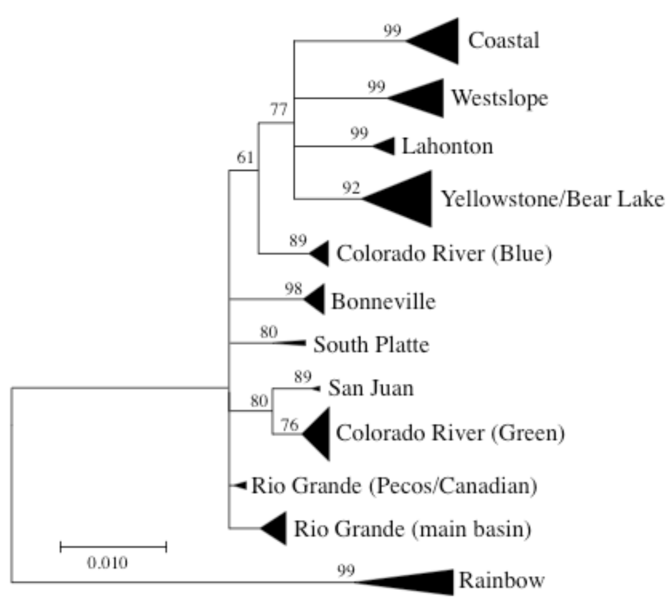

Figure 3: One hundred twenty six nucleotide sequences covering the mitochondrial NADH subunit 2 gene in Cutthroat Trout from across their range were obtained from GenBank and unpublished sources, and compared to 10 Rainbow Trout

sequences. Phylogenetic relationships were inferred with the Minimum Evolution (ME) method as implemented in MEGA7 after all sequences were trimmed to 648 common base pairs. Percent branching support was evaluated with 500 bootstrap replicates and branches with less than 60% were collapsed into polytomies. The evolutionary distances were computed using the Maximum Composite Likelihood method and are in the units of the number of base substitutions per site. The tree was searched using the Close-Neighbor-Interchange algorithm at a search level of one. The neighbor-joining algorithm was used to generate the initial tree.

Table 3.— Sequence divergence in a portion (648 base pairs) of the NADH subunit 2 gene comparing the San Juan lineage to Rainbow Trout and other Cutthroat Trout clades found in the southern Rocky Mountains using the Maximum Composite Likelihood method.

Clade	**$CRCT_{SJ}$**	$CRCT_G$	$CRCT_B$	GBCT	RGCT	BCT
San Juan ($CRCT_{SJ}$)						
Green ($CRCT_G$)	**0.011**					
Blue ($CRCT_B$)	**0.021**	0.024				
Platte (GBCT)	**0.018**	0.018	0.020			
Rio Grande (RGCT)	**0.013**	0.018	0.018	0.014		
Bonneville (BCT)	**0.021**	0.023	0.022	0.022	0.017	
Rainbow (RBT)	**0.081**	0.083	0.083	0.080	0.074	0.087

Interestingly, results from the standard AFLP tests on the six populations with large enough sample sizes for a reliable test suggest they align with the blue rather than green lineage CRCT (Figure 4) when forced to select between one of five reference groups (Table 1) despite mitochondrial DNA that suggests a much closer relationship to the green lineage (Figure 3, Table 3).

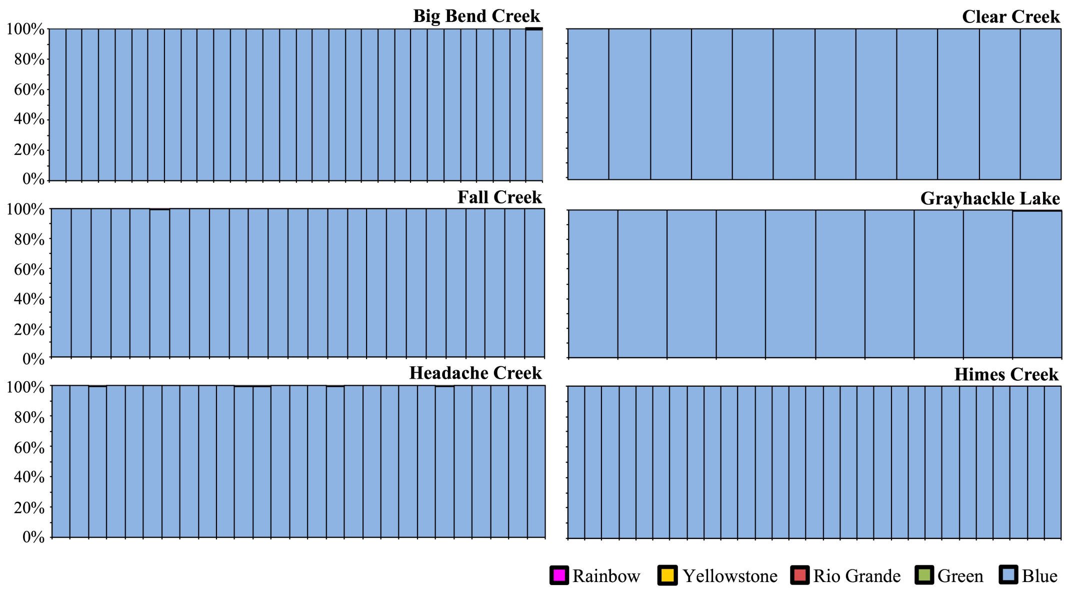

Figure 4: Individual admixture proportions (each bar represents a fish) measured by STRUCTURE with nuclear AFLP markers using K=5 and Rainbow Trout, Yellowstone Cutthroat Trout, Rio Grande Cutthroat Trout, green lineage CRCT and blue lineage CRCT as reference groups (prior information), suggest an alignment with blue lineage CRCT.

With lack of symmetry between nuclear and mitochondrial DNA results, we elected to explore the same 119 AFLP markers further in a principal coordinate framework to see why the San Juan fish might be aligning with blue lineage CRCT. The first two principal coordinates explain 38% of the variation in the data, and clearly suggest why blue lineage was selected over green when STRUCTURE was coerced into choosing between the two (Figure 5). With that information, it became clear that we should run the AFLP marker data through STRUCTURE without using any prior population information, and allowing K to vary from 3 to 7 groups. Surprisingly, San Juan fish appeared to separate from other Cutthroat Trout of the southern Rocky

Mountains at K=3, even before blue lineage CRCT and green lineage CRCT were distinguished (Figure 6). This result is unexpected since the markers used in the development of the standard AFLP test were selected for their ability to distinguish the two. This marker set has already been shown to perform poorly at distinguishing blue lineage CRCT and Rio Grande Cutthroat Trout (Rogers et al. 2011), so it was not unexpected that they did not separate until K=5 (the expected number of groups). Noteworthy was that at K=6 (more than the expected number of groups), STRUCTURE elected to parse out two San Juan clusters, rather than splitting out Rio Grande Cutthroat Trout from the Canadian River basin that have already been identified as unique (Pritchard et al. 2009), and appear to be more distinct than the San Juan fish in principal coordinate space (Figure 5).

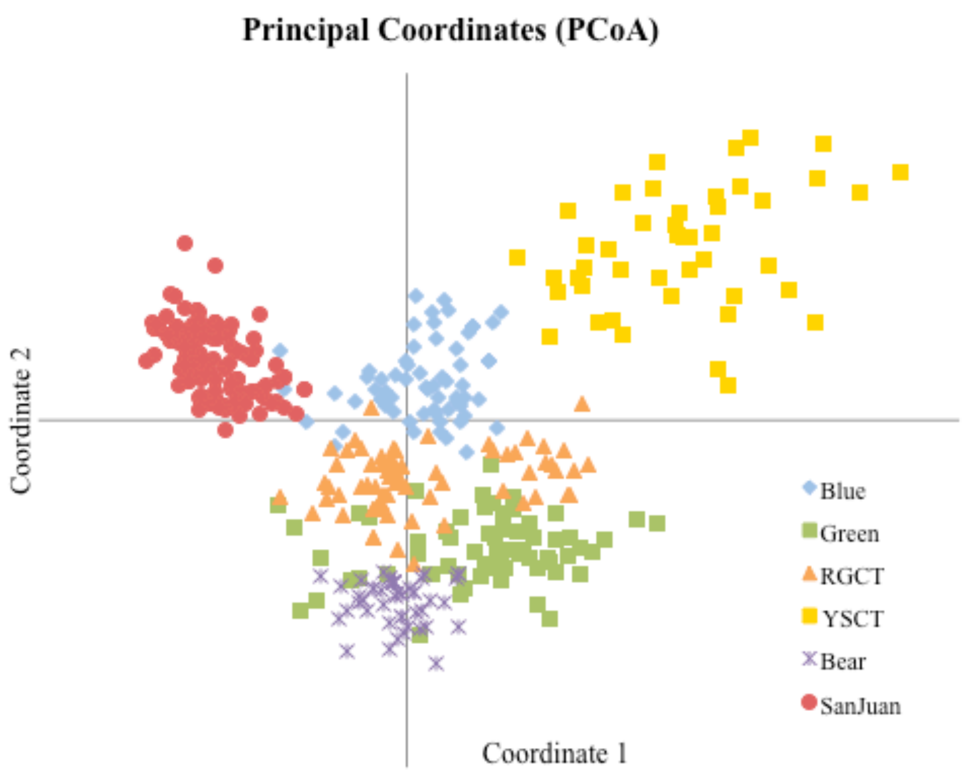

Figure 5: Samples from six putative San Juan lineage populations were included with 50 fish from Bear Creek and the standard AFLP reference fish in a principal

coordinates analysis (GenAlEx 6.5). Results of the first two principal coordinates are plotted with colors representing Cutthroat Trout lineages.

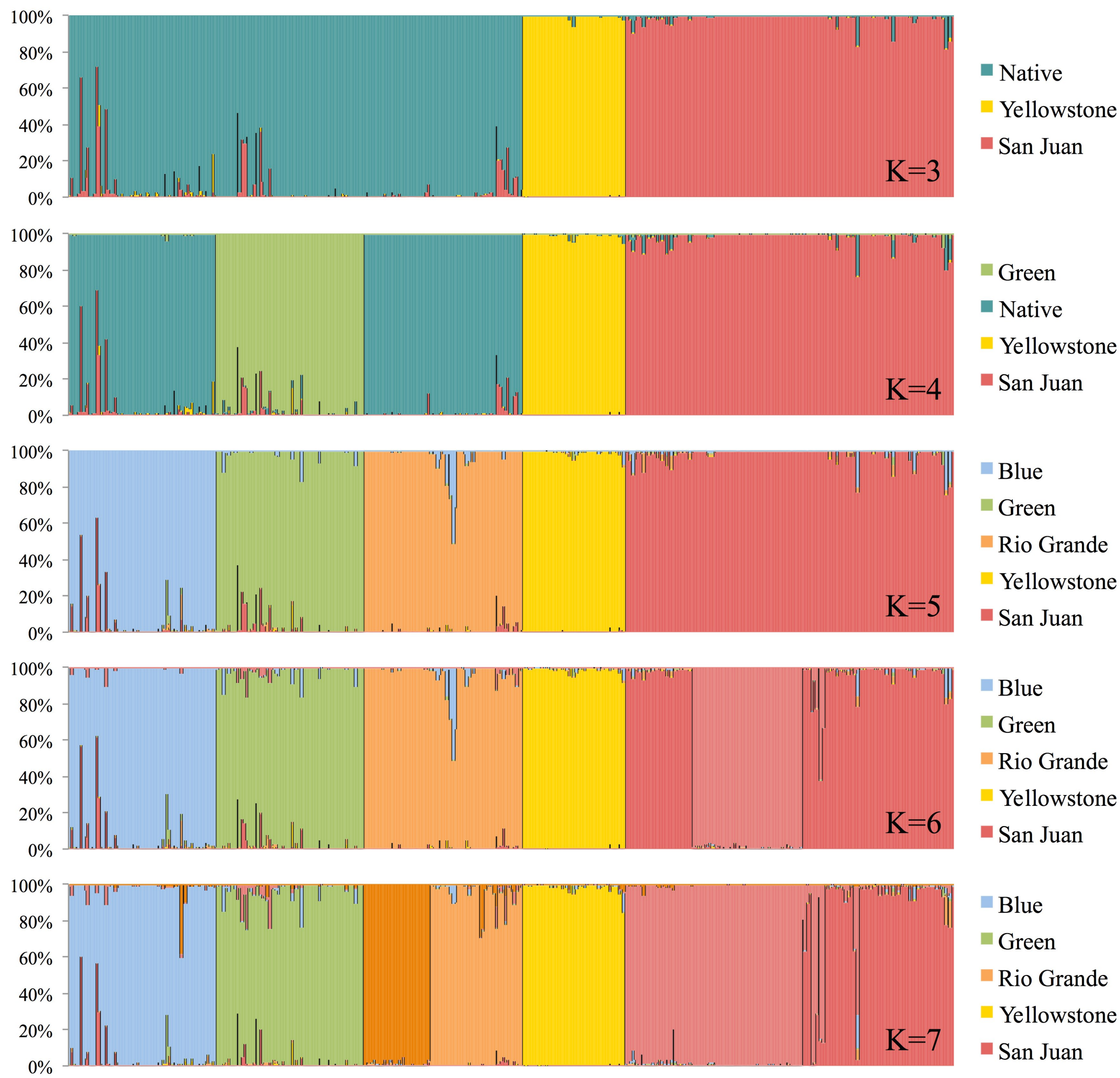

Figure 6: Individual admixture proportions (each bar represents a fish) as measured in STRUCTURE with 119 AFLP markers and no prior population information. Colors correspond to the various Cutthroat Trout lineages considered, and K ranged from 3-7. We use the generic term "Native" to describe clusters that cover more than one lineage.

Discussion

The discovery of admixed fish containing the San Juan mitome allowed for sequencing of the standard 648 bp covered in many other studies of extant Cutthroat Trout populations (Pritchard et al. 2009, Loxterman and Keeley 2012, Bestgen et al. 2013, Rogers et al. 2014) rather than no more than 388 ND2 base pairs explored in the museum study (Metcalf et al. 2012). A close affiliation with green lineage CRCT was revealed when 648 base pairs of the ND2 gene were compared to other native Cutthroat Trout (Figure 3), though the San Juan fish still comprise a monophyletic clade displaying roughly half the genetic distance (1.1%) observed between other Cutthroat Trout lineages across the southern Rocky Mountains (Table 3)

When DNAs were obtained from Cutthroat Trout in the San Juan basin were initially screened with nuclear AFLP markers using our standard reference populations, all fish aligned with blue lineage CRCT. It was assumed that these populations were among the many blue lineage CRCT populations founded across the state of Colorado by early undocumented stocking of pure CRCT produced at Trappers Lake between 1903 and 1938. These populations did not attract further interest until sequencing of their mitochondrial DNA revealed a match with museum specimens collected by Aiken from the San Juan River in Pagosa Springs, Colorado in 1874. This finding precipitated further exploration of the nuclear AFLP data. Since no confirmed reference populations were included in our AFLP analysis, STRUCTURE was coerced into selecting the "best fit" from the existing reference groups. Examination of the principal coordinate plot (Figure 5) not only helps explain why blue lineage CRCT were selected over other lineages, but demonstrated that, at least with the AFLP loci used, nuclear DNA also suggested that the San Juan lineage of Cutthroat Trout are a discrete entity worthy of conservation. To examine if STRUCTURE would also support that assessment, AFLP data were reanalyzed in STRUCTURE without using prior information (reference groups). Even at K=3 the San Juan lineage fish distinguished themselves from other Cutthroat Trout of the southern Rocky Mountains (Figure 6).

Our findings are consistent with earlier studies focused on evaluating admixture with Rainbow Trout and Yellowstone Cutthroat Trout using starch gel protein electrophoresis (Kanda et al. 2000). These authors recorded genetic variation in 16 of 41 loci examined among 24 CRCT populations. They used 10 loci to diagnose admixture with Rainbow Trout and three loci for evaluating admixture with Yellowstone Cutthroat Trout. It is noteworthy that these 16 loci with variable allele frequencies did not separate the one San Juan lineage fish (Headache Creek) from four blue lineage populations (East Fork Piedra River, Lake Nanita, Northwater Creek, Trapper Creek) but did distinguish them from six green lineage populations (Roan Creek, Antelope Creek, Hubbard Creek, Dyke Creek, Little Taylor Creek, and Rio Lado) at the *bGLUA* locus.

Finally, the same DNAs obtained from Headache Creek were shared with the Thorgaard Lab at Washington State University to be included in a Cutthroat Trout rangewide phylogeny developed around the OmyY1 gene near the sex-determining area of the paternally inherited Y-chromosome (Brunelli et al. 2013). Despite 10 CRCT populations being included, only three haplotypes were recovered. This is not an unexpected result since the OmyY1 region evolves 3-13 times more slowly than mitochondrial genes (Brunelli et al. 2013). In fact, several other subspecies (e.g. Lahonton Cutthroat Trout, Coastal Cutthroat Trout, Yellowstone Cutthroat Trout, and Rio Grande Cutthroat Trout) were represented only by a single haplotype (Brunelli et al. 2013). Of the three CRCT haplotypes recovered, one was found across all blue and most green lineage populations, one was found in Roan Creek (a green lineage population), and an additional private haplotype found only in Headache Creek (San Juan lineage). A broader survey of the OmyY1 gene across many more populations is warranted to determine if this marker is diagnostic for the native fish of the San Juan basin.

As genomic resources provide ever-increasing power for detecting finer-scaled genetic structure, we must be leery of equating population structure with species boundaries (Carstens et al. 2013; Sukumaran et al. 2017). If the diagnostic phylogenetic species concept is used to delineate species, great harm could accrue to small isolated populations subjected to inbreeding depression and genetic drift that are no longer considered as candidates for genetic rescue because they are now a putative species (Frankham et al. 2012). Structure revealed by modern molecular methods should only serve as tentative hypothesis of species boundaries (Sukumaran et al. 2017) that should subsequently be tested. Other classes of data (e. g. morphological or ecological) should be used to correctly attribute elements of genetic structure to either species or population-level processes (Sukumaran et al. 2017). Frankham et al. (2012) conclude that the diagnostic phylogenetic species concept is unsuitable for classifying allopatric populations in particular and for conservation in general.

Whether the San Juan lineage of CRCT represents a discrete taxonomic entity has been debated (Rogers et al. *in press*). Regardless of what we choose to call the native trout of the San Juan River basin, it represents a unit of diversity worthy of conservation (Funk et al. 2012; Rogers et al. 2014; Rogers et al. *in press*) as well as a conservation success story. We are fortunate those who came before adhered to fundamental conservation principles – specifically, preserving all of the pieces, even when they were unaware of the molecular diversity harbored by these fish. While biologists in the 1980s and 1990s had no way of knowing the unique molecular structure hidden in these rare trout, they recognized that with imperfect tools the prudent action was to manage with basin specific stocks, even when morphological trait differences could not obviously be detected. Above all, they focused on securing what populations were left. Now, armed with powerful molecular tools, it is clear how fortunate we are to have these remaining pieces of this evolutionary legacy to manage.

While the rediscovery of what appear to be San Juan lineage Cutthroat Trout presents some exciting opportunities for preserving the legacy of Colorado's native trout, these fish will require some anthropogenic assistance if their future is to be secure. Extant populations are small, with perhaps as few as 1000 fish remaining in aggregate. They occupy just 14.9 km of isolated headwater habitat, with the longest contiguous piece being only 3.8 km. Though protected by natural or man-made barriers, all are vulnerable to drought, fire, and flooding. Fish management histories for each population are detailed in Appendix 2 and include population and genetic surveys, as well as temperature profiles where available. Opportunities for near-term conservation actions include additional survey work, as well as building barriers to protect against nonnative invasions, chemical reclamations, translocations, developing broodstocks, and protecting in-stream flows. The demonstrated track record of successful conservation efforts by the CRCT Conservation Team suggests that all of these actions are reasonable and have been implemented with good success elsewhere across the range of CRCT. We feel fortunate that this remnant diversity has been identified so that appropriate conservation measures can be enacted to secure the future of these fish in Colorado.

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Literature cited

Behnke, R. J. 1992. Native trout of western North America. American Fisheries Society Monograph 6, Bethesda, Maryland.

Behnke, R. J. 2002. Trout and salmon of North America. The Free Press. New York, New York.

Bestgen, K. R., K. B. Rogers, and R. Granger. 2013. Phenotype predicts genotype for lineages of native Cutthroat Trout in the Southern Rocky Mountains. Final Report to U. S. Fish and Wildlife Service, Colorado Field Office, Denver Federal Center (MS 65412), Denver, CO. Larval Fish Laboratory Contribution 177. Available online at http://cpw.state.co.us/cutthroat-trout

Brunelli, J. P., J. M. Mallatt, R. F. Leary, M. Alfaqih, R. B. Phillips, and G. H. Thorgaard. 2013. Y chromosome phylogeny for Cutthroat Trout (*Oncorhynchus clarkii*) subspecies is generally concordant with those of other markers. Molecular Phylogenetics and Evolution 66:592-602.

Carstens B, T. Pelletier, N. Reid, and J. Satler. 2013. How to fail at species delimitation. Molecular Ecology 22:4369–4383.

Edgar, R. C. 2004. MUSCLE: multiple sequence alignment with high accuracy and high throughput. Nucleic Acids Research 32:1792-1797.

Falush, D. M., M. Stephens, and J. K. Pritchard. 2007. Inference of population structure using multilocus genotype data: dominant markers and null alleles. Molecular Ecology Notes 7:574-578.

Frankham R., J. D. Ballou, M. R. Dudash, M. D. B. Eldridge, C. B. Fenster, R. C. Lacy, J. R. Mendelson III, I. J. Porton, K. Ralls, O. A. Ryder. 2012. Implications of different species concepts for conserving biodiversity. Biological Conservation 153:25–31.

Funk, W. C., J. K. McKay, P. A. Hohenlohe, and F. W. Allendorf. 2012. Harnessing genomics for delineating conservation units. Trends in Ecology and Evolution 27:489-496.

Hirsch, C. L., M. R. Dare, and S. E. Albeke. 2013. Range-wide status of Colorado River Cutthroat Trout (Oncorhynchus clarkii pleuriticus): 2010. Colorado River Cutthroat Trout Conservation Team Report. Colorado Parks and Wildlife, Fort Collins, Colorado. Available online at http://cpw.state.co.us/cutthroat-trout

Juday, C. 1906. A study of Twin Lakes, Colorado, with especial consideration to the foods of the trouts. Bulletin of the U. S. Bureau of Fisheries document 616:147-178.

Kanda, N., R. F. Leary, F. W. Allendorf. 2000. Population genetic structure of Colorado River Cutthroat Trout in Colorado and Wyoming. Wild Trout and Salmon Genetics Laboratory report 00/2. University of Montana, Missoula.

Kumar, S., G. Stecher, and K. Tamara. 2016. MEGA7: Molecular Evolutionary Genetics Analysis version 7.0 for bigger datasets. Molecular Biology and Evolution 33:1870-1874.

Loxterman, J. L., and E. R. Keeley. 2012. Watershed boundaries and geographic isolation: patterns of diversification in Cutthroat Trout from western North America. BMC Evolutionary Biology 12:38.

Metcalf, J. L., Pritchard, V. L., Silvestri, S. M., Jenkins, J. B., Wood, J. S., Cowley, D. E., Evans, R. P., Shiozawa, D. K. and Martin, A. P. 2007. Across the great divide: genetic forensics reveals misidentification of endangered Cutthroat Trout populations. Molecular Ecology, 16: 4445–4454.

Metcalf, J. L., S. L. Stowell, C. M. Kennedy, K. B. Rogers, D. McDonald, J. Epp, K. Keepers, A. Cooper, J. J. Austin, and A. P. Martin. 2012. Historical stocking data and 19th century DNA reveal human-induced changes to native diversity and distribution of Cutthroat Trout. Molecular Ecology 21:5194-5207.

Peakall, R. and P. E. Smouse. 2012. GenAlEx 6.5: genetic analysis in Excel: population genetic software for teaching and research - an update. Bioinformatics 28, 2537-2539.

Pritchard, V. L., K. Jones, and D. E. Cowley. 2007. Estimation of introgression in Cutthroat Trout populations using microsatellites. Conservation Genetics 8:1311-1329.

Pritchard, V. L., J. L. Metcalf, K. Jones, A. P. Martin, and D. E. Cowley. 2009. Population structure and genetic management of Rio Grande Cutthroat Trout (*Oncorhynchus clarkii virginalis*). Conservation Genetics, 10: 1209–1221.

Rogers, K. B. 2008a. Using amplified fragment length polymorphisms to characterize purity of Cutthroat Trout in Colorado: results from 2007. Colorado Division of

Wildlife, Fort Collins.

Rogers, K. B. 2008b. QStrap: bootstrapping confidence intervals around admixture estimates from STRUCTURE output. Version 3.1. Colorado Division of Wildlife. Available online at http://cpw.state.co.us/learn/Pages/ResearchAquaticSoftware.aspx.

Rogers, K. B. 2012. Piecing together the past: using DNA to resolve the heritage of our state fish. Colorado Outdoors 61(5):28-32. Available online at http://cpw.state.co.us/cutthroat-trout.

Rogers, K. B., K. R. Bestgen, and J. Epp. 2014. Using genetic diversity to inform conservation efforts for native Cutthroat Trout of the southern Rocky Mountains. Pages 218-228 in R. F. Carline and C. LoSapio, editors. Wild Trout XI: Looking back and moving forward. Wild Trout Symposium, West Yellowstone, Montana. Available online at http://www.wildtroutsymposium.com/proceedings.php.

Rogers, K. B., K. R. Bestgen, S. M. L. Stowell, and A. Martin. *In press*. Cutthroat Trout diversity in the southern Rocky Mountains. Pages in P. Trotter, P. Bisson, L. Schultz, and B. Roper, editors. Cutthroat Trout: evolutionary biology and taxonomy. American Fisheries Society, Bethesda, Maryland.

Rogers, K. B., J. Epp, and J. Wood. 2011. Development of an amplified fragment length polymorphism (AFLP) test to distinguish Colorado River from Rio Grande Cutthroat Trout. Colorado Parks and Wildlife report, Fort Collins. Available online at http://cpw.state.co.us/cutthroat-trout.

Sukumaran, J. and L. L. Knowles. 2017. Multispecies coalescent delimits structure, not species. Proceedings of the National Academy of Sciences (USA) 114:1607-1612.

Appendices

Appendix 1

Sequence data representing 648 base pairs of the mitochondrial NADH subunit 2 gene from extant trout populations in the San Juan drainage that describe the two San Juan haplotypes recovered.

OcCOL-Tabegauche (H-106463)
TAATGTTAGCCCTCGCCCTCAAGCTTGGACTAGCACCCGTTCACTTCTGACTC
CCAGAAGTTCTTCAAGGACTTGAACTCACCACAGGATTAATCCTCTCAACCTG
ACAAAAACTCGCACCCTTCGCACTTATAATTCAAACAGCCCCAACCATCAAC
TCTTCCCTACTTATCGCAATCGGCCTTCTATCAACACTTGTGGGGGGTTGAGG
TGGGCTTAATCAAACCCAACTGCGTAAAATTCTAGCATATTCTTCAATTGCCC
ACCTAGGATGAATAGTACTAATTTTACAATTCGCACCCTCCCTCACACTCCTC
AGCCTATCCCTGTATATTATCATAACATCTTCAGCATTCCTCACATTAAAAAC
CAACAACGCTTTAACCATCAACACTCTCGCGACTTCATGAACTAAATCCCCG
ACCCTTGCCACATTAGCCGCTCTTGTACTGCTGTCCCTTGGGGGTCTCCCCCC
TCTCTCAGGCTTTATACCAAAATGACTTATTTTGCAAGAACTAACAAAGCAAG
GACTCCCGCTATCTGCCACACTAGCTGCTATAACAGCCCTCCTGAGCCTTTAC
TTTTATCTACGACTCTGCTACGCCTTAACCCTCACTATTTATCCCAACACCCTA
ACTGCCACTGCCC

OcCOL-Cutthroat (CUT-126486)
TAATGTTAGCCCTCGCCCTCAAGCTTGGACTAGCACCCGTTCACTTCTGACTC
CCAGAAGTTCTTCAAGGACTTGAACTCACCACAGGATTAATCCTCTCAACCTG
ACAAAAACTCGCACCCTTCGCACTTATAATTCAAACAGCCCCAACCATCAAC
TCTTCCCTACTTATCGCAATCGGCCTTCTATCAACACTTGTGGGGGGTTGAGG
TGGGCTTAATCAAACCCAACTGCGTAAAATTCTAGCATATTCTTCAATTGCCC
ACCTAGGATGAATAGTACTAATTTTACAATTCGCACCCTCCCTCACACTCCTC
AGCCTATCCCTGTATATTATCATAACATCTTCAGCATTCCTCACATTAAAAAC
CAACAACGCTTTAACCATCAACACTCTCGCGACTTCATGAACTAAATCCCCG
ACCCTTGCCACATTAGCCGCTCTTGTACTGCTGTCCCTTGGAGGTCTCCCCCC
TCTCTCAGGCTTTATACCAAAATGACTTATTTTGCAAGAACTAACAAAGCAAG
GACTCCCGCTATCTGCCACACTAGCTGCTATAACAGCCCTCCTGAGCCTTTAC
TTTTATCTACGACTCTGCTACGCCTTAACCCTCACTATTTATCCCAACACCCTA
ACTGCCACTGCCC

Appendix 2 – Populations of interest

A water by water summary of population characteristics relevant to the management of Cutthroat Trout populations in the San Juan River basin that harbor mitochondrial DNA native to the drainage. Colorado Parks and Wildlife (CPW) water codes (WC), CRCT Conservation Population ID's (from Hirsch et al. 2013), and length of occupied habitat in that same database are presented for each water.

Big Bend Creek (WC#47325)
CRCT Conservation Population ID:
14080104cp002
Occupied habitat: 3.2 km

Cutthroat Trout from Big Bend Creek

Big Bend Creek is a tributary to Hermosa Creek in the Animas River Basin. First surveyed in 1987, both hybridized and non-hybridized Cutthroat Trout were noted. In 1989, a 4.5 m bedrock cascading barrier was located, isolating only Cutthroat Trout upstream. With a severe drought that same summer, managers worried that the small population in Big Bend Creek might not persist, so 204 individuals were transplanted from the headwaters of Big Bend Creek to Clear Creek, another tributary of Hermosa Creek. These fish were placed above a 12 m waterfall barrier in the barren headwaters of Clear Creek. It is worth noting that a follow up survey in 1991 (Table A2-1) recovered no fish in Big Bend or Clear Creek. Managers assumed low water conditions over the winter resulted in the extirpation of both populations. Fortunately, subsequent surveys demonstrate these fish are resilient to drought conditions (Table A2-1), and both populations still persist today.

Table A2-1: Survey history and results for the Cutthroat Trout population in Big Bend Creek. Population estimates (adult fish per km) were based on the number of fish captured (n) that exceeded 150 mm over the surveyed station length (m).

Year	Date	n	Length (m)	Fish per km	Comments
1987	Jul 13	51	152	248*	First survey
1989	Jun 13	10	46		Barrier confirmed; fish salvage
1991	Aug 27	0	152		Half mile above barrier; no fish
1995	Oct 19	59	152	119	Half mile above barrier
2000	Aug 24	20	91		Taxonomy collection
2004	Jul 26	22	152	39	Half mile above barrier
2007	Jun 20	68	152	59	At barrier (9 fish >150mm)
2014	Jun 6	6	152	25*	Only single fish>150mm

* Single pass survey

Water temperatures were monitored in the summer of 2014 (May 10 – September 26th). The stream appears to be in no imminent threat of critically warm temperatures, with an MWMT = 14.5 °C with a daily maximum temperature (Todd et al. 2008; Rogers 2015) of 16.1 °C. A M30AT of 11.5 °C suggests that the stream should support robust recruitment (Coleman and Fausch 2007; Roberts et al. 2013), but that growth will be somewhat compromised as an M30AT near 15 °C is usually required for maximizing tissue elaboration in Cutthroat Trout (Bear et al. 2007; Ziegler et al. 2013).

Molecular surveys:

Ten Cutthroat Trout were collected by Mike Japhet on August 24, 2000 from Big Bend Creek and sent to Dr. Robb Leary at the University of Montana for analysis. Although they looked to be pure CRCT by PINES (Paired Interspersed Nuclear Elements), electrophoretic analysis results were less certain. One of three loci allegedly diagnostic for distinguishing CRCT from Yellowstone Cutthroat Trout (Leary 2002) showed Big Bend fish containing alleles characteristic of both taxa. In light of molecular findings from this report, it is certainly possible that the sMEP-1 locus is simply not a diagnostic marker for all CRCT populations.

On June 20, 2007, Jim White collected another 30 fish from three locations above the waterfall barrier for AFLP analysis. These all aligned with blue lineage CRCT when using the standard AFLP reference populations (Rogers 2008a). Twenty of these same DNAs were subsequently sequenced at the ND2 mitochondrial gene and all were found to exhibit the common San Juan lineage haplotype.

Clear Creek (WC#47565)
CRCT Conservation Population ID: 14080104cp001
Occupied habitat: 2.7 km


Cutthroat Trout from Clear Creek (archived)

Clear Creek is a tributary to Hermosa Creek, just south of Big Bend Creek and within the Animas River Basin. Clear Creek was barren of fish above a 12 m waterfall before 204 Cutthroat Trout were transplanted from nearby Big Bend Creek in 1989 with a helicopter. After no fish were captured in 1990 it was thought that the transplanted fish perished because the lower section of Clear Creek went dry. However, a 1996 survey discovered the population above the waterfall was in good condition with moderate densities of fish (140 fish/km). Below the waterfall, it is not unusual in dry years for sections of the creek to go sub-surface only to emerge near the confluence with Hermosa Creek.

A population survey conducted June 17, 2014 yielded 35 Cutthroat Trout ranging in size from 60-240 mm over two removal passes. The estimated density of trout in the 152 m reach of stream was 112 fish/km, with fish displaying robust relative weights despite post-spawn condition (mean Wr =106%). Twelve fish were preserved individually in 10% formalin for phenotypic evaluation and archiving at the Larval Fish Laboratory, Colorado State University, Fort Collins, Colorado.

Water temperatures were recorded hourly in Clear Creek from mid May through September of 2014. The maximum daily temperature (Todd et al. 2008) was 15.8 °C, while the MWMT for that summer was 14.0 °C. Clear Creek is a cold stream with M30AT of only 10.9 °C, well below the optimum for growth (Bear et al. 2007; Ziegler et al. 2013), but enough to register consistent recruitment (Coleman and Fausch 2007; Roberts et al. 2013).

Molecular surveys:

Fin clips from 12 fish from the 2014 survey effort were preserved in 80% ethanol and submitted to Pisces Molecular (Boulder, Colorado) for AFLP analysis. Using our standard reference groups (Rogers 2008a), these fish (like the ones from Big Bend Creek) aligned with blue lineage CRCT. Subsequent sequencing of 648 base pairs from the ND2 mitochondrial gene revealed that they too all harbored the common San Juan lineage CRCT haplotype.

Cutthroat Creek (WC#39415) and
Grayhackle Lake (WC#96457)
CRCT Conservation Population ID:
14080101cp005
Occupied habitat: 3.6 km and 1.4 ha

Cutthroat Trout from Grayhackle Lake

Cutthroat Creek is a small tributary to the Navajo River located on the eastern side of the Upper San Juan River Basin within the Banded Peak Ranch. Dolomite and Grayhackle lakes form the headwaters of Cutthroat Creek. The stream and lakes are protected near the confluence with the Navajo River by a 2 m high irrigation diversion structure. The ranch manager reinforced this diversion as a barrier to fish migration in 2016. There is no record of fish being stocked in Grayhackle or Cutthroat Creek, though the lake is accessible via a steep 4-wheel drive logging road. Rick Lapin, the old Banded Peak Ranch manager, reported that he caught “Rio Grande Cutthroat Trout” from Grayhackle Lake. It was later learned that the previous ranch manager, and former Colorado Division of Wildlife officer (Judd Cooney), claimed he stocked Yellowstone Cutthroat Trout in Grayhackle Lake in the late 1970s. In 1998, Mike Japhet discovered an old abandoned automatic fish feeder at the lake and evidence that the spillway was once dammed up with plastic sheeting to deepen the water. Grayhackle Lake has a maximum depth of 8 feet and an average depth of only 5 feet. There is ample spawning habitat in the inlet of the shallow lake and numerous fry were observed during the 1998 fish survey.

Molecular surveys:

The stream was first surveyed on June 20, 1998. Ten trout were collected for meristic and DNA analysis and a population estimate was generated for occupied habitat just above the barrier. Fish density was estimated to be 52 fish/km over 150 mm (total length) with many smaller fish in the survey. If the minimum size threshold is relaxed to 100 mm, the estimate rises to 191 fish/km. The 10 fish samples were sent to Dr. Robb Leary at the University of Montana for electrophoretic analysis. Although rainbow trout alleles were detected at two of ten putatively diagnostic loci (Leary 2002), he suggested they likely represented genetic variation previously unknown in CRCT populations, and therefore not diagnostic. A second collection of 40 fish from the middle and upper reaches of Cutthroat Creek occurred on July 18 of 2002, and were sent to Dr. Dennis Shiozawa at Brigham Young University for analysis. These samples appeared to be pure CRCT with no evidence of Rainbow Trout or Yellowstone Cutthroat Trout introgression (Evans and Shiozawa 2003). Six more fin clips were collected on June 9th, 2013 and 648 base pairs in the ND2 mitochondrial gene were sequenced. Four of these shared the common San Juan lineage CRCT haplotype while the remaining two harbored a single base pair variant (Appendix 1).

Grayhackle Lake in the headwaters of Cutthroat Creek was surveyed by gillnet on August 20, 1998. An overnight set resulted in the capture of 29 fish ranging from 150-458 mm. Six of these fish were submitted to BYU for purity testing in 1998, while the remainder were too degraded. Results suggest 5 of the 6 fish were pure CRCT but the remaining fish was a Rainbow Trout (Evans and Shiozawa 2000) as measured with both mitochondrial and nuclear markers. An additional 10 fish were collected on June 19th, 2013, none of which appeared to display any Rainbow Trout or Yellowstone Cutthroat Trout admixture as measured with AFLPs (albeit a small sample size). Subsequent sequencing of the ND2 mitochondrial gene showed that all ten fish shared the common San Juan lineage CRCT haplotype.

Fall Creek (WC#38117)
CRCT Conservation Population ID: 14080101cp008
Occupied habitat: 0.3 km

Cutthroat Trout from Fall Creek

Fish were first collected from Fall Creek, located at the base of Wolf Creek Pass and a tributary to the West Fork of the San Juan River, in October 1976. The stream is very small and the Cutthroat Trout only inhabit a reach from Treasure Falls to the Highway 160 road crossing. The highway culvert serves as a barrier to invasion by downstream nonnative trout.

Molecular surveys:

Tissue samples were collected from 10 trout in August 1999 and sent to Dr. Robb Leary at the University of Montana for study. Dr. Leary was unable to extract any high quality nuclear DNA for PINEs testing. Biologist Mike Japhet noted numerous spots on the heads of the fish suggesting these fish might be introgressed with Rainbow Trout and therefore not worthy of further consideration. As part of the search for the lost San Juan trout, a small sample of fin clips (11 fish) were collected on June 19th, 2014 to at least determine if any remnant San Juan haplotypes were evident. Indeed, all 11 fish harbored the San Juan lineage CRCT haplotype, which precipitated another collection on July 23rd, 2015 of 25 additional fish that would allow for evaluation of Rainbow Trout admixture in the population. Again, all 25 fish displayed the San Juan lineage CRCT haplotype, but more importantly, no evidence of Rainbow or Yellowstone Cutthroat Trout admixture was detected with AFLP markers.

Headache Creek (WC#39491)
CRCT Conservation Population ID: 14080101cp004
Occupied habitat: 1.3 km

Cutthroat Trout from Headache Creek

Headache Creek is a small tributary of the Navajo River within the confines of the Banded Peak Ranch. The fish community was first surveyed on July 22, 1998 and resident Cutthroat Trout were documented despite no stocking history. Headache Creek contains a very small population (85 -152 fish/km) of Cutthroat Trout in an equally small section of the stream (<1 km; Table A2-2). With no natural barrier to protect this population from invasion by nonnative salmonids in the Navajo River, it was not surprising to find Brook Trout also occupying the stream. In 2000, the Banded Peak Ranch managers (Lesli Allison and Anna Jester) contracted Dave Rosgen (Wildland Hydrology Consultants, Fort Collins, Colorado) to build a double drop barrier (Figure A2-1) above the confluence to secure the population from future invasions. Brook Trout were then removed from this reach of Headache Creek during annual single pass electrofishing efforts from 1999 to 2005. The removal effort appears to have been successful, as no brook trout have been detected since 2004. This barrier was fortified in 2017 after high spring flows washed out the downstream drop structure.

Figure A2-1: Double drop fish passage barrier on Headache Creek circa 2009 on left and again in 2017 on right.

Table A2-2: Survey history and results for the Cutthroat Trout population in Headache Creek. Population estimates (adult fish >150 mm per 1.6 km) and associated confidence intervals (95% CI) were generated from two removal passes over 152 m of stream.

Year	Date	n	Density	95% CI	Comments
1998	Jul 22	17			Single pass; 10 samples for genetic analysis
1999	Sep 3	10			Single pass; 10 samples for genetic analysis
2005	Aug 3	15	85	34	High water (Capture P=0.71)[1]
2006	Aug 30	27	152	8	Low water (Capture P=0.91)
2014	Aug 7	17			Single pass[2]
2015	Jun 29	27	85	408	High water/crippled tech (Capture P=0.60)
2017	Jun 5	0			Single pass[3]

[1]Thirty six Cutthroat Trout captured in entire length of occupied habitat
[2]Electrofished around upper headgate and in spawning channel and moved 17 fish to Gramps Ponds
[3]Electrofished spawning channel and adjacent mainstem headgate area looking for spawning Cutthroat Trout but found none

Much of the best habitat in Headache Creek is dewatered by the Virginia Meadow Diversion. The Virginia Meadow irrigation ditch takes about half the water during the irrigation season. However, there is a headgate and ditch downstream near the barrier, that diverts most of the remaining water into a series of 3 reclaimed ponds near the Banded Peak Ranch headquarters that are devoid of nonnative fishes. These basins had been used to contain effluent from oil and gas operations in the 1970s. Although cleaned and remediated, the liner on the bottom should not be disturbed according to the ranch manager. "Gramps Ponds" average about an acre in size each and were specifically designed to serve as broodstock ponds complete with a small spawning channel entering the ponds and barrier (culvert stand pipe) upon exit. Anecdotal evidence suggests the Cutthroat Trout from Headache Creek have not colonized the lakes in appreciable numbers since they were reclaimed in 2003. Concern over fish mortality precluded setting gill nets for more than a few hours at a time in Gramps Ponds, but a 23 m experimental gill net set for 2 hours near the inlet on the South Pond on May 17, 2014 captured only a single Cutthroat Trout. Two more set on June 2, 2015 (one each in Middle and North ponds) for 3 hours each yielded no fish.

Macroinvertebrate densities and temperatures appear suitable for Cutthroat Trout in the ponds. Freshwater scuds (*Gammarus* sp.) are abundant and a small littoral area has developed around the margins. The headgate from Headache Creek to the spawning channel and ponds remains open during the winter allowing freshly oxygenated water to enter the ponds suggesting winterkill conditions are unlikely. Temperatures did not exceed critical thresholds for Cutthroat Trout from 2015-2017, with near optimal conditions for growth (Table A2-3).

Table A2-3: Maximum daily temperature (MDT), maximum weekly maximum temperature (MWMT), and average 30-day average temperature (M30AT) in ºC were calculated from a temperature logger positioned on the surface of Gramps Pond` #1.

Year	MDT	MWMT	M30AT
2015	16.2	15.7	14.7
2016	16.5	16.1	14.4
2017	14.6	14.0	13.0

Molecular surveys:

Ten trout were collected on July 22, 1998 and sent to Dr. Robb Leary (University of Montana) for analysis with horizontal starch gel protein electrophoresis. Dr. Leary indicated that they were probably pure CRCT fish but noted that they possess a rare allele indistinguishable from Rainbow Trout (Kanda and Leary 1999; Kanda et al. 2000). An additional 10 tissue samples were collected on September 3, 1999 and sent to Brigham Young University for analysis. Both mitochondrial and nuclear DNA suggested this collection did not contain admixture with Rainbow Trout or Yellowstone Cutthroat Trout, and that they were consistent with CRCT (Evans and Shiozawa 2000). Fin clips were collected from two-dozen trout in 2006, which too suggested these fish were pure with no evidence of nonnative alleles as measured with AFLPs (Rogers 2008a). Subsequent mitochondrial analysis suggested these fish harbor the same San Juan River basin ND2 mitochondrial haplotype found in Aiken's museum specimens collected from Pagosa Springs in 1874.

Himes Creek (WC#39502)
CRCT Conservation Population ID: 14080101cp002+14080101cp003
Occupied habitat: 3.8 km

Cutthroat Trout from Himes Creek

The Cutthroat Trout population in Himes Creek was first discovered in 1994. The adult population (those over 150 mm) has ranged from 46 to 164 fish/km (Table A2-4). Brook Trout are present within the occupied habitat, but occur in very low numbers, mostly within the first quarter mile upstream of the barrier. They appear to have been introduced in the 1930s into a small, shallow headwater beaver pond named Rod and Gun Club Lake. This lake was surveyed with a 75 foot gillnet in 2001 for 1.5 hours. Leeches and larval form Tiger Salamanders were present but no fish were seen or caught. A mechanical removal effort on Brook Trout has been ongoing since 1999. A downstream barrier was constructed in 2001 to protect the population from subsequent invasions of nonnative salmonids, but most of the stream flow is diverted above the barrier and into hay fields during the irrigation season. During that time, the 460 m long channel below the diversion is typically dewatered.

Table A2-4: Survey history and results for the Cutthroat Trout population in Himes Creek. Population estimates (adult fish per km) and associated confidence intervals (95% CI) were generated from two removal passes over 152 m of stream during which time Brook Trout (BRK) were removed

Year	Date	Density	95% CI	BRK	Comments
1994	7/19/94	52	7	1	BRK at Diversion
1998	8/17/98	72	0		
2005	8/01/05	52	7	1	Single 5 inch BRK below diversion
2006	8/29/17			1	BRK at diversion; 137 CRN in reach*
2007	10/1/07	121	34	1	Single 250 mm BRK above diversion

2009	7/15/09			0	83 CRN from barrier to FS diversion tarp
2013	8/15/13	164	58	3	At diversion
2014	8/14/14			3	No pop est; 137 CRN captured
2017	8/02/17	46	8	3	BRK at diversion

*Electrofishing reach starts at USFS/Ranch boundary and ends at the Rod and Gun Club Lake tributary outlet on Himes Creek.

Molecular surveys:

Ten fish from Himes Creek were collected in 1994 (presumably on July 19th while a population estimate was being generated) and preserved in formalin. Don Proebstel (Colorado State University) examined morphological characters on these fish and found them to be consistent with CRCT (meristic counts within range), but did note that they had smaller spots on average than other CRCT (Proebstel et al. 1996). Genetic samples were first collected in 1998 and 1999 from Himes Creek and sent to Drs. Paul Evans and Dennis Shiozawa at BYU. These fish were determined to be pure CRCT and had "Colorado River mtDNA haplotypes". Two unique alleles were identified but not characterized because they were of unknown origin (Evans and Shiozawa 2000). An addition, 30 tissues samples were collected in October of 2007 for AFLP testing. These fish scored 100% CRCT with no evidence of Rainbow Trout or Yellowstone Cutthroat Trout admixture. Subsequent sequencing of the ND2 mitochondrial region from 20 fish showed that all shared the common San Juan lineage CRCT haplotype.

Rio Blanco River (WC#38439)
CRCT Conservation Population ID: NA
Occupied habitat: NA

Cutthroat Trout from Rio Blanco River

The Rio Blanco is a tributary to the Upper San Juan River. It is broken into two management sections by a large diversion dam that services the San Juan-Chama Water Project. The upper section (Rio Blanco #2), flows out of the South San Juan Wilderness then winds primarily through private land down to the diversion structure. There are no barriers to nonnative fishes in this reach, and Rainbow Trout are stocked extensively on the private lands. However, Cutthroat Trout and Brook Trout persist in the high gradient, unstable upper reaches of the river. An August 13, 1997 electrofishing survey in this area (upstream of Summit Creek confluence) recovered only 2 Brook Trout. No Cutthroat Trout were captured in a brief survey 400 m upstream of the Summit Creek confluence. Periodic floods in the headwaters scour the river channel through a box canyon starting at about Hondo Creek leaving little physical habitat for fishes. Cutthroat Trout are generally found from Hondo Creek upstream. Flash flooding occurred a few days before the August 16, 2013 sampling trip. Within a few hours flows the Rio Blanco rose from a baseflow of 20 cfs to almost 800 cfs then back to baseflow conditions. The scouring effect was obvious (Figure A2-2).

Figure A2-2. Flash flood scoured river channel in the headwaters of the Rio Blanco above Box Canyon.

The Rio Blanco headwaters are steep and no trails pierce the head of this very remote and rugged drainage. There are no headwater lakes and no records of fish being stocked in its two main tributaries (Hondo Creek and Summit Creek). In the fall of 1899, 10,000 fry were stocked somewhere in the drainage but no record of species or location could be found. It is likely that these fish were progeny from the Emerald Lakes Fish Hatchery as were several better-documented earlier stocking events in Archuleta County. Rainbow Trout had already been introduced into Emerald Lakes at that time, but majority of the spawn was likely taken from genetically intact San Juan lineage fish or "native fry". The drainage was stocked again in 1973 with "Pikes Peak natives" (see Rogers and Kennedy 2008), and with Colorado River Cutthroat Trout ("CRN" likely from Trappers Lake sources) in 1986, though we are uncertain as to how far up the drainage these were placed. Author Jim White's family moved to the Rio Blanco basin in 1976 where he grew up fishing the river and surrounding tributaries, but does not ever recall catching Rainbow Trout up in the Blanco Canyon reach in the early 1980s or at any other time.

Molecular surveys:

A return angling trip in 2013 yielded two Cutthroat Trout specimens, both which harbored the common San Juan lineage CRCT ND2 mitochondrial haplotype. This presents the intriguing possibility that San Juan lineage trout remain in this drainage, but a more robust survey effort will be required to evaluate purity in this population.

Appendix 2 citations:

Bear, E. A., T. E. McMahon, and A. V. Zale. 2007. Comparative thermal requirements of Westslope Cutthroat Trout: implications for species interactions and development of thermal protection standards. Transactions of the American Fisheries Society 136:1113-1121.

Coleman, M. A., and K. D. Fausch. 2007. Cold summer temperature limits recruitment of age-0 Cutthroat Trout in high-elevation Colorado streams. Transactions of the American Fisheries Society 136:1231-1244.

Evans, R. P. and D. K. Shiozawa. 2000. The genetic status of selected Cutthroat Trout populations in Colorado. Interim Report to David Langlois, Colorado Parks and Wildlife. 151 E. 16th Street, Durango, Colorado.

Evans, R. P. and D. K. Shiozawa. 2003. Genetic relationships of seven Cutthroat Trout populations from five streams in the Colorado River drainage of Colorado. Report to Colorado Parks and Wildlife, Colorado.

Hirsch, C. L., M. R. Dare, and S. E. Albeke. 2013. Range-wide status of Colorado River Cutthroat Trout (Oncorhynchus clarkii pleuriticus): 2010. Colorado River Cutthroat Trout Conservation Team Report. Colorado Parks and Wildlife, Fort Collins, Colorado. Available online at http://cpw.state.co.us/cutthroat-trout

Kanda, N., and R. F. Leary. 1999. Letter to Mike Japhet (CDOW) regarding electrophoretic analysis of Cutthroat Trout. Wild Trout and Salmon Genetics Laboratory, University of Montana, Missoula. Dec 7, 1999

Kanda, N., R. F. Leary, F. W. Allendorf. 2000. Population genetic structure of Colorado

River Cutthroat Trout in Colorado and Wyoming. Wild Trout and Salmon Genetics Laboratory report 00/2. University of Montana, Missoula.

Leary, R. 2002. Letter to Sherman Hebein (CDOW) regarding electrophoretic analysis of Cutthroat Trout. June 27, 2002.

Proebstel, D. S., A. M. Martinez, and R. P. Ellis. 1996. Taxonomic status of Cutthroat Trout, Rio Grande suckers, and Arkansas darters, determined through morphometric, meristic, and mitochondrial DNA analysis. Report to Colorado Division of Wildlife. 149 pp.

Roberts, J. J., K. D. Fausch, D. P. Peterson, and M. B. Hooten. 2013. Fragmentation and thermal risks from climate change interact to affect persistence of native trout in the Colorado River basin. Global Change Biology 19:1383-1398.

Rogers, K. B. 2008. Using amplified fragment length polymorphisms to characterize purity of Cutthroat Trout in Colorado: results from 2007. Colorado Division of Wildlife report, Fort Collins.

Rogers, K. B., and C. M. Kennedy. 2008. Seven Lakes and the Pike's Peak native (PPN): history and current disposition of a critical Cutthroat Trout brood stock. Colorado Division of Wildlife report, Fort Collins. Available online at http://cpw.state.co.us/learn/Pages/ResearchGreenbackCutthroatTrout.aspx.

Rogers, K. B. 2015. User manual for WaTSS 3.0 (Water temperature summary software). Colorado Parks and Wildlife, Steamboat Springs, Colorado. Retrieved from http://cpw.state.co.us/learn/Pages/ ResearchAquaticSoftware.aspx.

Todd, A. S., M. A. Coleman, A. M. Konowal, M. K. May, S. Johnson, N. K. M. Vieira and J. F. Saunders. 2008. Development of new water temperature criteria to protect Colorado's fisheries. Fisheries 33:9, 433-443.

Zeigler, M. P., S. F. Brinkman, C. A. Caldwell, A. S. Todd, M. S. Recsetar, and S. A. Bonar. 2013. Upper thermal tolerances of Rio Grande Cutthroat Trout under constant and fluctuating temperatures. Transactions of the American Fisheries Society 142:1395-1405.

Attachment I

Himes Creek Habitat Survey and Inventory Report

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Prepared for and in cooperation with the
Colorado Water Conservation Board
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Introduction

In December of 2015, the Colorado Water Conservation Board (CWCB) and Colorado Parks and Wildlife (CPW) initiated discussions with the San Juan National Forest (SJNF) staff regarding a collaborative effort to study and quantify instream flow (ISF) requirements on several streams of interest to the SJNF. The SJNF was interested in investigating the applicability of the Colorado ISF Program (administered by the CWCB) to meet SJNF stream protection and fishery management goals. Four streams on the SJNF were selected for "a pilot study" to test the overall ability of the CWCB program to satisfy the Forest Service's (USFS) stream protection goals and objectives. During the spring and summer of 2016, SJNF, CWCB, and CPW personnel collaborated on the collection of ISF quantification data on the four stream segments pre-selected for the pilot study. Himes Creek in Mineral County was one of the four pilot streams. Himes Creek is a small, first and second order tributary to the West Fork of the San Juan River near the base of Wolf Creek Pass, approximately 12 miles north of Pagosa Springs, CO.

The initial analyses that came to the State from the SJNF for Himes Creek indicated that the USFS thought R2CROSS was not appropriate for this stream type. The rationale for this opinion was based on the general lack of riffle or run habitat in Himes Creek. The stream is a very steep, plunge-pool stream, Rosgen stream type A or Aa+ (Rosgen, 1996 at 4-30) where the limiting low flow fish habitat are the small pools associated with plunges and waterfalls, rather than riffle habitat in a typical R2CROSS generated ISF recommendation. While riffles are not totally absent from Himes Creek (two riffles were located in the reach of interest to the FS), they are atypical for this stream and this stream type and do not represent conditions characteristic of the reach.

The natural environment in Himes Creek was originally thought to be a pure, self-sustaining population of Colorado River cutthroat trout. Later, genetic investigations on the Himes Creek cutthroats revealed that these fish are genetically rare and unique and are therefore of great importance to both the USFS and the State of Colorado. The precise genetic nature of this fish population is documented by CPW (Rogers et al, 2018) and this written report has been made available to the CWCB to support the Himes Creek ISF recommendation. SJNF personnel have expressed a preference for an "all unappropriated water" ISF recommendation for Himes Creek based on this fish species, the plunge-pool nature of the stream, and land status of the Himes Creek watershed.

Due to the opinions of the USFS described above and the USFS's somewhat unique approach to the Himes Creek ISF recommendation, CWCB staff requested an evaluation of Himes Creek by CPW. Specifically, CPW was asked to look at the recommended Himes Creek ISF reach in detail and assess the habitat and the USFS claims regarding the lack of riffle habitat, document the size and nature of the pool habitat, assess limiting habitat types, and photo document the reach for the benefit of the CWCB's ISF appropriation process. Such an assessment is largely qualitative in nature but there are quantitative comparative methods whereby an investigator is able to measure and report stream habitat characteristics. CPW and CWCB personnel determined that the R1/R4 methodology described in the USFS publication, *Fish and Fish Habitat Standard Inventory Procedures Handbook (INT-GTR-346),* could be modified to quantify, to some degree, the habitat in Himes Creek.

Background and Methods

In September of 2017, staff from CPW and CWCB conducted a modified R1/R4 habitat survey of Himes Creek; a first and second order stream located on the SJNF, Pagosa Ranger District, in southwest Colorado. The survey began at the point of diversion for Himes Creek Ditch, near the USFS boundary and ended at a point just upstream of the confluence with the Rod and Gun Club Lake tributary (Figure 1). Overall, 279 feet of stream was physically measured, distributed along 0.65 miles of Himes Creek using the sub-sampling protocol described below.

The R1/R4 survey protocol was developed to provide a tool for fisheries managers to describe the structure and dimension of fish habitat in wadeable streams using quantitative and repeatable metrics. This survey was specifically designed to detect changes or impacts to fish habitat from land-use practices. Surveyors identify specific Habitat Units (HU) delineated by fast or slow water types (i.e. a pool HU is defined by the head crest and tail crest of the pool). Within each HU, surveyors measure the dimensions of the pool, riffle, run, or cascade and quantify habitat attributes such as large wood, substrate size, and bank stability.

The R1/R4 survey protocol has numerous classifications for pool type or riffle type depending on the formative feature. Fast-water habitat types in Himes Creek were often steep cascades or high gradient riffles between step-pool channel types (Figure 4). A High Gradient Riffle (HGR) is a habitat type with a steep slope and fast, turbulent water, with large boulder and cobble substrate. This is distinct from a Low Gradient Riffle (LGR) that more closely resembles the traditional riffle habitat used in ISF quantification techniques such as R2CROSS. The distinction between a cascade, high gradient riffle, and low gradient riffle is primarily channel slope and substrate size. For slow-water habitat types, the survey uses a hierarchy structure to identify the type of pool (dammed or scour), the position in the channel, and the formative feature. For example, a common slow-water habitat type in Himes Creek is a scour plunge pool formed by boulders, or SPB. See Figures 4 - 8 for examples of high gradient riffles, scour pools, and runs in Himes Creek. For a more detailed description of habitat units and survey metrics see Overton, et al (1997).

Within each HU, the habitat type was classified using the above referenced manual; surveyors then measured the channel dimensions (length, width, and depth) within the HU. Several habitat attributes were quantified in addition to channel morphology, including bank stability as a percentage of the total bank length and large woody debris within the bankfull channel (single pieces and aggregates). Substrate size was quantified using a Wolman Pebble Count at two cross-sections. Each habitat unit was documented with photos and GPS coordinates, and detailed field notes regarding unique habitat features such as waterfalls or large cascades.

Sub-sampling

Surveyors used a sub-sampling protocol in order to survey a longer section of stream than would otherwise be possible with time constraints and the steep terrain of Himes Creek. The R1/R4 manual describes methods for determining a sub-sampling interval based on survey objectives. For the Himes Creek survey, staff sampled every tenth habitat unit, walking the entire stream channel and counting the number of Habitat Units between physical measurement locations.

Reference Streams

The R1/R4 survey produces several metrics that are suitable for comparison to other survey protocols, such as the Environmental Protection Agency's Wadeable Streams Assessment (WSA). Reference streams were selected from the WSA database based on the North American Level 3 Ecoregion Code, stream order, and reference condition noted in the database (see Table 4). Two streams that were classified as 'Slightly disturbed' (Red Mountain Creek and Adams Fork Conejos River) were added to the comparison due to their close proximity to Himes Creek (Figure 2).

Habitat inventory methods, such as R1/R4, use reference streams to provide context for habitat survey data by providing a benchmark to evaluate change over time (for repeated surveys) or for evaluating current stream condition. The reference streams identified in Table 5 can give insight to typical conditions in undisturbed landscapes subjected to similar habitat forming processes (ie: bank stability, large wood abundance). The reference stream comparison can also be used to identify areas where habitat types differ significantly (ie: channel slope, substrate size). However, the objectives of each habitat survey will influence the type and location of data collected; therefore, interpretations derived from comparisons of reference stream data should be used cautiously.

Results

Himes Creek is characterized by a steep, confined channel dominated by step-pools and cascades. The average channel slope is 18-20% with a width to depth ratio of 12. The average wetted width for all habitat types was 4.8 feet and the average depth was 0.4 feet. Approximately 52% of the habitat in Himes Creek is pool habitat, reflecting the series of step-pool type features that dominate this system (Table 1 and 2). Numerous small step-pools were measured in the survey of which the average pool depth was 0.4 feet. Large, deep pools were rarely encountered during the survey; the maximum pool depth was only 2.0 feet. Among all pools, the average residual pool depth was 0.8 feet (Table 1).

Approximately half (52%) of the habitat-units measured in Himes Creek were classified as slow-water habitat, reflecting the steep, step-pool environment of this system. The predominant slow-water habitat type observed was scour pools formed by a plunge over boulders (habitat type = SPB). The most abundant fast-water habitat types were Runs and High Gradient Riffles (HGR). Surveyors also measured two cascades with lengths of 17 and 44.5 feet that are representative of the abundance and size of cascades in this reach. Often times, the distinction between a cascade, HGR, or LGR was difficult to discern as the channel transitioned from cascades to HGR with subtle breaks in channel slope and braided channels.

The substrate of Himes Creek is comprised of large boulders and cobbles with a median size (D50) of 86.3 mm and D84 of 237.5 mm (Table 1). Large wood is abundant in this system and is a formative feature in many habitat units (Figure 11 and 12). Surveyors measured 946 pieces of "large wood" per mile (wood > 0.1 ft diameter and 3 ft long) primarily existing in one or two logs per Habitat Unit rather than as aggregates or debris jams. The stream banks are armored by large boulders or bedrock in most locations, resulting in greater than 95% of the banks classified as stable (Table 1 and 3). Several locations did show evidence of mass wasting adjacent to the stream with steep, bare soil banks approximately 30 feet long and 50 feet high; these adjacent landforms are a major source of sediment to this system (Figure 9). The riparian forest is primarily late successional fir and spruce, interspersed with large stands of aspen. Several areas had numerous wind-felled trees within the bankfull channel.

Himes Creek has a similar width to depth ratio to the nine reference streams that were selected (Table 5). This can be attributed primarily to the stable banks and lack of landscape disturbances that would induce over-widening or incising of the channel (Table 3). The average residual pool depth is also similar among Himes Creek and the reference streams. However, the stream metric for pool habitat (percent pool = 52%) in Himes Creek differs significantly when compared to the reference sites; this is primarily due to the steep channel gradient (18%) and large substrate size (D50 = 86.3mm). In comparison, the reference streams have a pool percentage of 4-27%, an average channel slope of 7%, and an average D50 of 16mm. In summary, the surveyed reach of Himes Creek has a much higher percentage of pools than the reference streams due to the step-pool nature of the stream. Figure 3 illustrates the unique habitat types found in Himes Creek when compared to reference streams with similar land-use patterns and basin size.

Discussion

Himes Creek and its watershed are largely free of anthropogenic disturbances that would disrupt the natural processes forming and maintaining fish habitat. There is no obvious evidence of present or historic livestock grazing, roads, timber harvest, or mining in the watershed and the entire basin, except for a small portion below the Himes Creek Ditch diversion structure, which is located on USFS system lands. The stream banks are primarily stable and armored by large boulders or bedrock; this limits excessive sediment source areas along the stream. As noted above, there are several points within the valley where landslide deposits or mass wasting deposits are adjacent to the stream; these areas are characterized by high, nearly vertical banks of bare soil. These features are natural but are a significant source of sediment to the stream. Himes Creek also has abundant riparian vegetation and large woody debris that provide cover and habitat features that are critical for fish.

Despite the undisturbed condition of Himes Creek, fish habitat availability is limited due to the high channel gradient and numerous cascades and plunge pools. Surveyors noted numerous small waterfalls that were 4-5.5 feet high, as well as long cascades, that may be a barrier to some life stages of fish, or a complete barrier during certain periods of the year. Habitat types that are important to specific fish life stages and seasons are also limited in this type of system. Suitable spawning gravels occur infrequently as the substrate is dominated by large boulders and cobbles. Sufficient pool depth for over-wintering habitat may also be limited as the average pool depth observed was only 0.4 feet. There were virtually no riffles in the segment, only a few short (less than 8 feet) higher gradient runs, and a few “rock garden” habitat units that were dominated by small basketball-size “pocket water pools.”

Comparing the R1/R4 survey data of Himes Creek to the reference streams highlights the unique habitat conditions found in this stream. There were few habitat types on Himes Creek that resemble the habitat conditions typically surveyed in other habitat inventories that would allow a more direct comparison (ie: gradient = 3-7%, D50 = 2-3mm). Although Himes Creek is characteristic of headwater mountain streams, this system is unique from a fish population perspective because water diversions downstream and waterfalls upstream impede fish movement. Steep channel gradient, numerous waterfalls and cascades, and large substrate size presents challenges for fish attempting to access over-wintering, spawning, or rearing habitat and the lack of habitat connectivity with downstream tributaries eliminates access to refugia during periods of drought, severe winters, excessively high flows, or other forms of disturbance.

Conclusions

The Himes Creek site visit and R1/R4 survey and analysis support the USFS's position on the following:

- Himes Creek is a very steep stream that is not conducive to standard R2CROSS or hydraulic modeling for ISF recommendation development. We observed very few habitat units where R2CROSS data could be collected. Furthermore, the few sites where such data could be collected and analyzed are not representative of the reach (they are more accurately categorized as outliers), and they do not fall under any definition of the "critical low flow habitat" that is the underlying assumption of the R2CROSS methodology.
- The Himes Creek survey was conclusive and confirmative of observations made previously by USFS and CPW Fishery Biologists and SJNF Hydrologists, namely that:
    - No true critical riffles exist in Himes Creek above the FS boundary.
    - While fish passage from pool to pool during low flow is a significant challenge to the fish population, the passage challenges are small cascades and waterfalls, not riffles. These are not appropriate sites for R2CROSS analysis.
    - The critical low flow habitats are pools and the available pool habitat consists of very small, relatively shallow pools. We know, from fish sampling events (including those before, during and following drought), that the Himes Creek fish survived in these small pools.
    - Spawning habitat, specifically spawning gravel substrate, seems to be rare in Himes Creek. To optimize spawning habitat availability and protection throughout the spawning and incubation seasons for the Himes Creek fish population, CPW believes that an ISF water right for all of the available flow is necessary to preserve the natural environment.
    - Professional judgment leads to the conclusion that the Himes Creek fish over-winter in these same small pools.
    - There is not a commonly accepted ISF methodology that can efficiently and accurately model pool dynamics (hydraulics) that will result in an accurate ISF recommendation.
    - Given the nature of the rare and unique natural environment in Himes Creek (the rare lineage Colorado River cutthroat trout – see Rogers et al, 2018) and the critical nature of the pool habitat upon which these fish depend, it is important that any ISF protection strategy ensure the perpetual existence and maintenance of the pools – they must be maintained in their current volume and quality, free from sediment accumulation over time. CPW is in agreement with the USFS that, in the case of Himes Creek, the full range of available flows are needed to ensure the protection this critical low flow habitat into the future.

- Due to the nature of the Himes Creek ISF reach – its natural environment characteristics, the aquatic habitat, and its hydraulics, CPW believes that the SJNF's approach to an ISF recommendation for Himes Creek is both reasonable and appropriate.

Tables

Table 1: Himes Creek R1/R4 habitat survey data summary

All habitat types				
Average depth (ft)	**Average length (ft)**	**Average width (ft)**	**Average slope**	**W/D ratio**
0.4	13.3	4.8	18-20%	12

Slow Water Habitat Type					
% of survey = pool	**# of pools per mile**	**Average pool depth (ft)**	**Average residual pool depth (ft)**	**Maximum pool depth (ft)**	**# of deep pools (>1ft)**
52%	208	0.4	0.8	2	5

Fast Water Habitat Type			
% of survey = Fast Water	**Average depth (ft)**	**Average length (ft)**	**Average width (ft)**
48%	0.34	15.9	3.7

Substrate size	
D50 (mm)	**D84 (mm)**
8630%	237.50

Bank stability	
Bank stability (% of total length)	**Undercut banks (% of total length)**
>95%	7

Large woody debris (LWD)		
LWD singles/mile (>0.1ft dia, >3ft length)	**Root wads/mile**	**LWD aggregates/mile**
946	19	340

Table 2: Dimensions for all habitat units measured during the Himes Creek R1/R4 habitat inventory. HGR: High Gradient Riffle, SPB: Scour Plunge Boulder, STP: Step-pool, DMW: Dammed Main LWD, RUN: Run, SMB: Scour Mid-scour Boulder, CAS: Cascade, LGR: Low Gradient Riffle

							Fast-water	Slow-water habitat type					
Habitat Unit #	Channel code	Habitat description	Habitat type**	Length (ft)	Width (ft)	Avg depth (ft)	Avg max depth (fast type) (ft)	Max depth (ft)	Crest depth (ft)	Step pool #	STP # pools >1m	STP avg max depth (ft)	Residual pool depth
1	Main	Fast	HGR	16	4	0.18	0.3						
2	Main	Slow	SPB	6.8	5	0.28		0.85	0.4				0.45
3	Main	Slow	SPB	7.5	6.6	0.2		0.6	0.2				0.4
4	Main	Slow	STP	10	4.5	1.05				3		1.05	
5	Main	Slow	DMW	8	6.6	0.31		1.1	0.2				0.9
6	Main	Fast	RUN	6.5	1.8	0.4	0.7						
7	Main	Fast	RUN	13	4.7	0.5	0.8						
8	Main	Slow	SMB	9.5	4.1	0.5		1.1	0.3				0.8
9	Main	Fast	HGR	9.2	2.6	0.25	0.6						
10	Main	Slow	SMB	8.2	7.5	0.4		0.9	0.3				0.6
11	Main	Slow	DMW	13.6	6.2	0.4		1.5	0.2				1.3
12	Main	Fast	HGR	9.5	2.2	0.2	0.7						
13	Main	Slow	SPB	9.4	4.5	0.25		1.3	0.2				1.1
14	Main	Fast	RUN	11.7	2.3	0.3	1						
15	Main	Fast	CAS	44.5	5.5	0.5	0.6						
16	Main	Fast	LGR	16.5	3.9	0.2	0.7						
17	Main	Slow	STP	27.3		0.7				6		0.7	
18	Main	Slow	SPB	7.5	7.1	0.4		1.3	0.2				1.1
19	Main	Fast	CAS	17	6.5	0.5	0.5						
20	Main	Slow	SPB	12.5	6.5	0.4		0.6	0.2				0.4
21	Main	Fast	RUN	15	3.7	0.4	1						

Table 3: Bank stability and large woody debris (LWD) for all habitat units measured during the Himes Creek R1/R4 habitat inventory.

	Bank stability						LWD		
Habitat Unit #	Bank length L (ft)	Bank length R (ft)	Stable L (ft)	Undercut L (ft)	Stable R (ft)	Undercut R (ft)	LWD singles	LWD aggregates	LWD root wads
1	16	18	16	0	18	0	0	0	0
2	6.8	6.8	6.8	0	6.8	0	1	0	0
3	7.5	8	7.5	0	8	4.5	0	0	0
4	10	10	10	0	10	0	0	0	0
5	8	8	8	0	8	4	1	1	0
6	6.5	6.5	6.5	0	6.5	0	0	0	0
7	13	13	13	0	13	0	2	0	0
8	9.5	9.5	9.5	3	9.5	0	4	0	0
9	9.7	9.7	9.7	0	9.7	7	3	10	0
10	8.2	8.2	8.2	0	8.2	0	0	0	0
11	7	13	7	0	13	0	5	1	1
12	9.5	9.5	9.5	0	9.5	0	1	0	0
13	9.4	9.4	9.4	7	9.4	4.5	4	0	0
14	11.7	11.7	11.7	0	11.7	0	1	0	0
15	44.5	44.5	44.5	0	44.5	0	0	0	0
16	16.5	16.5	16.5	0	16.5	0	5	4	0
17	27.3	27.3	27.3	0	27.3	0	10	0	0
18	7.5	7.5	7.5	4	7.5	0	4	0	0
19	17	17	17	0	17	0	1	1	0
20	15	15	15	0	15	0	4	0	0
21	15	15	15	5	15	0	4	1	0

Table 4: Selection criteria used to identify reference streams for comparison with the Himes Creek R1/R4 data.

Reference stream selection criteria		
Stream order	**Eco Region**	**Reference condition***
1st or 2nd	6.2.14 (Western Cordillera, Southern Rockies)	Reference

*two streams were included that are classified as 'slightly disturbed'

Table 5: Habitat data from nine reference streams and Himes Creek used for comparison of the Himes Creek R1/R4 habitat inventory results. Reference streams were surveyed by the Environmental Protection Agency's Wadeable Streams Assessment (WSA) program.

Site Name	State	LWD in bankfull (#/100ft)	D50 (mm)	% pool (% of reach)	Mean residual pool depth (ft)	Thalweg mean depth (ft)	Channel slope (%)	W/D ratio	Mean wetted width (ft)	Reach length (ft)	Reference condition (R = reference, S = slightly disturbed)
Saladon Creek	NM	0	2.10	4.3	0.48	0.43	3.05	47	12.57	463	R
Lost Man Creek	CO	0	3.00	19.3	0.44	0.64	18.74	6	3.28	492	R
Ouzel Creek	CO	19	1.51	12.9	0.77	1.66	6.19	18	28.28	912	R
Crystal Creek	CO	1	1.51	6.0	0.74	1.69	2.91	20	30.40	1230	R
Rock Creek	CO	8	3.00	5.0	0.53	1.57	10.42	16	26.89	787	R
No Name Creek	CO	4	3.00	16.0	0.84	1.64	6.45	13	18.16	656	R
Red Mountain Creek	CO	0	2.10	8.7	0.30	0.90	3.60	16	13.93	512	S
Adams Fork Conejos River	CO	0	2.10	14.0	0.42	0.50	6.57	13	6.59	492	S
Jack Creek	WY		130	27.0			5.50	16		413	
Himes Creek	CO	18	86.30	43.1	0.80	0.40	18.00	15	4.80	279	

Figures

Figure 1: Map of Himes Creek and survey reach

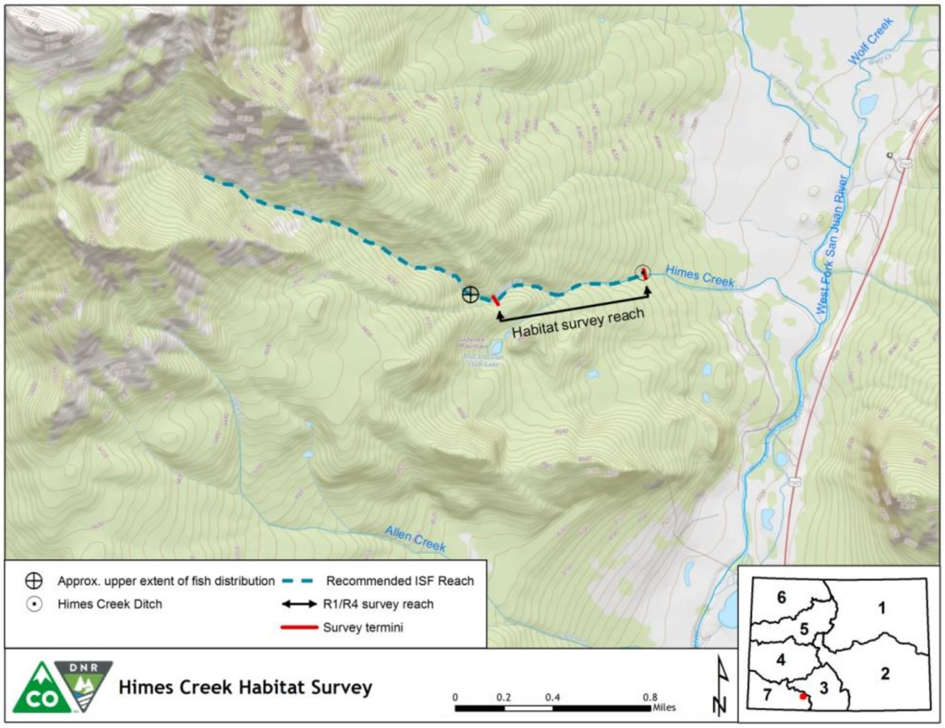

Figure 2: Reference streams location

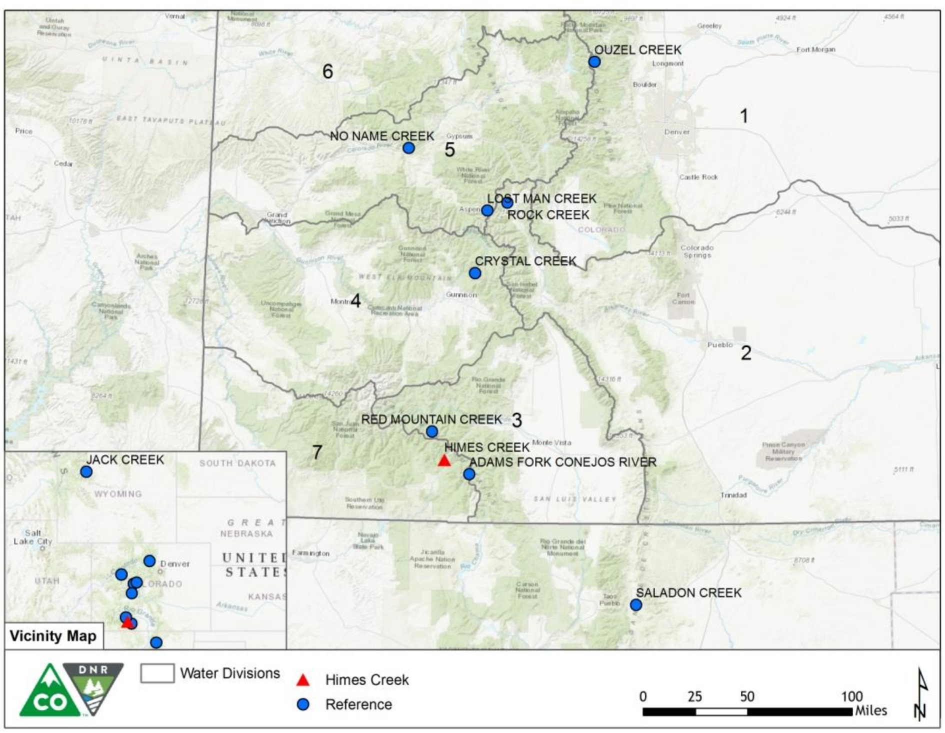

Figure 3: Boxplot of habitat survey data from Himes Creek (R1/R4 protocol) and reference streams (WSA protocol)

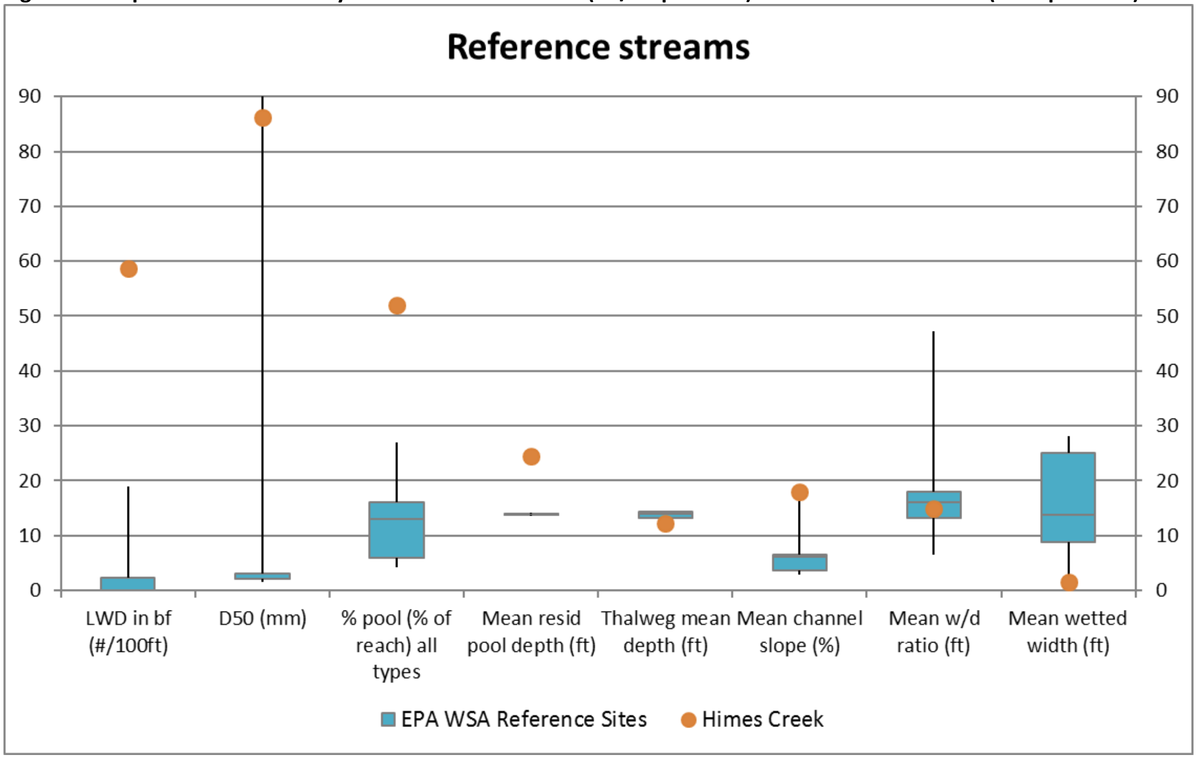

Figure 4: High Gradient Riffle (background) and Scour Plunge Boulder pool (foreground) at HU1 and HU2.

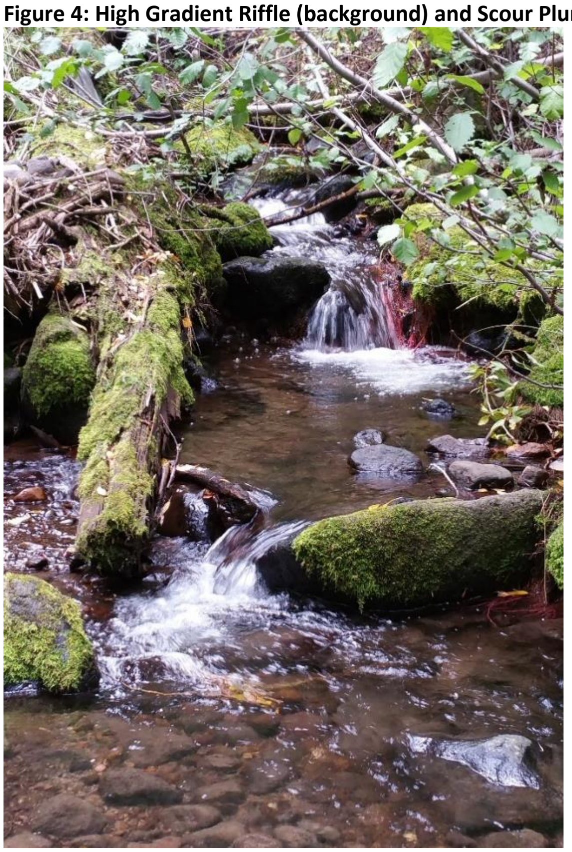

Figure 5: Run habitat type at HU7

Figure 6: Dammed pool formed by large wood (DMW) and High Gradient Riffle (HGR) at HU11 and HU12

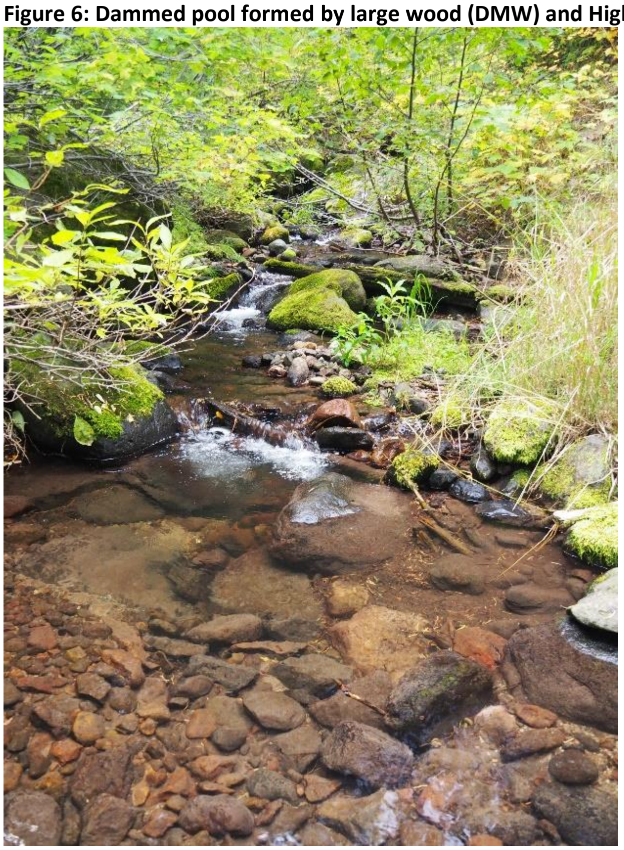

Figure 7: Cascade upstream of HU18

Figure 8: Step-pools and large substrate in HU15 classified (Habitat type = cascade)

Figure 9: Large eroding bank in the vicinity of HU15. Stream is at the foot of this slope.

Figure 10: Waterfall at the upper extent of the survey

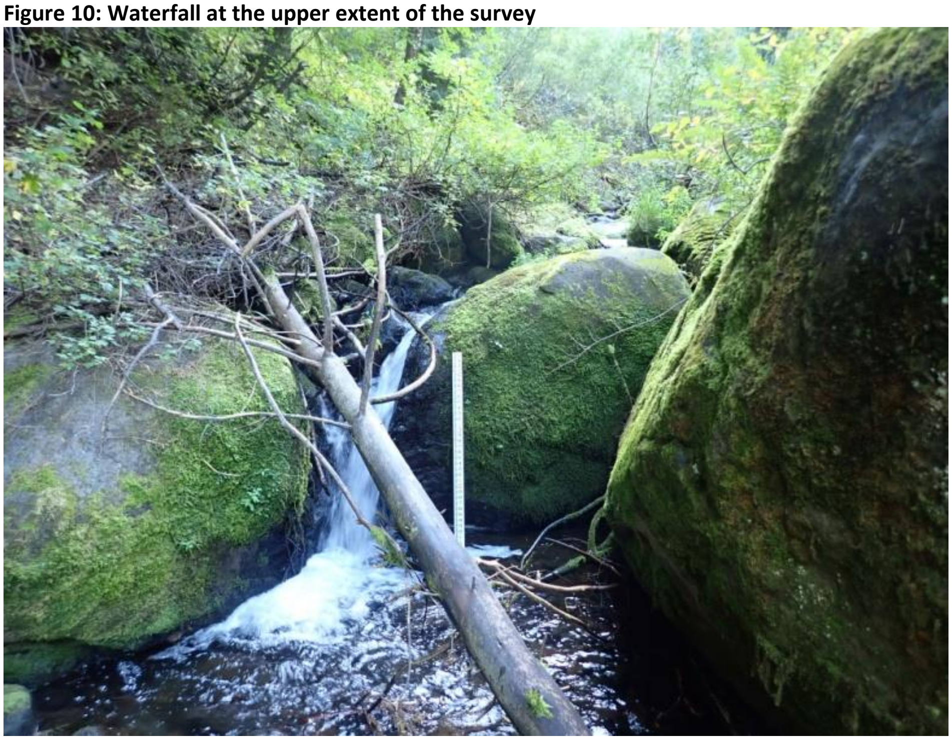

Figure 11: Braided channels and LWD in channel

Figure 12: Large pool at HU20

Acknowledgments
CPW would like to thank Jack Landers and Jeff Baessler of the CWCB staff for their valuable assistance in the field conducting this inventory. CPW would also like to thank David Smith and Dennis Burch of the Bootjack Ranch for their help with logistics and access to Himes Creek.

References
Overton, C.K. and S.P. Wollrab, B.C. Roberts, and M.A. Radko. 1997. R1/R4 (Northern/Intermountain Regions) Fish and Fish Habitat Standard Inventory Procedures Handbook. INT-GTR-346. Ogden, Utah: USDA Forest Service: 1-72.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology. ISBN 0-9653289-0-2

Rogers, K.B., White, J. and Japhet, M. 2018. Rediscovery of a Lost Cutthroat Trout Lineage in the San Juan Mountains of Southwest Colorado. Colorado Parks and Wildlife.

Attachment J

COLORADO
Parks and Wildlife
Department of Natural Resources

Water Resources Section
Capital, Parks, and Trails Branch
6060 Broadway
Denver, CO 80216

March 8, 2019

Linda Bassi
Colorado Water Conservation Board
Stream and Lake Protection Section
1313 Sherman Street, 7th Floor
Denver, CO 80203

Dear Ms. Bassi:

Colorado Parks and Wildlife (CPW) is submitting this letter in support of the US Forest Service (USFS) recommendation for an instream flow (ISF) appropriation on Himes Creek, from its headwaters to the Himes Ditch headgate (approximately 2 miles), in Water Division 7. The USFS recommends that all of the unappropriated flow in Himes Creek is the amount of flow necessary to preserve the natural environment to a reasonable degree. We agree with the USFS that this recommendation is appropriate given the extremely rare nature of the fishery in Himes Creek and their need for the full range of the natural hydrograph. Additionally, we believe this is reasonable because the subject reach is upstream of all water rights on Himes Creek and is entirely located on public lands.

Himes Creek supports a self-sustaining population of the San Juan lineage of the Colorado River cutthroat trout. Himes Creek was initially identified as a stream containing a Core Conservation population of Colorado River cutthroat trout until genetic testing revealed that the Himes Creek population contained genetic markers consistent with museum specimens of the San Juan lineage of the Colorado River cutthroat trout. Leading up to this discovery, the San Juan lineage was thought to be extinct. Currently, Himes Creek is one of only seven streams in Colorado known to contain the San Juan lineage. The discovery of this remnant population of San Juan lineage trout is critically significant and warrants special consideration of necessary protective measures.

Himes Creek is a headwaters stream tributary to the West Fork of the San Juan River at the base of Wolf Creek Pass. The creek has a small contributing basin, lacks significant tributary inputs, and is physically isolated from the West Fork San Juan River because of a diversion structure known as the Himes Ditch, which is the lower terminus of the proposed ISF reach, that diverts a majority of the flow from the stream. The disconnected nature of Himes Creek could be considered positive in that isolation from non-native fish is an advantage that has allowed the San Juan lineage to persist, but the diversion also precludes large scale movement of its resident fish to seek better conditions if Himes Creek habitat is degraded.

Himes Creek is an extremely high gradient step-pool stream that is approximately 3 miles long. The resident trout population is therefore required to carry out their entire life cycle in a challenging environment with limited suitable habitat for spawning and overwintering. The Himes Creek cutthroat trout live, grow, and reproduce in a series of small turbulent pools created by high-gradient steps formed by large boulders and wood in the channel. The pool habitat in Himes Creek is critical in both late summer and over-winter for survival of resident adults and juvenile fish.

When the Himes Creek cutthroat trout population was discovered to be one of only a handful of remnant populations of the San Juan lineage of the Colorado River cutthroat trout, agencies participating in the instream flow effort (CPW, USFS, and CWCB) began a scientific review process of potential approaches for the ISF recommendation. R2CROSS, which is traditionally used, applies hydraulic criteria to determine critical flows, but relies on the assumption that riffles are the critical habitat type for fish survival. In Himes Creek, riffles are not the critical habitat type, and in fact, there are no true riffles in this reach; thus, an R2CROSS-based approach was deemed inappropriate. For the San Juan lineage trout in Himes Creek, the limiting habitat type is pools. Maintaining pool volume is critical for fish survival from the standpoint of maintaining pool depths that supports fish development and passage between pools.

The participating agencies, in consultation with professionals in the sphere of fluvial geomorphology and river ecology, spent over two years reviewing available approaches for recommending flows that would scour fine sediments and maintain pool volume from year to year, as well as perform channel reconfiguration functions. All participating experts in this effort reached the conclusion that in order to support the entire life-cycle of the Himes Creek fish population, the full range of flows contained within the natural hydrograph must be protected. This includes base flows, snowmelt runoff flows, and short-duration peak flows (such as monsoonal events that occur typically between July and October), and their variability from year to year.

As a signatory agency to the Colorado River Cutthroat Trout Conservation Plan, CPW has committed to conservation measures aimed at protection of Colorado River cutthroat trout, and furthermore, CPW has a responsibility to manage and conserve aquatic resources, particularly those with such significant genetic importance. The USFS is also a committed signatory to the Colorado River Cutthroat Conservation Plan. CPW supports the recommendation put forth by the USFS to protect the full range of the nature flow regime in Himes Creek. This protection measure is especially timely and appropriate in light of the recent CPW press release identifying the importance and rarity of the few self-sustaining populations of San Juan lineage cutthroat trout, a handful of which were impacted by the 2018 drought and fires.

CPW and the USFS recognize that the Himes Creek population of San Juan lineage cutthroat is exceptionally rare and at-risk, and thus, this ISF recommendation requires special considerations. We recognize that this approach stems from a set of unique circumstances, and we strongly believe that the scientific approach to ISF appropriations are a case-by-case determination of the best available science and appropriate flow recommendation formulation. CPW remains committed to the effort and offer our support of the Himes Creek ISF recommendation. In you have any questions, please don't hesitate to contact Katie Birch (303-291-7335).

Sincerely,

Margaret Taylor, CPW Assistant Director
Capital, Parks, and Trails

Attachment K

Five Rivers Chapter

TROUT UNLIMITED

February 22, 2019

Colorado Water Conservation Board
1313 Sherman St., Room 718
Denver, CO 80203
Via email rob.viehl@state.co.us

Re: Proposed Instream Flow Appropriation for Himes Creek

Dear Board Members,

We are writing on behalf of Trout Unlimited and the Five Rivers Chapter of Trout Unlimited (jointly referred to as TU) to urge you to adopt the instream flow appropriation for Himes Creek recommended by the U.S. Forest Service and supported by Colorado Parks and Wildlife (CPW) and the CWCB staff.

Preservation of native trout species and their habitat is a priority for TU's members who have dedicated hundreds of volunteer hours in reintroduction efforts, including efforts in southwest Colorado. It was with great joy that we received the news that a species of native San Juan cutthroat trout thought to be extinct had been discovered in a few drainages in the San Juan Mountains. The news was a cause of celebration for the entire community and reported by the area's major newspapers,
https://durangoherald.com/articles/249973;
https://durangoherald.com/articles/239945#modal=in-article-images-modal-386766,slide=undefined;
http://www.pagosasun.com/unique-cutthroat-trout-discovered-in-southwest-colorado/;
https://www.9news.com/article/news/local/this-type-of-trout-was-supposed-to-be-extinct-but-it-was-found-in-southwest-colorado/73-591533154

Himes Creek supports one of only eight identified populations of these very rare native species. Preserving sufficient flows to ensure their survival is of critical importance.

CPW, the state's biological expert agency, has determined that, given the physical characteristics of Himes Creek, using the R2Cross methodology usually relied upon by the CWCB is not possible due to the lack of riffle habitat. The species needs flows that are sufficient to ensure the perpetual existence and maintenance of the pool habitat that is critical for its survival. CPW has determined that, in the case of Himes Creek, "the full range of available flows is needed to ensure the protection of this critical low flow habitat into the future." *Himes Creek Habitat Survey and Inventory Report (Skinner 2018).*

We urge the CWCB to follow the recommendations of the state's biological experts.

We understand that concerns have been expressed about the different approach from the usual R2Cross methodology. However, the CWCB is empowered to appropriate "minimum flows necessary to protect the natural environment to a reasonable degree." There is no specific methodology mandated to the CWCB to calculate the needed minimum flows. Here, expert determinations have been made as to the minimum flows needed and no counter argument has been made that a lesser amount will be protective.

TU does not assert that the approach recommended for Himes Creek should be generally applied. Nor do we agree with the argument that by applying it here, the CWCB is opening the door to unbridled instream flow appropriations in the future. The CWCB has proven to be very judicious in its appropriations and in the very few instances when it has gone beyond the R2Cross methodology, it has done so based on very specific facts dictating the need for a different approach. Such is the case with Himes Creek, where the R2Cross methodology is not capable of determining the flows needed to maintain the life-saving pools.

Thank you for the opportunity to weigh in. We appreciate the CWCB's efforts and trust that you will do what's needed to help preserve these rare species once thought to be lost.

Sincerely,

Amelia S. Whiting

Mely Whiting
Legal Counsel, Colorado Water Project
Trout Unlimited

Buck Skillen

Frank (Buck) Skillen, President
Five Rivers Chapter
Trout Unlimited

Attachment L

WYOMING GAME AND FISH DEPARTMENT

5400 Bishop Blvd. Cheyenne, WY 82006

Phone: (307) 777-4600 Fax: (307) 777-4699

wgfd.wyo.gov

January 25, 2018

Jay Skinner
Colorado Parks and Wildlife
6060 Broadway
Denver, CO 80216

Dear Mr. Skinner:

This letter is in response to your request for peer review of a letter dated November 30, 2017 and written by Forest Service Supervisor Kara Chadwick pertaining to a recommendation to establish an instream flow water right on Himes Creek. This letter should not be considered to represent the official opinions or perspectives of the Wyoming Game and Fish Department (WGFD). Rather, I am providing my perspective as Aquatic Habitat Program Manager and as a member representative of the Instream Flow Council. The Instream Flow Council (IFC) is an organization of state, provincial, and territorial fish and wildlife agencies working to improve the effectiveness of instream flow programs and activities for conserving fish and wildlife and related aquatic resources). This letter also contains the perspective of Dave Zafft, WGFD Fisheries Management Coordinator and Colorado River Cutthroat Trout Conservation Team interagency team leader. Our joint comments are provided below:

Our understanding is that Himes Creek is a very small, high gradient stream located on the San Juan National Forest and tributary to the West Fork San Juan River. The stream is laterally confined, has step pools and large cobble and boulder substrate. The trout community includes a population of Colorado River cutthroat trout (CRCT). The Forest Service is recommending that all unappropriated flow in Himes Creek is the amount needed for maintaining this cutthroat population and is petitioning for an instream flow water right pursuant to the rules of the Colorado Instream Flow and Natural Lake Level Program.

The CRCT population in question is one of only eight known populations of CRCT that have retained characteristics of a lineage native to the San Juan River drainage. The headwater reach of Himes Creek is home to one of only five known core conservation populations (>99% genetically pure) containing the unique San Juan River haplotype of CRCT. Conservation of these few core conservation populations is essential if we are to conserve the unique genetic characteristics that have likely enabled CRCT to persist in the upper reaches of the San Juan River basin in Colorado.

We support efforts to secure the stream flows necessary to protect a unique CRCT population. The flow regime recommendation for Himes Creek appears reasonable based on our experience with similar streams in Wyoming. We adopt an approach similar to that of the FS on Himes Creek in that we assess all portions of the flow regime and the needs of all life stages of the fishery. We are familiar with the R2Cross methodology and employ a similar riffle-based approach we call "Habitat Retention" when developing flow recommendations. It is not surprising that this approach would be deemed inappropriate in Himes Creek because of its small, steep step-pool configuration and lack of conventional riffles. We have encountered similar streams where we could not employ our riffle-based approach. Likewise, in small headwater streams trout survival depends on maintenance of small pools which, by their nature, are susceptible to small changes in flow. It appears reasonable to recommend the entire flow regime in this instance to provide a margin of safety for an important fishery. As noted by the IFC (Annear et al. 2004) "in these situations it is wise to adopt what is known as the precautionary principle—that when in doubt about outcomes or their potential harm to the protection or restoration of valuable public resources, society also should err on the conservative side when making decisions."

The approach and recommendations developed by the Forest Service appear consistent with practices applied nationally by recognized experts. These practices include developing presumptive flow standards (Richter 2011) and identifying flows to protect aquatic life (Novak et al. 2016). The approach also appears to consider essential elements of biology, water quality, geomorphology, etc. as advocated by the Instream flow Council (Annear et al. 2004).

In summary, we have reviewed the Forest Service's recommendation for an instream flow water right on Himes Creek and find it makes a strong case for protecting all the flow in order to preserve a rare population of a genetically unique lineage of CRCT.

Sincerely

Paul Dey, Aquatic Habitat Manager
Dave Zafft, Team Leader, Colorado River Cutthroat Conservation Team

References

Richter, B., M. Davis, C. Apse, and C. Konrad. 2011. A presumptive standard for environmental flow protection. Short Communication. River Research and Applications. 28(8).

Novak, Rachael, Kennen, J.G., Abele, R.W., Baschon, C.F., Carlisle, D.M., Dlugolecki, Laura, Eignor, D.M., Flotemersch, J.E., Ford, Peter, Fowler, Jamie, Galer, Rose, Gordon, L.P., Hansen, S.E., Herbold, Bruce, Johnson, T.E., Johnston, J.M., Konrad, C.P., Leamond, Beth, and Seelbach, P.W, 2016, Final EPA-USGS Technical Report:Protecting Aquatic Life from Effects of Hydrologic Alteration: U.S. Geological Survey Scientific Investigations Report 2016–5164, U.S. Environmental Protection Agency EPA Report 822-R-156-007, 156 p.,http://pubs.usgs.gov/sir/2015/5160/ and http://www2.epa.gov/wqc/aquatic life-ambient-water quality-criteria

Annear, T., I. Chisholm, H. Beecher, A. Locke, P. Aarrestad, C. Coomer, C. Estes, J. Hunt, R. Jacobson, G. Jöbsis, J. Kauffman, J. Marshall, K. Mayes, G. Smith, R. Wentworth, and C. Stalnaker. 2004. *Instream Flows for Riverine Resource Stewardship, Revised Edition.* Instream Flow Council, Cheyenne, WY. 268 pp.

Attachment M

ADDITIONAL REFERENCE MATERIAL

Abrahams, G. Li, and S.F. Atkinson, 1995. Step-pool Streams: Adjustments to Flow Resistance. Water Resources Research, Vol 31, No 10, 2593-2602.

Bisson et al., 2006. Valley Segments, Stream Reaches, and Channel Units. In Methods in Stream Ecology, 23-49.

Comiti et al., 2005. Morphological Effects of Local Scouring in step-pool Streams. Earth Surface Processes and Landforms, 30, 1567-1581.

Chin, A., Haltiner, J.P., and L.S. O'Hirok, 2008, Linking Theory and Practice for Restoration of Step-Pool Streams. Environmental Management. DOI 10.1007/s00267-008-9171.

Grant et al., 1990. Patterns and Origin of Stepped-bed morphology in high-gradient streams, Western Cascades, Oregon. Geologic Society of America Bulletin, Vol 102, 340-352.

Kondolf, G.M., G.F. Cada., M.J. Sal.e, and T. Felando, 1991. Distribution and Stability of Potential Salmonid Spawning Gravels in Steep Boulder-Bed Streams of the Eastern Sierra Nevada. Transactions of the American Fisheries Society, 120, 177-186.

Lenzi et a., 2006. Effective Discharge for Sediment Transport in a Mountain River: Computational Approaches and Geomorphic Effectiveness. Journal of Hydrology 326, 257-276.

Lenzi and Mao, 2010. Bedload Dynamics in Steep Mountain Rivers: Insights from the Rio Cordon Experimental Station (Italian Alps). U.S. Geological Survey Scientific Investigations Report 2010-5091.

Marian and Weirlich, 1999. Fine-Grained Bed patch Response to Near-Bankfull Flows in a Step-Pool Channel. American Water Resources Association, Special Proceedings Wildland Hydrology 1999, 93-100.

Metcalf et al., 2012. Historical Stocking Data and 19th Century DNA Reveal Human-Induced Changes to Native Diversity and Distribution of Cutthroat. Molecular Ecology, 21, 5194-5207.

Molnar, P., A.L. Densmore, B.W. McArdell, and P. Burlando., 2008. Flood-induced Changes in the Step-Pool Morphology of a Steep Mountain Stream. In: Schmidt, Chochrane, Phillips, Elliot, Davies, Brasher (Eds.)Sediment Dynamics in Changing Environments. IAHS-AISH Publ. 325, 302-307.

Montgomery and Buffinton, 1997. Channel-Reach Morphology in Mountain Drainage Basins. Geological Society of American Bulletin, Vo. 109, No 5, 596-611

Rickenmann, D. and B.W. McArdell, 2007. Continuous measurement of sediment transport in the Erlenbach stream using piezoelectric bedload impact sensors. Earth Surface Processes and Landforms, 32, 1362-1378.

Rickenmann, D., 1998. New results from sediment transport measurements in two Alpine torrents. Hydrology, Water Resources and Ecology in Headwaters. In proceedings of the Head Water 98 Conference, 283-289.

Rickenmann, D., Turowski, J.M., Fritschi, B., Klaiber, A., and A. Ludwig, 2012. Bedload transport measurements at the Erlenbach stream with geophones and automated basket samplers. Earth Surface Processes and Landforms, 37, 1000-1011.

Rogers et al., 2014. Using Genetic Diversity to Inform Conservation Efforts for Native Cutthroat Trout of the Southern Rocky Mountains. Wild Trout Symposium XI- Looking Back and Moving Forward, 1-11. Is this sited by Rodgers?

Ryan, S., 1997. Morphological response of subalpine streams to transbasin Flow Diversion. Journal of the American Water Resources Association, vol 33, No4, 839-859

Wohl and Thompson, 2000. Velocity Characteristics Along a Small Step-Pool Channel. Earth Surface Processes and Landforms 25, 353-367.

Yager, E.M., Dietrich, W.E., J.W. Kirchner, and W.W. McArdell, 2012. Prediction of sediment transport in step-pool channels. Water Resources Research, Vol 48, W01541, doi:10.1029/2011WR010829

Attachment N

DRAFT

CDOW STREAM SURVEY (1991 REVISION)
LEVEL 1: PERMANENT FILE INFORMATION

STREAM: Himes Creek SEC# 1 WATER CODE: 39502 CDOW REGION: SW
DATE: 7/19/94 HYDROCODE: ______ USGS TOPO: Saddle Mountain

LOWER TERMINUS: Description: confluence with West Fork San Juan River
Elevation: 7730 County: MIN Township: 37N Range: 1E Section: 29
UTM ZONE: ______ UTM X: ______ UTM Y: ______ WIDTH: 7.3 (FEET)

UPPER TERMINUS: Description: headwaters
Elevation: 10850 County: MIN Township: 37N Range: 1W Section: 23
UTM ZONE: ______ UTM X: ______ UTM Y: ______ WIDTH: 1.0 (FEET)

MAJOR DRAINAGE: SJ TOTAL SECTION LENGTH: 3.4 (MILES)
PRIMARY DRAINAGE: West Fork San Juan TOTAL SECTION AREA: 2.0 (ACRES)

ACCESS MILEAGE
PAVED ______ UN-PAVED ______
4WD ______ TRAIL ______
NO TRAIL 3.4

LAND OWNERSHIP AND MILEAGE
USFS 2.6 BLM ______
CDOW ______ STLB ______
PRIVATE-NO ACCESS 0.8
OTHER ______

STOCKING
Y or N N
FREQUENCY ______
(ANNUAL, BIENNIAL OTHER)

MANAGEMENT CATEGORY CODE: 321 STREAM GRADIENT: 17.4 (% per mile)

LEASE OR EASEMENT: N

REGULATIONS: standard

INSTREAM FLOW APPROPRIATION (Y, N or UNKNOWN): N DATE: ______

COMMENTS/RECOMMENDATIONS: Access to Himes Creek is controlled by the Bootjack Ranch in the West Fork San Juan River valley. There is no record of fish stocking on Himes Creek, although brook trout found in lower Himes Creek may have originated from Rod and Gun Club Lake (historically stocked by private individuals).

MANAGEMENT CATEGORY CODES

INTENSIVE MANAGEMENT
(PUT & TAKE AND PUT-GROW & TAKE OR NATURAL RECRUITMENT)
130: CW STREAMS

OPTIMUM MANAGEMENT
(PUT-GROW & TAKE AND/OR NATURAL RECRUITMENT)
220: CW STREAMS- STOCKED
221: CW STREAMS- WILD TROUT
240: WW STREAMS

SPECIAL MANAGEMENT
(NATURAL RECRUITMENT OR MINIMAL STOCKING)
301: CW STREAMS
311: BIG FISH STREAMS
321: NATIVE/UNIQUE SPECIES STREAMS

MAJOR DRAINAGE CODES

AR: Arkansas River
CR: Colorado River
DO: Dolores River
GR: Green River
GU: Gunnison River
NP: North Platte River
RE: Republican River
RG: Rio Grande River
SJ: San Juan River
SP: South Platte River
WR: White River
YP: Yampa River

ELECTROFISHING RECORD

STREAM NAME: Himes Creek CODE # 39502 STATION # 1

LOCATION: SW1/4 Sec19, T37N, R1E above Rod & Gun Club Lake tributary DATE: 7/19/94

PERSONNEL: Japhet, Vanderbilt, Morrell, Slack, Davis, Stout LENGTH OF STATION 500 ft.

AVG. WIDTH 7.3 FT ACREAGE 0.08 ELEVATION 8520 ft. POP EST MADE? X YES ___ NO

LENGTH-FREQUENCY RECORD (INCHES)

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21+
NAT			1	6	9	14	5	3	1												

SUMMARY INFORMATION

estimates for trout > or = 4 inches

SPECIES	# FISH CAUGHT	AVG. LENGTH	LENGTH RANGE	AVG. WEIGHT	WEIGHT RANGE	% TOTAL CATCH	BIOMASS LB/ACRE	DENSITY FISH/ACRE	DENSITY CONF/INT
NAT	39	5.7 in.	2-9 in	32 g.	6-105 g	100%	29.5	296-439	(95%)

367 fish/Acre

COMMENTS: 2 trout fry netted, but not kept at Station 1. One brook trout was found in lower Himes Creek at irrigation diversion to Bootjack Ranch (see map for location). Purpose of survey: initial stream survey; check for possible presence of Colorado River cutthroat trout (CRN). 10 of the largest trout were collected and preserved for taxonomic analysis. Management implications: These trout *could* be pure CRN. No stocking record exists for this stream and public access has been controlled for many years by the Bootjack Ranch. A lifelong resident of Pagosa Springs reported that brook trout were stocked in the Rod and Gun Club Lake, but that no stocking was done in Himes Creek. A definite upstream fish migration barrier was not found in this survey. However numerous 3 ft. falls are present on Himes Creek as it drops into the West Fork San Juan River valley. Trout density and biomass estimates are based on Seber-Le Cren population estimate for trout > or = 4 inches, where C1=21, C2=6, N=29.4, and variance = 8.5.

ELECTROFISHING RECORD

STREAM NAME: Himes Creek CODE #: 39502 STATION #

LOCATION: Japhet, Vanderbuilt, Skach, Morrell, Davis, Stout DATE: 7-19-94

PERSONNEL: LENGTH OF STATION: 500'

AVG. WIDTH 7.3 FT ACREAGE ELEVATION 8520 POP EST MADE? X Yes No

FISH SAMPLE

	1st Pass			1st Pass cont.			2nd Pass					
	SPECIES	LENGTH (cm)	WGT (g)	SPECIES	LENGTH (cm)	WGT (g)	SPECIES	LENGTH (cm)	WGT (g)	SPECIES	LENGTH (cm)	WGT (g)
*	NAT	23	105	NAT	9.5	10	NAT	11	13			
	"	16	45	"	9.5	8	"	16.4	35			
*	"	19	74	"	8.5	6	"	19	48			
*	"	15.5	32	"	16	32	"	14.5	32			
	"	14.5	30	"	9	8	"	14.5	30			
*	"	16.5	43	"	9	8	"	12.3	18			
-	"	16	38									
-	"	18	70	2 Fry netted, not kept								
	"	20	66	3 cm @								
	"	13.5	27									
	"	13	19									
	"	15	30									
*	"	16	42									
*	"	15.5	32									
	"	12	17									
*	"	17.5	42									
	"	15	31									
	"	13.5	23									
	"	17	42									
	"	9	6									
*	"	14	26									
	"	12	14									
*	"	16	36									
	"	12.5	16									
	"	12	15									
*	"	13.5	29									
	"	18	52									

* = Preserved for taxomomic analysis

brook trout present in lower Himes Creek

FISH COLLECTION RECORD

WATER: Himes Creek CODE: 39502 STATION # 1 DATE: 7/19/94

LOCATION: SW 1/4 Sec 19, T37N, R1E above Rod & Gun Club Lake tributary

PERSONNEL: Mike Japhet, Pete Vanderbilt, USFS temporaries: Morrell, Slack, Davis

LENGTH OF STATION: 500 feet AVG WIDTH: 7.3 ft. ACREAGE: 0.08 POP.

EST. MADE? X Yes ____ No COLLECTION CODE NO. MJ-94-2

LENGTH-FREQUENCY RECORD

Specimen Code	Species	Length (cm)	Weight (g)
01	NAT	23.0	105
02	NAT	19.0	74
03	NAT	15.5	32
04	NAT	16.5	43
05	NAT	16.0	
06	NAT	17.5	
07	NAT	15.5	
08	NAT	14.0	
09	NAT	16.0	
10	NAT	13.5	

09/96 report by Don Proebstel, CSU rated these specimens as grade A CRN, based on meristics and morphological characters.

COMMENTS: Specimens 01-10 were collected and preserved for standard taxonomy analysis. Specimens were sent to Don Proebstl at CSU. These trout could be pure CRN. No stocking record exists for this stream and public access has been controlled for many years by the Bootjack Ranch. A lifelong resident of Pagosa Springs reported that brook trout were once stocked in Rod and Gun Club Lake (a tributary to Himes Creek), but said that no stocking was done in Himes Creek. Several fish barriers were located on lower Himes Creek by a USFS fish crew in 1994. Thus, these fish were isolated from contact with fish in the West Fork San Juan River. This is a very small stream with few trout present. Access is very difficult due to steep terrain, lots of brush, and no trail. This is not a suitable transplant source for brood stock.

CDOW STREAM SURVEY (1991 REVISION)
LEVEL 2: FIELD SURVEY SUMMARY

STREAM: Himes Creek SEC#: 1 WATER CODE: 39502 CDOW REGION: WE

SURVEYORS: M. Japhet, C. Ellis, A. Holland, B. Brantlinger DATE OF SURVEY: 08/17/98

SURVEY LOCATION: T 37N R 1E S 19 ELEVATION: 8700 ft. STATION #: 1

UTM ZONE: UTM X: UTM Y:

LOCATION DESCRIPTION: immediately above 6 ft.fish barrier, about 1000 ft. above Rod & Gun Club tributary

STREAM FLOW PROFILE (Y or N): N IF YES-DATE AND TYPE:

HABITAT EVALUATION (Y or N): N IF YES-DATE AND TYPE:

WATER CHEMISTRY ANALYSIS (Y or N): N IF YES-ATTACH SEPARATE ANALYSIS SHEET

FISH PRESENT (Y or N): Y POP. EST. METHOD: 2 pass removal STATION LENGTH: 500 (FEET)

AVG. WIDTH: 7.3 (FEET) TOTAL STATION AREA:0.08 (ACRES)

FLOW (CFS) AT TIME OF SURVEY: METHOD:

LIMITING FACTORS TO FISHERY: A-5 (steep gradient)

COMMENTS: Purpose of this survey was follow-up monitoring to assess population status since initial survey in 07/94, when 367 fish per acre, 29.5 lb/acre were found. Meristics analysis of ten trout from the 1994 survey indicated this population is grade A Colorado River cutthroat (CRN). Adipose fins from the ten largest trout in this survey were collected and preserved in 100% ethanol for DNA testing to further characterize the genetics of this population.

Brook trout were found in Himes Creek below a 6 ft.vertical rock barrier, located about 1000 ft. above the confluence of the Rod & Gun Club tributary.

Trout density and biomass estimates in the summary table below were based on Seber-Le Cren population estimate for trout > or = 10 cm, where C1=16, C2=0, N=16. (Trout density and biomass for fish > or = 15 cm is 163/acre and 32.2 lb/acre).

Since 1994 survey, the population density of cutthroat trout in Himes Creek has decreased, but the biomass is unchanged. With multiple age classes present, it appears this population is fairly stable in the short term. Long term, this small, isolated population is vulnerable and could be lost if measures are not taken to to preserve this genetic strain.

LENGTH FREQUENCY RECORD (CM)

SPECIES	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	30-32	32-34	34-36	36-38	38-40	40-42	42-44	44-46	46-48	48-50	50 UP
CRN			1	12	1		2	1	2	5	3	2	1													

INCHES 2 4 6 8 10 12 14 16 18 20

SUMMARY INFORMATION

SPECIES	NO. FISH CAUGHT	AVG. LENGTH	LENGTH RANGE	AVG. WEIGHT (Grams)	WEIGHT RANGE (Grams)	% TOTAL CATCH	BIOMASS lb/Acre (fish > 10 cm)	DENSITY No./Acre	Conf. Int.
CRN	30	13.5 cm (5.3 in)	6.0-24.1 cm (2.4-9.5 in)	46 g.	5-155 g.	100 %	35	200	200-200 (95%)

FISH COLLECTION RECORD

STREAM NAME: Himes Creek **CODE #:** 39502 **STATION #:** 1

LOCATION: 1000 ft above Rod & Gun Club tributary, above a 6 ft vertical fish barrier

DATE: 08/17/98

UTM ZONE: E N T 37N R 1 E S 19

COUNTY: Archuleta **TOPO MAP NAME:** Saddle Mountain

PERSONNEL: M. Japhet, C. Ellis, A. Holland, R. Brantlinger **LENGTH OF STATION:** 500 ft

AVG. WIDTH: 7.3 ft **ACREAGE:** 0.08 **POP EST MADE?** Yes

COLLECTION CODE NO.: MJ-98-HIM

SPECIMEN RECORD

SPECIMEN CODE	SPECIES	LENGTH (cm)	WEIGHT (g)	SPECIMEN CODE	SPECIES	LENGTH (cm)	WEIGHT (g)
01	CRN	21.1	76				
02	CRN	19.5	77				
03	CRN	23.9	155				
04	CRN	16.8	60				
05	CRN	23.6	105				
06	CRN	20.0	76				
07	CRN	21.8	90				
08	CRN	24.1	135				
09	CRN	21.8	99				
10	CRN	19.4	85				

COMMENTS: Adipose fins only were collected from these fish and preserved in 100% ethanol for DNA testing. All fish were returned alive to the water. No spots on head were observed on these fish.

ELECTROFISHING RECORD

STREAM NAME: Himes Creek CODE #: ______ STATION # ______

LOCATION: above barrier, above Rod & Gun Club tributary DATE: 8/17/98

PERSONNEL: Japhet, Ellis, Holland, Branflinger LENGTH OF STATION: 500 ft

AVG. WIDTH 7.3 FT ACREAGE 0.08 ELEVATION ______ POP EST MADE? X Yes ___ No

FISH SAMPLE

1st pass

	SPECIES	LENGTH (~~cm~~ mm)	WGT (g)
	CRN	67	5
	↓	65	5
		63	5
ecimen 01		211	76
		74	5
pecimen 02		195	77
		60	5
specimen 03		239	155
specimen 04		168	60
imen 05		236	105
en 06		200	76
pecimen 07		218	90
pecimen 08		241	135
specimen 09		218	99
pecimen 10		194	85
		178	62
		183	75
		~~75~~ 75	16
		188	80
		148	42
		128	30
		77	12
		125	27
		75	20
		70	15
		69	10

2nd pass

SPECIES	LENGTH (~~cm~~ mm)	WGT (g)
CRN	72	5
↓	60	5
	85	5
	63	5
	~~7~~	

no spots on head

selected photos taken of some specimens

adipose fins collected and preserved in 100% ethanol specimens 01 - 10

FISH COLLECTION RECORD

STREAM NAME: Himes Creek CODE #: 39502 STATION #: 1

LOCATION: above Rod & Gun Club tributary on USFS land

DATE: 07/27/99

UTM ZONE: E N T 37 N R 1 E S 19

COUNTY: Archuleta TOPO MAP NAME: Saddle Mountain

PERSONNEL: M. Japhet, C. Ellis, R. Brantlinger LENGTH OF STATION: ~500 ft

AVG. WIDTH: 7.3 ft ACREAGE: POP EST MADE? No

COLLECTION CODE NO.: MJ-99-HIM

SPECIMEN RECORD

SPECIMEN CODE	SPECIES	LENGTH (cm)	WEIGHT (g)	SPECIMEN CODE	SPECIES	LENGTH (cm)	WEIGHT (g)
01	CRN	10.9					
02	CRN	20.7					
03	CRN	15.3					
04	CRN	13.3					
05	CRN	24.0					
06	CRN	16.2					
07	CRN	20.0					
08	CRN	14.0					
09	CRN	13.0					
10	CRN	18.0					

COMMENTS: Tissue samples were collected using a paper punch and removing a plug of tissue from the caudal fin from each trout. All specimens were preserved in individually labelled plastic vials with 100% ethanol. Fish specimens are numbered in ascending order moving upstream. Specimens 01-03 were collected below the barrier, where brook trout were also found. Specimens 04-10 were collected above the barrier in upper Himes Creek where only cutthroat are found. Specimens 05 and 07 had missing adipose fins, which were collected as part of the 1998 fish tissue collection from Himes Creek, Collection Code MJ-98-HIM. All fish were returned to the water alive. No spots on the head were observed on these fish.

CDOW STREAM SURVEY (1991 REVISION)
LEVEL 2: FIELD SURVEY SUMMARY

STREAM: Himes Creek SEC#: 1 WATER CODE: 39502 CDOW REGION: WE

SURVEYORS: Japhet, Gerhardt, Garcia, Brantlinger DATE OF SURVEY:05/26/99 (updated 06/15/2001)

SURVEY LOCATION: T R S ELEVATION: 8,560 ft. STATION #:2

UTM ZONE: UTM X: UTM Y:

LOCATION DESCRIPTION: 200 yards below Rod and Gun Club Lake

STREAM FLOW PROFILE (Y or N): N IF YES-DATE AND TYPE:

HABITAT EVALUATION (Y or N): N IF YES-DATE AND TYPE:

WATER CHEMISTRY ANALYSIS (Y or N): N IF YES-ATTACH SEPARATE ANALYSIS SHEET

FISH PRESENT (Y or N): N POP. EST. METHOD: one pass electrofishing STATION LENGTH: 50 (FEET)

AVG. WIDTH: 2.0 (FEET) TOTAL STATION AREA: .002 (ACRES)

FLOW (CFS) AT TIME OF SURVEY: less than 0.1 cfs METHOD: visual estimate

LIMITING FACTORS TO FISHERY: low flows, intermittent drainage

COMMENTS: The unnamed tributary to Himes Creek that drains Rod and Gun Club Lake contains no fish and very little water. This tributary of Himes Creek has no fishery value.

LENGTH FREQUENCY RECORD (CM)

SPECIES	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	30-32	32-34	34-36	36-38	38-40	40-42	42-44	44-46	46-48	48-50	50-UP
no fish taken																										

INCHES 2 4 6 8 10 12 14 16 18 20

SUMMARY INFORMATION

SPECIES	NO. FISH CAUGHT	AVG. LENGTH	LENGTH RANGE	AVG. WEIGHT (Grams)	WEIGHT RANGE (Grams)	% TOTAL CATCH	BIOMASS lb/Acre	DENSITY No./Acre	DENSITY Conf. Int.
No fish taken									

Send Completed Reports to: mailto:Andrew.Treble@state.co.us
Any questions or issues about reporting data, please call:
Andrew Treble
Aquatic Research Data Analyst
970-472-4372

CPW Contacted Prior to Sampling:
Date of Contact:

*Required Fields:

End-of-Year Aquatic Scientific Collector's Data Submission

Water:	Himes Creek				
CPW Water Code:	39502	CPW Scientific Collector Permit #:		Protocol:	TWO-PASS REMOVAL
CPW Station Code:		Survey Purpose:	Standard Survey or Population Estimate		Units
Date:	9/7/2016			Water Temp:	F
Location Dscrptn:	100 yards upstream from private-FS boundary	Target Species:	CRN	Air Temp:	F
Drainage:	SJ			Gear:	
UTM Zone:	13 *(NAD83, Zone 13)*			Time:	1:30
UTM X:	331107 m		Top of Station:	UTM X:	
UTM Y:	4143708 m			UTM Y:	
Station Length:	500 ft			Flow:	cfs
Station Width:	7.3 ft			Wet/Dry:	W
Crew:	C. Kampf, H. McIntyre, D. Anderson				
Notes:	Purpose of survey was to monitor CRN population and remove brook trout. All brook trout were encountered in the first 100 feet of the 500 ft of river electrofished.				

Field Chemistry from Hach kit

pH:				
DO:		mg/L		% Sat.
Hardness:		mg/L		Units
1st conductivity:		µs @		F
2nd conductivity:		µs @		F
Salinity:		ppt @		F
Phen Alkalinity:		mg/L		
Total Alkalinity:		mg/L		

Species	Count	Length (mm)	Weight (g)	Status	Mark	TagID
BRK	1	22	132	2		
CRN	1	14	40	2		
CRN	1	15	63	2		
CRN	1	23	126	2		
CRN	1	21	92	2		
BRK	1	17.5	68	2		
CRN	1	18.5	70	2		
CRN	1	4.5	8	2		
CRN	1	5	8	2		
CRN	1	22.5	125	1		
CRN	1	18	62	1		
CRN	1	19.5	80	1		
CRN	1	23	146	1		
CRN	1	16.5	50	1		
CRN	1	17.5	65	1		
CRN	1	21	104	1		
CRN	1	15	48	1		
CRN	1	17.5	62	1		
CRN	1	14.5	40	1		
CRN	1	13.5	32	1		
CRN	1	10.5	20	1		
CRN	1	19	76	1		

Observed YOY Length

Species	YOY Length (mm)

Send Completed Reports to: mailto:Andrew.Treble@state.co.us
Any questions or issues about reporting data, please call:
Andrew Treble
Aquatic Research Data Analyst
970-472-4372

CPW Contacted Prior to Sampling:
Date of Contact:

*Required Fields:

End-of-Year Aquatic Scientific Collector's Data Submission

Water: Himes Creek
CPW Water Code: 39502
CPW Station Code:
Date: 8/2/2017
Location Dscrptn: 100 yards upstream from private-FS boundary
Drainage: SJ
UTM Zone: 13 (NAD83, Zone 13)
UTM X: 331107 m
UTM Y: 4143708 m
Station Length: 500 ft
Station Width: 7.3 ft
Crew: J. White, (USFS) C. Kampf, B. Janowski, M. Hammer, B. Richardson
Notes: Purpose of survey was to monitor CRN population and remove brook trout. All brook trout were encountered in the first 100 feet of the 1500 ft of river electrofished (1st 500 ft was part of the population estimate).

CPW Scientific Collector Permit #:
Survey Purpose: Standard Survey or Population Estimate
Target Species: CRN

Protocol: TWO-PASS REMOVAL

		Units
Water Temp:	56	F
Air Temp:		F
Gear:		
Time:	12:30	
Top of Station: UTM X:		
UTM Y:		
Flow:		cfs
Wet/Dry:	W	

Field Chemistry from Hach kit

				Units
pH:				
DO:		mg/L		% Sat.
Hardness:		mg/L		
1st conductivity:	80	µs @	56	F
2nd conductivity:		µs @		F
Salinity:		ppt @		F
Phen Alkalinity:		mg/L		
Total Alkalinity:		mg/L		

Species	Count	Length (mm)	Weight (g)	Status	Mark	TagID
CRN	1	70		2		
CRN	1	160	50	2		
BRK	1	250	193	1		
BRK	1	220	158	1		
BRK	1	150	66	1		
CRN	1	120	53	1		
CRN	1	200	125	1		
CRN	1	230	184	1		
CRN	1	130	38	1		
CRN	1	200	100	1		
CRN	1	90	29	1		
CRN	1	210	134	1		
CRN	1	150	76	1		
CRN	1	90	44	1		
CRN	1	175	80	1		
CRN	1	100	15	1		
CRN	1	110	24	1		
CRN	1	140	40	1		
CRN	1	110	33	1		
CRN	1	100	19	1		
CRN	1	95	20	1		
CRN	1	130	35	1		
CRN	1	100	25	1		
CRN	1	100	19	1		
CRN	1	80	20	1		
CRN	1	80	21	1		

Observed YOY Length

Species	YOY Length (mm)