PRIORITIZED DROUGHT RESILIENCE

FOR THE MANCOS WATERSHED

Prioritized Drought Resilience for the Mancos Watershed

Report Prepared for:

Bureau of Reclamation WaterSmart Program

and

Mancos Watershed Group

March 2021

Cover Photo: Hesperus Peak, @Michael Remke.
All other photos are credited to Mancos Conservation District unless noted.

TABLE OF CONTENTS

LIST OF FIGURES

GLOSSARY OF TERMS

BLM	Bureau of Land Management
BOR	Bureau of Reclamation
CNHP	Colorado Natural Heritage Program
CSU	Colorado State University
MCD	Mancos Conservation District
MWCD	Mancos Water Conservancy District
MEVE	Mesa Verde National Park
MSI	Mountain Studies Institute
NCCSC	North Central Climate Adaptation Science Center
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRCS	Natural Resources Conservation Services
PJ	Pinyon-Juniper
SECR	Social-Ecological Climate Resilience Project
SJNF	San Juan National Forest
TNC	The Nature Conservancy
UMUT	Ute Mountain Ute Tribe
USFS	United States Forest Service
USGS	United States Geologic Survey
US	United States
WCS	Wildlife Conservation Society

1. EXECUTIVE SUMMARY

Figure 1. The Mancos River

The challenges facing the Mancos Watershed parallel those of many Southwest landscapes and communities: water resources are already over-allocated, population density is expected to increase, and climate change will result in more frequent and severe droughts, with resulting consequences for local communities, livelihoods, and ecosystems.

In the Mancos watershed, this is abundantly true. The Mancos Rivers confluences with the San Juan River at nearly 5,000 feet of elevation along the Colorado and New Mexico state line. Because of agricultural livelihoods that depend on and draw water from the Mancos River, it's lower reaches regularly run dry, thereby putting fish, riparian habitat, economic, and cultural values at risk – a risk that is further exacerbated by long term drought and aridification. Even in the last ten years, the frequency and severity of drought has put increasing stress on all of these values. Looking to the future, the breadth and depth of the specific impacts, and responses, are not perfectly known.

Across this landscape, managers and landowners are tasked with making decisions and taking actions in the face of drought and changing climate while balancing multiple objectives.

To support land and resource managers in addressing this uncertainty, we developed a process that integrates existing best practices and research to identify and prioritize locally relevant, climate-informed drought resilience strategies across multiple values. Through an iterative, multi-stakeholder effort, we integrated innovations in participatory approaches and scenario planning with a structured decision support framework. Specifically, the decision support framework entailed the following steps:

- Identify community concerns, challenges, and questions, and develop shared values
- Define key vulnerabilities and stressors under future climate scenarios both spatially and narratively
- Determine specific and shared goals for the persistence of each of those values
- Brainstorm strategies for achieving goals associated with each value (both existing and potential strategies)
- Rank and prioritize strategies; identify spatially explicit opportunities for implementation in identified sub-reaches

Through multiple concern gathering and stakeholder engagement efforts, the Mancos Conservation District and project partners surveyed the community to identify their top concerns, which were: climate change and drought; lack of current storage and sound infrastructure; and watershed education. Community members stressed the importance of satisfying all user groups' needs for water in the basin. We focused on seven targeted values: irrigated lands, non-irrigated lands, riparian habitat, cold and warm water fish, Pinyon-juniper woodlands and Ponderosa pine forests.

Flows in the Mancos River are highly vulnerable and depend upon winter snowpack and summer monsoon rains. Under future climate scenarios, conditions in this already impacted watershed are exacerbated. As seasonal temperatures are projected to get hotter and flow in the river to decrease, hydrological connectivity will decline. Shortages of water during hot summers will lead to lower flows that impact the river, increased crop water demands will result in maximum draws from the river and, ultimately, reduced crop production, and deep pools will be the only water left for fish. Winter precipitation may increase under some future climate scenarios and could present some opportunities to bolster low flows later in the hydrologic year by increasing groundwater levels; however, in the few scenarios where winter precipitation is predicted to increase, rising temperatures and increased and earlier photosynthesis will likely negate those increases.

To develop adaptation strategies for each of the seven values identified by the community, we assessed their climate vulnerabilities and developed a list of strategies and tactics that were subsequently prioritized based on their ability to mitigate impacts of drought and climate change. While the inputs for each value were different, the framework used to determine and prioritize climate-informed strategies was repeatable. Further, this effort developed spatial analyses to better identify specific locations for both vulnerabilities and responding strategies.

Final strategies were vetted by stakeholders and presented in an easily accessible, eye-catching, summary overview document (included in the attachments) that land and resource managers can reference without having to rely on the full report, which will also be widely available. Of the strategies identified for each value, eight strategies rose to the top as "cross-cutting strategies" with the greatest impact across multiple values (Figure 2).

In the process, it was clear that the Mancos Watershed and the values that stakeholders identified are highly vulnerable to changing climate conditions, that there are actions we can take to reduce those vulnerabilities, and that where we work within the watershed matters when it comes to where we can have the greatest impact. While this effort alone does not constitute a complete drought resilience plan for the Mancos Watershed, the drought resilience decision framework will help managers both consider and demonstrate the integration of climate-informed strategies into deciding what actions to take and where to take them across the entire watershed. The process may be applied to additional conservation values to integrate drought-informed thinking into existing investments and future management plans, and could also be adapted for use in other watersheds or regions.

Top Cross Cutting Strategies

- ☑ Promote research, education, and monitoring
- ☑ Identify and protect climate refugia
- ☑ Promote landscape connectivity
- ☑ Maintain and enhance hydrologic processes
- ☑ Maintain and restore riparian vegetation
- ☑ Reduce the risk and long-term impacts of severe disturbances
- ☑ Sustain fundamental functions of soil and water
- ☑ Facilitate adjustments through community species transition

Figure 2. Top Cross Cutting Strategies for Drought Resilience

The top strategies for each value are identified in Figure 3. For the full list of strategies, objectives, and tactics, see the summary documents included in the Appendix.

Top Drought Resilience Strategies	
Irrigated lands	☑ Alter management to accommodate expected hotter and drier conditions ☑ Alter infrastructure to match new and expected conditions ☑ Create economic incentives for soil and water conservation ☑ Manage farms and fields as part of a larger landscape ☑ Sustain fundamental functions of soil and water
Non-irrigated lands	☑ Alter infrastructure to match new and expected conditions ☑ Identify and protect climate refugia ☑ Promote landscape connectivity ☑ Sustain fundamental functions of soil and water
Riparian ecosystems	☑ Identify and protect climate refugia ☑ Maintain/ enhance hydrologic processes and water quantity and quality ☑ Maintain and restore riparian vegetation ☑ Reduce the impact of biological stressors
Cold water fish	☑ Identify and protect climate refugia ☑ Moderate base flow decreases ☑ Reduce uncertainty through research and monitoring
Warm water fish	☑ Expand the warm water fish populations ☑ Identify and protect climate refugia ☑ Maintain/ enhance hydrologic processes and water quantity and quality ☑ Maintain and restore riparian vegetation ☑ Promote landscape connectivity
Pinyon-juniper woodlands	☑ Facilitate native shrub establishment following stand-replacing fires ☑ Identify and protect climate refugia ☑ Reduce the risk and long-term impacts of severe disturbances ☑ Sustain fundamental ecosystem functions
Ponderosa pine forests	☑ Allow forest regeneration to warmer and drier forest species ☑ Identify and protect refugia ☑ Maintain and enhance genetic diversity ☑ Reduce the risk and long-term impacts of severe disturbances ☑ Sustain fundamental ecological functions

Figure 3. Top Drought Resilience Strategies for Seven Community Values

2. ACKNOWLEDGEMENTS

The technical team that informed and guided this project included the following: Molly Cross, Wildlife Conservation Society; Renee Rondeau, Colorado Natural Heritage Program; Imtiaz Rangwala, North Central Climate Adaptation Science Center; Stephen Monroe, Independent Contractor; Marcie Bidwell, Mountain Studies Institute (MSI); Scott Roberts, MSI; and Page Buono, Independent Contractor. Throughout the report, this team is referred to as "we."

These drought resilience strategies and the decision framework for identifying and prioritizing them would not have been possible without the time, energy, and expertise from these individuals and organizations: Gretchen Rank, Mancos Conservation District; Colin Larrick and Margie Connolly, Ute Mountain Ute Tribe; Jack Burk, Rancher; Duncan Rose, Trout Unlimited; Tova Spector, Mesa Verde National Park; Andrew Spear, Mesa Verde National Park; Jeff Fowlds, NRCS & MCD; Celene Hawkins, The Nature Conservancy; Jim White, Colorado Department of Natural Resources; Gary Kennedy, Mancos Water Conservancy District; and Shauna Jensen, San Juan National Forest.

The authors would like to thank our funders: BOR WaterSmart grant to the Southern Rockies Landscape Conservation Collaborative, Colorado Water Conservation Board Southwest Basin Roundtable, Colorado Non-point Source 319 Program, The Nature Conservancy, Wildlife Conservation Society, Temper of the Times Foundation, Mountain Studies Institute, and Colorado State University. The North Central Climate Adaptation Science Center contributed foundational funding.

Figure 4. Monitoring the Mancos River

3. SUGGESTED CITATION

Buono, P., Rondeau, R., Bidwell, M., Monroe, S., Rank, G., Roberts, S., Cross, M., and Rangwala, I. 2021. Prioritized Drought Resilience Strategies for the Mancos Watershed. Prepared for Mancos Watershed Group.

4. DEFINING A WATERSHED

The Mancos watershed is home to a few thousand people, rare native aquatic and wildlife species, and diverse forest and riparian ecosystems. The Mancos River is a perennial stream that flows approximately 85 miles from its headwaters at 13,000 feet in the La Plata Mountains, through irrigated ranch and farmlands in the Mancos Valley, into the remote Mancos Canyon and through Mesa Verde National Park, and finally—for nearly two thirds of its length—through the sovereign lands of the Ute Mountain Ute Tribe. The Mancos River confluences with the San Juan River at nearly 5,000 feet near the Colorado/New Mexico state line. Because of agricultural livelihoods that depend on and draw from Mancos River, the lower reaches of the river regularly run dry, thereby putting fish, riparian habitat, economic, and cultural values at risk – a risk that is further exacerbated by climate change. The breadth and depth of the specific impacts, and responses, are not well known.

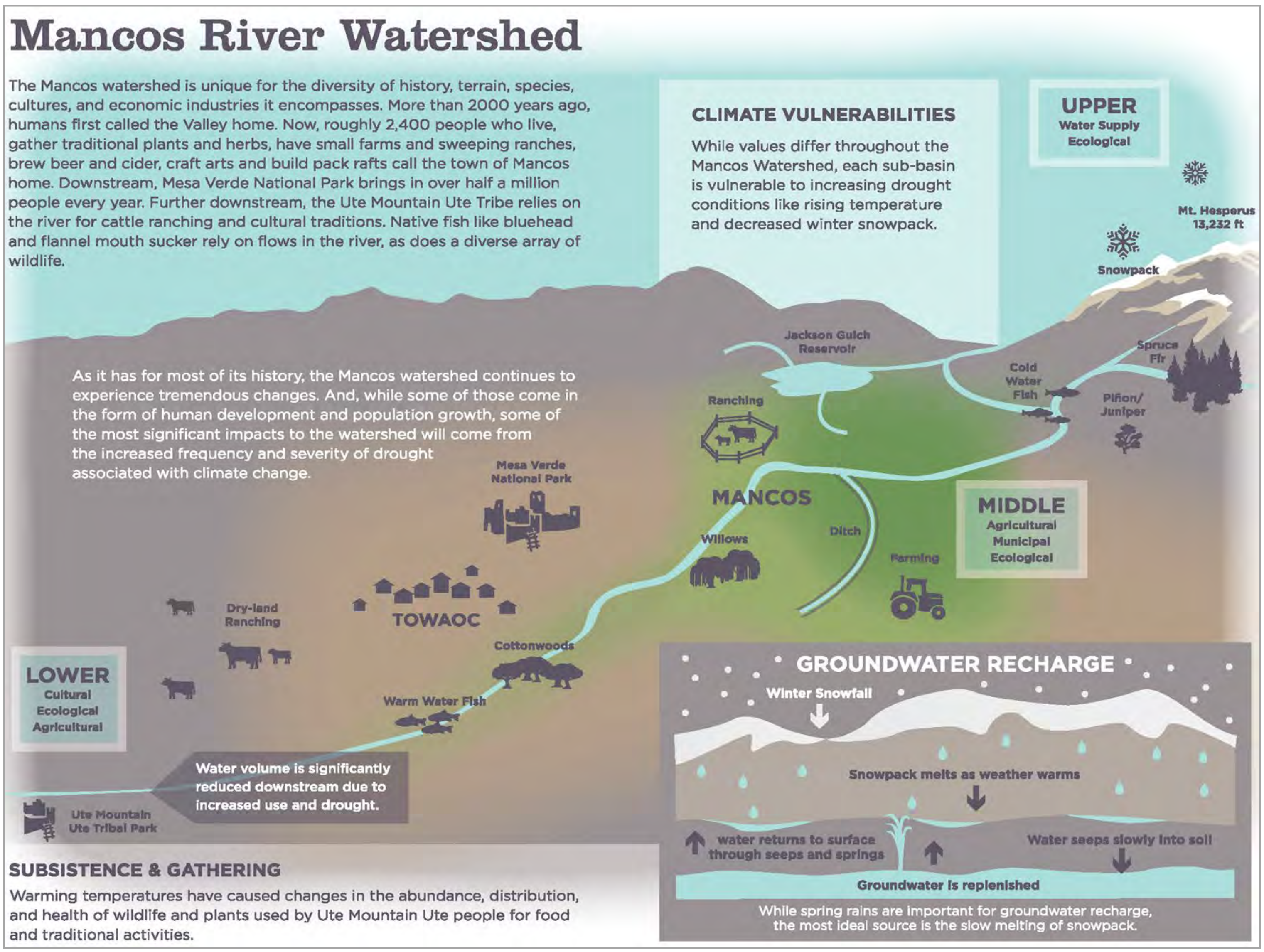


Figure 5. Overview of the Mancos Watershed

5. INTRODUCTION

The Mancos Watershed is dramatic, moving quickly through diverse ecosystems from alpine to desert across a short distance. Some of the ecosystems are relatively intact. The diversity of ecological systems that rely on the Mancos River span

In 2002, 2012, 2018, and 2019 communities in the Mancos Watershed were hit hard by severe droughts. A deficit in precipitation and higher than average temperatures impacted farmers, ranchers, subsistence activities, fish, and municipal water users in profound ways: local irrigators let their fields fallow; ranchers sold their cattle; sections of the river in Mesa Verde National Park and on Ute Mountain Ute Tribal lands were dry for weeks at a time; and a survey by Colorado Parks and Wildlife found very few warm or cold-water fish species in the Mancos. Trees and shrubs in the riparian zone and forests were stressed and regeneration virtually non-existent. While the 2019 Water Year began with a wet winter and looked like it was going to provide some reprieve, the monsoons never arrived and by July, the Mancos Watershed was again in drought (Figure 6, Alder et al 2013). A recent study by Williams et al. (2020) considers southwest Colorado to be experiencing a mega drought that is likely to continue.

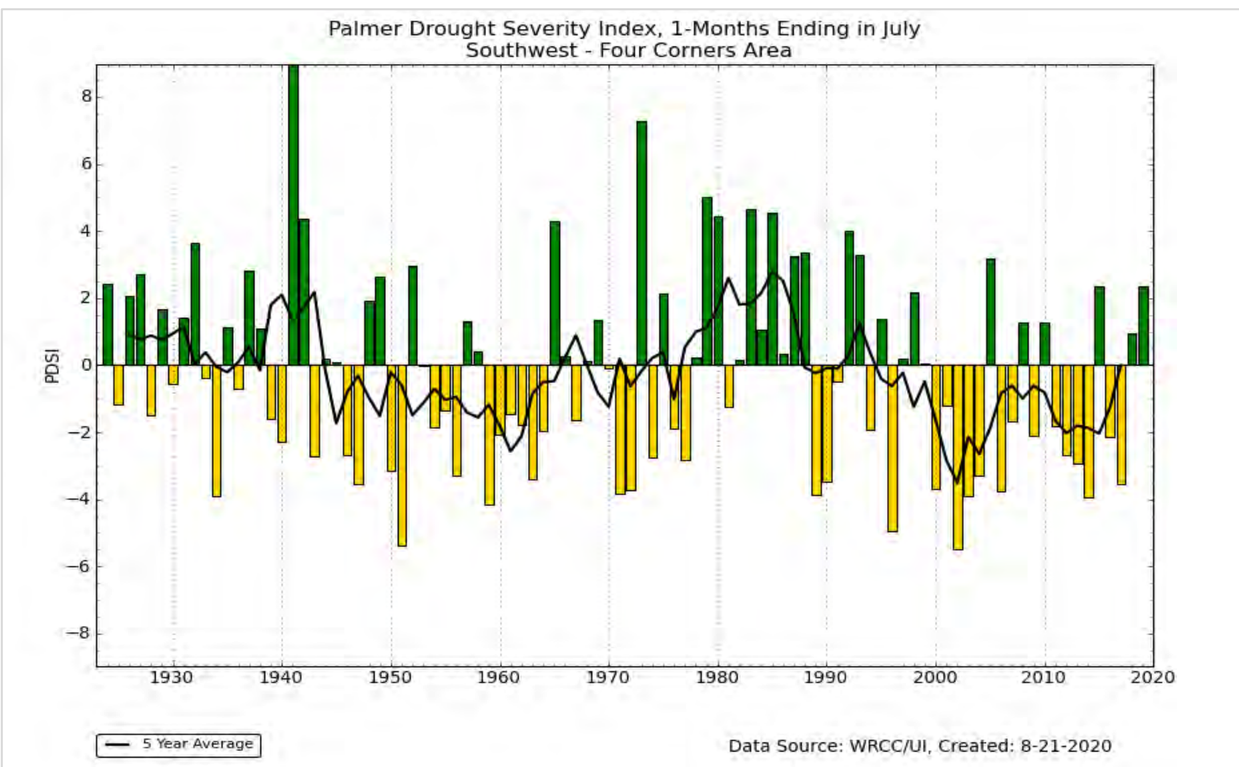


Figure 6. Palmer Drought Severity Index for 100 Years

These droughts and their impacts— across social, ecological, and economic values— provided a catalyst for many of the conversations, strategies, and next steps determined through this project. As is true in many places around the world, proactive management is often propelled when concerns are high, and certainly that is the case in the Mancos Watershed.

In response to these drought challenges, a multi-stakeholder group that initially formed in the early 2000s worked together on this BOR WaterSMART funded process to develop drought resilience strategies for both social and ecological values in the Mancos Watershed. The partners shared a sense of urgency and were motivated to identify and understand drought resilient strategies to protect the values that they care about: forests, irrigated agriculture, non-irrigated agriculture, riparian, and fish. This project provided a process through which to do that and resulted in a prioritized list of strategies that can be advanced immediately.

6. PROJECT BACKGROUND

The communities of the Mancos River have a long history of working collaboratively to develop locally driven solutions to natural resource concerns. The "Prioritized Drought Resilience Framework" for the Mancos Watershed built upon individual efforts and diverse collaborations to develop resilience for the Mancos River, along with the communities of people, wildlife, and ecosystems that rely on the water. In 2011, the Mancos Watershed Plan provided a foundation for addressing concerns, identifying gaps, and prioritizing future efforts (Figure 7). This project builds upon their foundation. A full list of projects (historic and ongoing) in the Mancos Watershed is included in the attachments. Immediately after the plan was completed, 2012 was an extremely dry year which resulted in Weber Fire burning 10,000 acres on the eastern edge of the Mancos watershed. Since 2000, nearly 30,000 acres of Mesa Verde National Park has burned. These fires are a challenge to MWG project goals within the Mancos River was heavily impacted from debris flows, sedimentation, and changes in runoff. MWG realized that they needed to update the plan to analyse the of future drought and wildlfire in the plan.

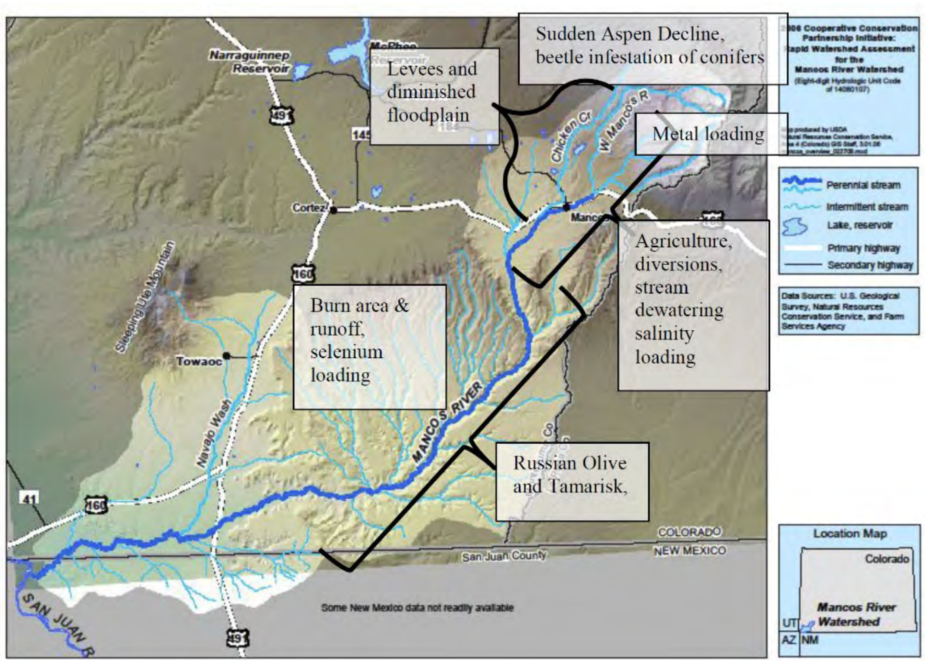


Figure 7. Mancos Watershed Plan Map of Challenges, 2011

The Mancos Valley, which includes the town of Mancos, is a small rural community historically inseparable from its relationship with Jackson Gulch Reservoir and the Mancos Water Project, which supports agriculture in a semi-arid climate made possible only through irrigation and hard work. Additionally, Reclamation supplies water to the Ute Mountain Ute Tribe through treaty and decree, with rights partially satisfied from the Mancos River, and to Mesa Verde National Park by state appropriative and federal reserve rights. Finally, Figure 8 shows the project's geography where six Reclamation projects in the Upper San Juan/Dolores Basin that are facing the same issues that will benefit from Jackson Gulch Reservoir serving as a pilot project (i.e., Animas- La Plata Project, McPhee, Lemon Reservoir, Vallecito Reservoir, and Navajo Lake, representing 691,942-acre-feet of water storage).

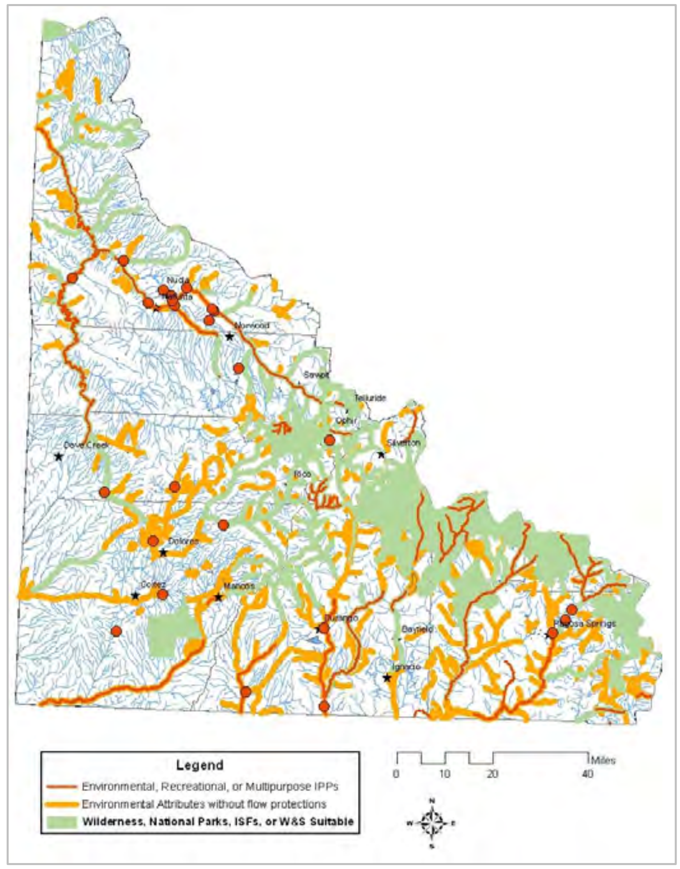


Figure 8. River Segments with Protection and/or Implementation Project Plans, Southwest Basin Roundtable

The Mancos River is included in the San Juan River Basin Recovery Implementation Program, whose goal is to protect and recover endangered fish species in the San Juan River basin while water development proceeds in compliance with all applicable Federal and State laws. Mesa Verde National Park and Ute Mountain Ute Tribe recognize the vital role the Mancos River has in providing critical habitat to three native and imperiled warm water fish and wildlife and for its economic and infrastructure values. An irrigation diversion structure on the lower Mancos River serves as a fish barrier preventing upstream movement of non-native fish. The San Juan Recovery Program acknowledges the potential for the Mancos River to serve a role in supporting habitat for the imperiled warm water fish in part due to this structure.

The Mancos River supports cold water and warm water fisheries, riparian and wetland ecosystems, irrigation for 11,300 acres, and the livelihoods of well over 4,000 people. Key species of conservation concern include three federal agency Sensitive Species – flannelmouth sucker (*Catostomus latipinnus*), bluehead sucker (*Catostomus discobolus*), and roundtail chub (*Gila robusta*) – commonly referred to as "The Three." Distributions of these three fish have contracted by more than 50% compared to historic distributions (UDWR 2006), and there is potential for future federal listings under the Endangered Species Act for all of them. Although these species occur in the Mancos River, abundances are extremely low and they are affected by several compounding stressors. The Ute Mountain Ute Tribe and the National Park Service value the Mancos Canyon for its natural landscapes and cultural and traditional significance and have a special interest in protecting and restoring native fish, cottonwood galleries, and willows.

The Mancos Valley community recognizes that the character of the valley is changing (MWCD 2002, SWBRT BIP 2015) and they desire to address a variety of water availability issues, including demands that are increasingly connected to uses other than traditional agriculture, threats of weather extremes from droughts and floods, costs of aging infrastructure, and increasing risks of wildfire in its headwaters. Four Corners communities and tribal nations are vulnerable to drought, loss of water supplies, and dramatic shifts in vegetation due to the loss of precipitation. Drought impacts over the last 20 years have affected river flows, altered the frequency and intensity of wildfires, transformed vegetation communities and rangelands (Floyd et al. 2004; Romme et al. 2009), expanded invasive weeds, and increased pressures on water supplies (Averyt et al. 2013). These environmental pressures are further compounded by the social dynamics of increasing municipal water needs, changing agricultural practices, and

Mancos River near Mancos Comparing Flows across Representative Years

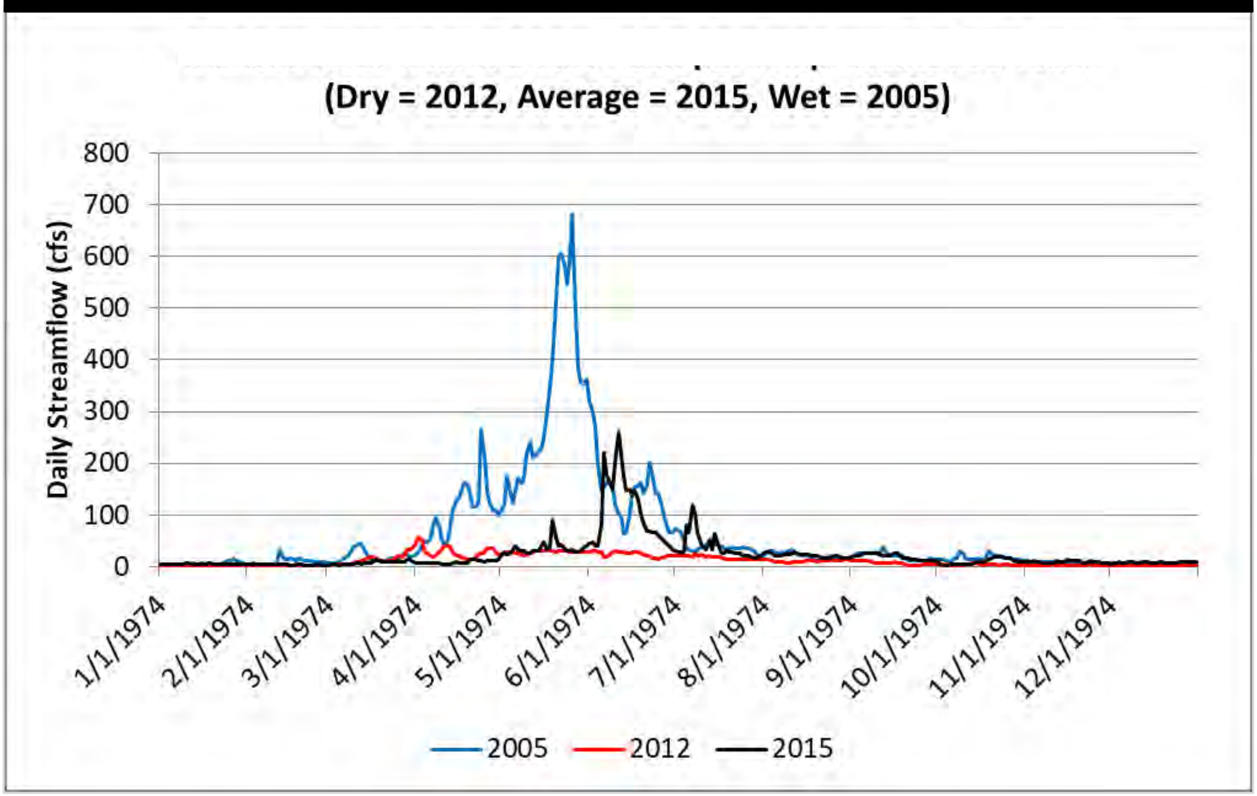


Figure 9. Mancos River Flow in Wet, Dry and Average Years (Wilson et al, 2020)

Figure 10. Lower Reaches of Mancos River in a Typical Dry Year

population growth via "amenity migration" (i.e., the increasing migration of telecommuters from urban centers to places with greater quality of life values such as mild weather, scenic beauty, and recreation opportunities). Figures 9 shows the ranges of low flows as seen in Figure 10.

The primary limiting factor for all values is lack of sufficient water in the river, especially during summer, as well as loss of habitat connectivity, sedimentation that occurs downstream from fire, and destruction by debris jams or an increase in large woody debris following multiple high severity wildfires (Mancos Watershed Plan, 2011; Ute Mountain Ute Tribe 2013; Friggens et al. 2015; White 2016). Nearly every summer, the lower reaches of the Mancos River are impacted by extremely low flows, and dry stretches. This trend in dry reaches is moving up the watershed: in 2020 and other years, those dry spots existed above Highway 160. Diversion structures in the middle reaches of the Mancos River consume the entire flow of the Mancos River during low water summer months as agricultural and domestic uses are appropriated by senior water rights before reaching Mesa Verde National Park and Ute Mountain Ute tribal lands (Ute Mountain Ute, 2012). Agricultural producers, the consumptive use for Mesa Verde

National Park, ecosystems and cultural values are all impacted be these dry-ups. The Mancos River hydrograph is influenced heavily by agricultural production in the Valley, where the majority of irrigation and municipal use occurs. While traditionally the primary activity has been cattle ranching, the dynamics in the Valley are changing as many of the large ranches are sub-divided, and as traditionally open ditches are moved to pipe (Wilson et al, 2020). Figure 11 portrays the four subregions.

Both 2018 and 2019 exemplified the recurring impacts of drought in the Mancos Watershed. While many stakeholders have shared anecdotal evidence about the realities of living and farming or ranching in an arid environment, the back-to-back droughts of 2018 and 2019 created novel drought situations and challenges. In 2018, an exceptionally low snowpack limited baseflows in the summertime. In 2019, winter snowfall was above average and offered some respite for drought-impacted people and ecosystems, but a lack of summer monsoonal rains pushed the area back into drought conditions. The 2020 monsoonal season was also atypical, underscoring the fact that when the water is gone, it's gone. This confluence of back-to-back but unique drought years fed conversations about novel and worsening future drought conditions and established the groundwork for difficult conversations about the realities of resilience and recovery under those conditions.

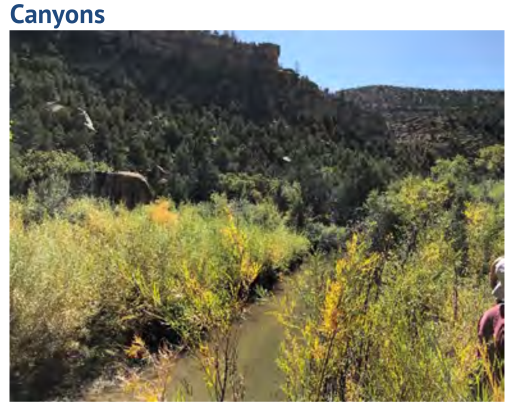
7. PROJECT OBJECTIVES

This project proposed to develop decision support tools for the Mancos Watershed by merging innovations in scenario planning with a decision framework to help land and resource managers navigate the complex social, ecological, and economic needs of the communities that rely on the river. We utilized lessons learned during the Social-Ecological Resilience Project (Burkhardt et al. 2018) as a process for integrating climate and drought models with iterative scenario

Headwaters

Valley

Canyons



Range Lands

Figure 11. Mancos Watershed Major Subregions

building, and we adapted the "Three Step Decision Support Framework for Climate Adaptation" (Nelson et al. 2016), which developed a structured framework for cold-water ecosystems, to include drought resilience strategies for multiple values that were directly identified by a range of stakeholders in the watershed. Through this combined approach, we aimed to help land managers scientifically and spatially apply drought information to their management decisions by developing tools to aid them in identifying, locating, and prioritizing conservation actions for achieving multiple conservation objectives.

As stated by the Mancos River Basin Instream Flow Report, "no single, silver-bullet solution exists" for solving the water shortage problems (2013). Despite the many challenges and likeliness that the river will, at times, run dry, many residents and managers of the Mancos River watershed are concerned about the long-term viability of the Mancos River the face of competing demands, and that adaptations to address current demand and challenges with a healthy river in mind are critical. This collective desire was demonstrated by the shared effort at the end of the project to pursue implementation funding for prioritized drought strategies.

Throughout the process, and in order to help managers and stakeholders address the social and ecological barriers to developing drought resilience strategies, our project team worked closely with scientists and Mancos Valley managers to co-develop a framework that guides decision-makers through a step-by-step process.

Specifically, we worked to:

- Identify community concerns, challenges, and questions, and develop shared values.
- Define key vulnerabilities and stressors under future climate scenarios both spatially and narratively
- Determine specific and shared goals for the persistence of each of those values.
- Brainstorm additional strategies for achieving goals associated with each value for both existing and potential strategies
- Rank and prioritize strategies and identify spatially explicit opportunities for implementation in identified sub-reaches

While this process is articulated stepwise, it was an iterative and concurrent process. Stakeholders were given the chance to revisit and review specifics throughout, strategies were captured and considered throughout, and climate vulnerabilities were understood, shared, and incorporated at various points throughout the process.

8. PROCESS AND METHODOLOGY

The proposed methodology for this project was adapted from several previous projects, frameworks and approaches, including those presented in the "Three-Step Decision Support Framework for Climate Adaptation"; the Socio-Ecological Climate Resilience project (Rondeau et al. 2017); and the Ecological Drought framework (Crausbay and Ramirez et al. 2017). The objective was to develop a five-step decision framework to develop and prioritize drought resilience strategies for fish, riparian ecosystems, forests, irrigated lands and non-irrigated lands—essentially to understand drought impacts on fish, livelihoods, and flows (Figure 12).

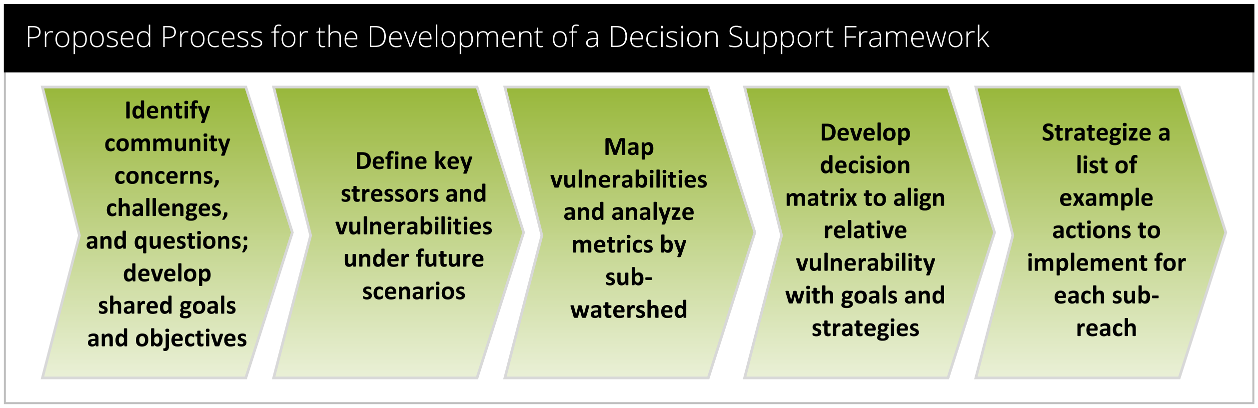


Figure 12. Process diagram of proposed project approach, adapted from Nelson et al. 2016

During the course of the project, the team adapted the Framework Development Process to reflect the iterative and replicable nature of the process, as reflected in Figure 13 below.

8.1 Identify community concerns, challenges, and questions, and develop shared values

The Mancos Conservation District's *Mancos Watershed Water and Drought Concern Gathering* project began in 2017 and was completed in 2019. The project used a survey to invite input from any and all water users, landowners, and stakeholders in the Mancos Watershed, asking for input on a variety of issues related to water and drought. Responses to the survey identified climate change and drought, lack of current storage and sound infrastructure, and water education as the highest priority water supply issues. Respondents suggested the best ways to address these issues would be through education, community building, and conservation. Participants stressed the importance of satisfying all user groups and expressed strong interest in being engaged in future meetings and discussions about water supply concerns.

8.2 Define key vulnerabilities and stressors under future climate scenarios

We assessed four mid-century climate scenarios that were chosen to represent the uncertainty in changes to temperature and precipitation to Southwest Colorado. The four scenarios are "Hot and Dry," "Feast or Famine," "Warm and Wet," and "Hot and Wet" (see Climate Scenario Tables in the Appendix). These scenarios were presented in a workshop with stakeholders in March of 2019 and used throughout the project.

Further, the Vulnerability Summaries for each were shared with small breakout groups who reviewed and offered feedback. Comments ranged from concern about missing information (e.g., how much are water temperatures likely to increase) and highlighting the need to address the ongoing impacts of ditching rivers (a relatively new endeavor in the Mancos Watershed). Feedback from stakeholders was integrated into the final vulnerability summaries value (see "Vulnerability Summaries + Priority Strategies" included as attachments to this report).

In April 2019, key stakeholders gave presentations about their respective experiences with droughts—both the impacts they had experienced and the strategies they had developed to date. Through this workshop, the project team captured an initial list of existing strategies, and better understood some barriers to implementation and understanding. Further, land managers and key stakeholders were asked to take the lead in helping the project team develop feasible and watershed-relevant strategies.

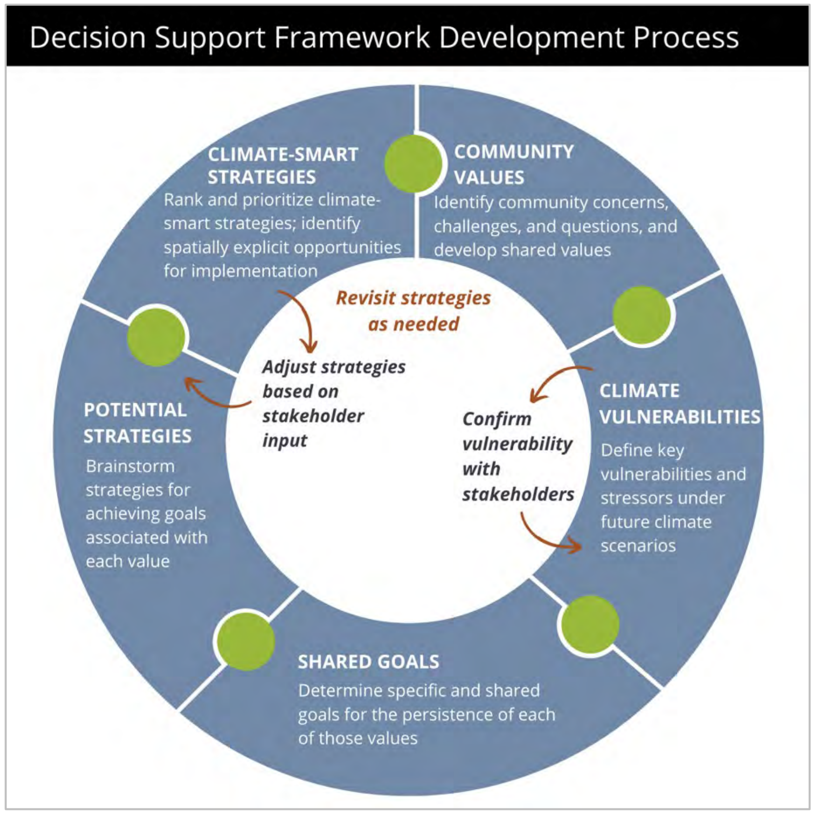


Figure 13. Process Diagram Illustrating Project Approach

8.3 Brainstorm strategies for achieving goals associated with each value

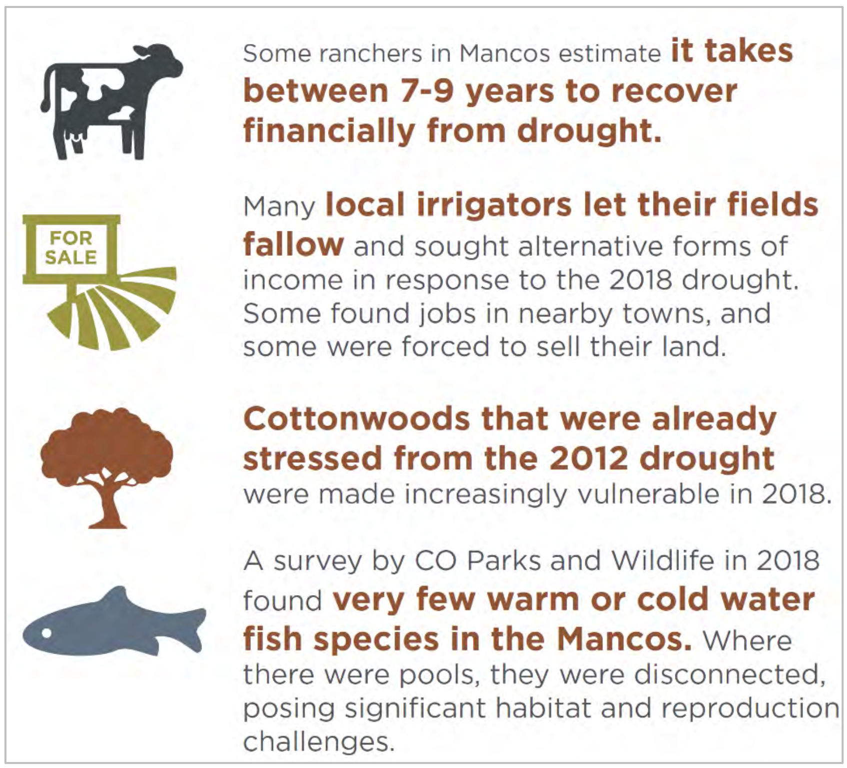
During the fall of 2019, we convened stakeholders in small groups for each of four values: irrigated lands, non-irrigated lands, fish (warm and cold water), and riparian ecosystems. The project team worked with these small groups to articulate shared goals for each value, and to expand upon the spring 2019 conversations to identify more strategies and tactics (summary documents included as attachments). Additional small-group workshops were hosted between spring and summer 2019 to identify strategies for the remaining values (namely ponderosa pine and pinyon-juniper).

8.4 Rank and prioritize climate-smart strategies; identify spatially explicit opportunities for implementation

During the fall of 2020, the core team worked to develop the climate filter, and apply it to the initial strategies that were identified by stakeholders. In the spring of 2020, we convened small stakeholder groups to review the list of strategies. We walked participants through the process of applying the climate filter, engaging managers and stakeholders in the process of developing strategies, and explaining the methodologies developed for determining whether or not the strategies for managing a value are climate smart. Further, by engaging stakeholders and managers in the process or prioritizing climate smart strategies, we had the opportunity to facilitate conversations about next steps for implementation.

9. IDENTIFYING SOCIO-ECOLOGICAL VULNERABILITIES UNDER FUTURE CLIMATE SCENARIOS

Southwestern Colorado is already experiencing the effects of climate change in the form of larger and more severe wildfires, prolonged drought, and earlier snowmelt. Climate scientists predict more frequent and intense heat waves, longer-lasting and more frequent droughts similar to that experienced by Colorado in 2002, and decreased river flows in the future. Ute Mountain Ute elders attribute reductions in availability of wildlife and plants used for medicine, ceremonies and food to the changing climate (UMUT 2020). For farmers and ranchers, depth, soil health, the price of hay, seniority of water rights and the size of land holdings all contribute to the impacts of drought. While everyone (and everything) in the watershed may experience drought differently, the reality is that droughts like those that occurred in 2002, 2012, and 2018 impact everything (Figure 9).



The Mancos River could potentially experience a 15-20% increase in water stress by mid-century, compared to the 1900-1970 baseline (Figure 6). Mean annual temperatures in Southwestern Colorado have risen almost 2ºF in only three decades (Rangwala and Miller

2010; Williams et.al. 2020), a rate of warming greater than the western U.S., or any other region of the U.S. except Alaska (Lukas et al. 2014). Drought, especially low winter snowpack during 2000-2007, has been linked to landscape-level changes in forests due to pests and diseases, which has affected 17% of all aspen forests and millions of pinyon-pine and spruce trees (Romme et al. 2009; Decker, Rondeau 2014).

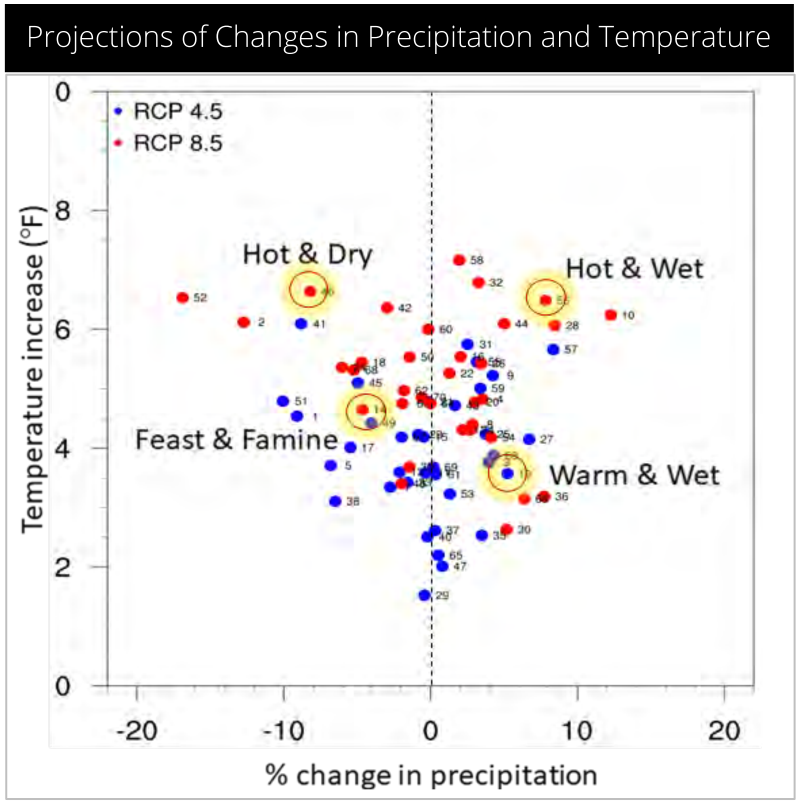


Figure 14. Climate Scenarios (Rondeau et al, 2017)

These changes will ultimately impact local communities and challenge natural resource managers in allocating water under unpredictable drought conditions, managing forests in the face of changing fire regimes and other stressors like insects and disease, and conserving threatened species under shifting ecological conditions, all while continuing to support the needs of human communities. To address these challenges, we collaborated with scientists, land managers, and local communities to identify strategies for proactively reducing impacts on people and nature. Understanding potential changes and implementing adaptation strategies to respond to those changes can help nature and people remain healthy into the future. Our work focused on the intersection of climate, ecological, and social systems.

To address uncertainty, we developed attributes associated with four climate scenarios for the 2020-2050 period. The four climate models that represent different, but equally plausible, potential future pathways for the region were selected: a hotter, drier future; a warmer future with increased annual precipitation; a future with high inter-annual variability between hot dry years and warm wet years; and also a potential for hot and wet. We called these scenarios "Hot and Dry," "Warm and Wet," "Feast or Famine," and "Hot and Wet."

	Hot & Dry	Feast or Famine	Warm & Wet	Hot & Wet
Annual temperature	+ 3.9 F°	+ 2.6 F°	+ 1.9 F°	+ 4.0 F°
Winter precipitation	- 8%	+ 24%	+ 28%	No change
Summer monsoon	-18%	+ 9%	+ 20%	+ 17%
Total Runoff	> 25% decrease	5% decrease	5% increase	5% decrease
Bad Drought like 2002	every 3-5 years	every 5-10 years	every 30-40 years	every 5-10 years

Figure 15. Introduction to Four Scenarios (Rondeau et al, 2017)

In addition to each of the four scenarios, we adapted the "Drought, Temperature, Precipitation and Snowpack, 2020-2050" report compiled by CNHP for The Nature Conservancy to understand how the four scenarios would potentially impact important weather patterns and indicators for assessing how vulnerable each of our seven values are to a range of future conditions. We hosted meetings with local managers, ranchers, and experts to compare temperature, precipitation, runoff, soil moisture, evaporative demand, extreme drought frequency, and other metrics from the four scenarios (Figure 16).

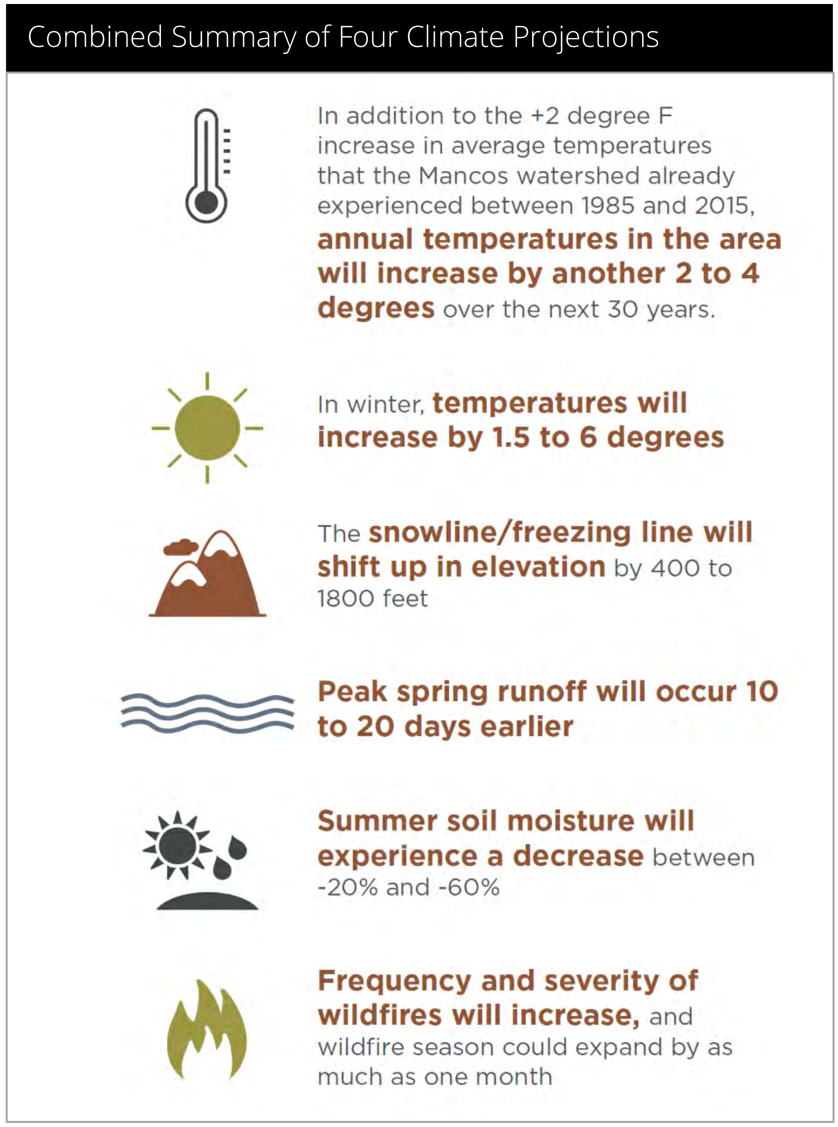


Figure 16. Climate Outlook for 2050 in Mancos Watershed

The models project long-lasting and extreme drought events. Climate models depict the American West, including the Mancos Watershed, moving toward aridification and mega-drought conditions comparable to what drove early Native American populations to migrate away from the region in the 1200s. All but one of our scenarios project an increase in extreme drought frequency. In addition to precipitation, warming temperatures have been identified as a significant confounding factor as warm air can hold more moisture contributing to additional drying of the soil and aridification. As temperatures rise 4-6° F by 2050, any anticipated increase in precipitation cannot offset warmer temperatures. Stream flows, soil moisture, and groundwater levels are expected to decrease.

As summers get hotter and stream flows are threatened, hydrological connectivity will decline, highlighting the need for creative water storage, soil conservation, and deep-water pools for refugia for fish. Without intervention, shortages of water during hot summers will lead to lower flows and reduced crop production. However, winter flows are not necessarily reduced by climate change; therefore, shifting availability of water from peak winter runoff to bolster low flows later in the hydrologic year may preserve some fish populations and agricultural opportunities.

The frequency, intensity, and duration of droughts are expected to increase across the region, with potentially dire consequences for fisheries, riparian ecosystems, forests, and the human communities in the watershed.

10. STRATEGIES FOR ACTION

Strategies were developed to be place-based and appropriate for each sub-region in the watershed. While we identified specific values within the four distinct reaches, a key takeaway from this process was how significantly the values, and strategies required to protect them, overlap throughout the watershed. Though each basin has different geography, ownership, and ecosystems, options abound for taking actions that improve conditions for flows, people,

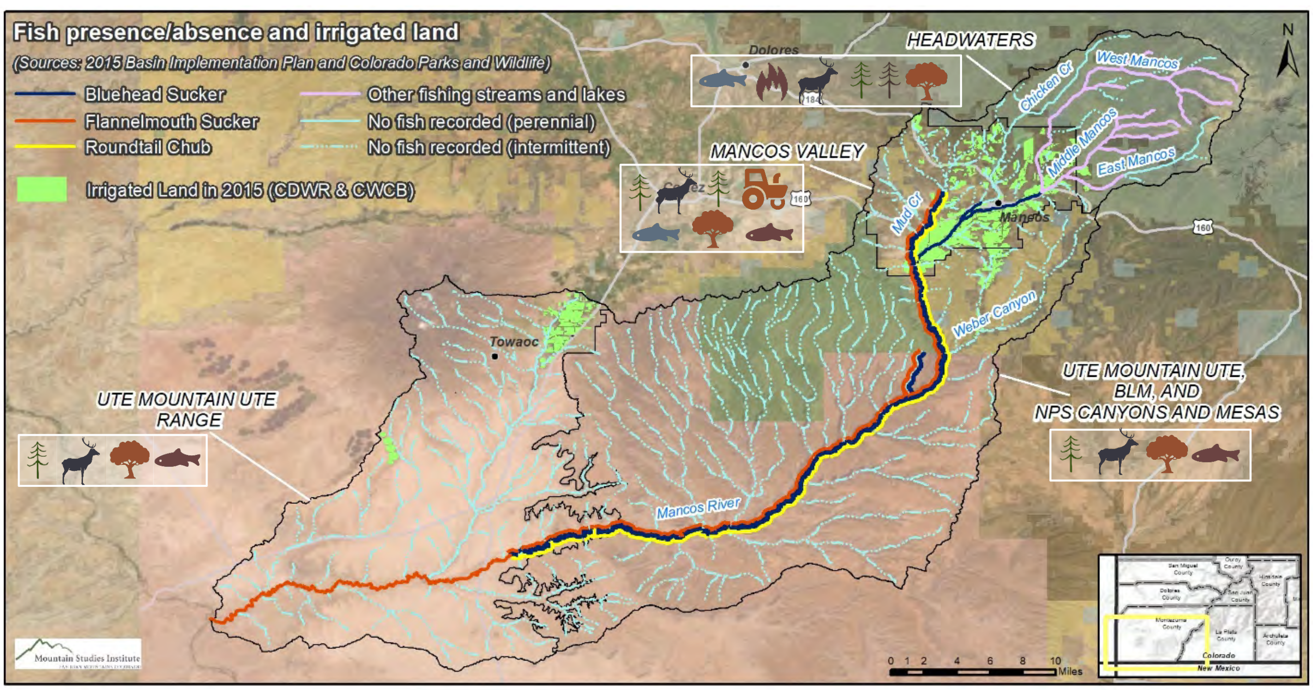
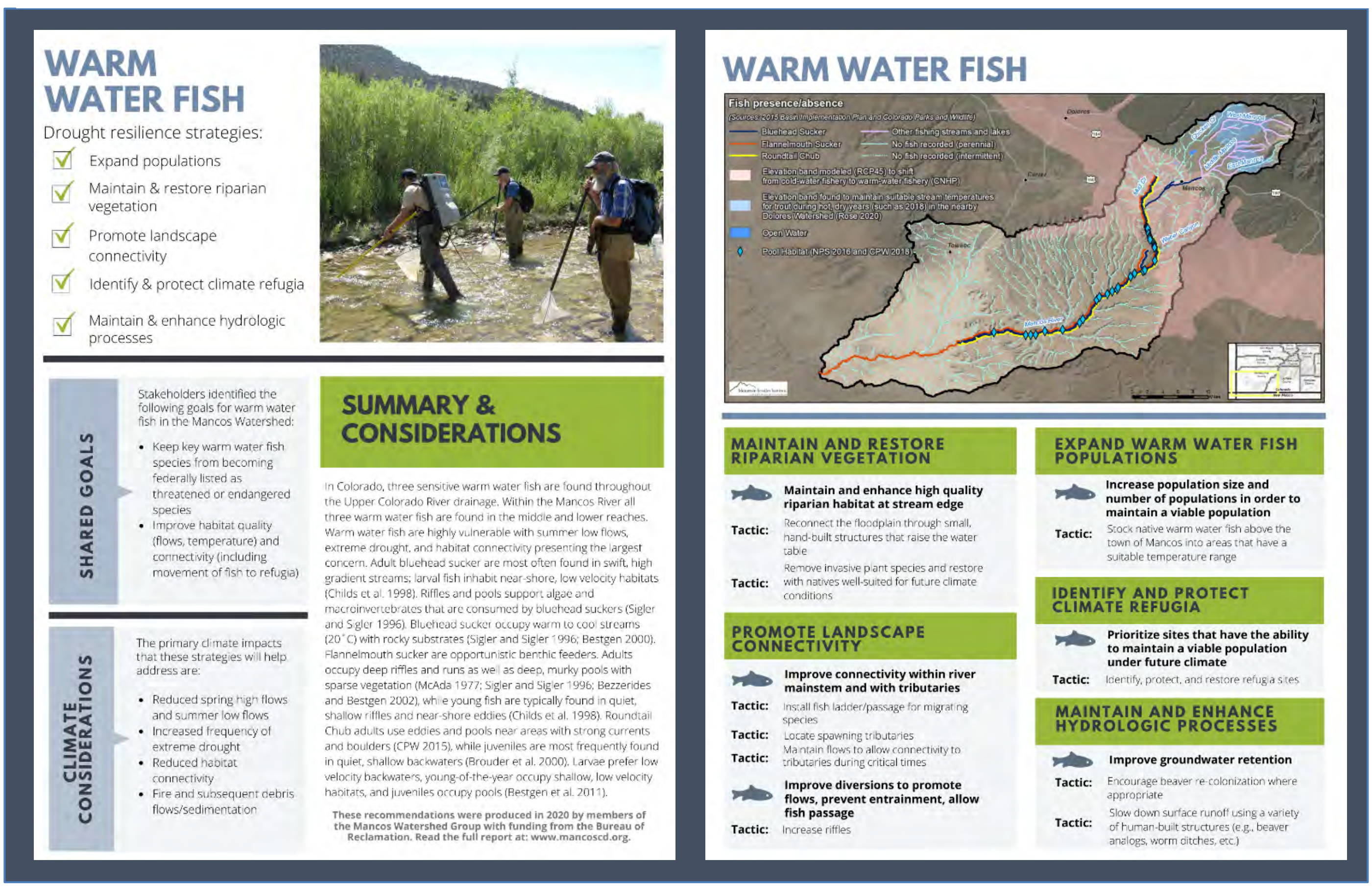


Figure 17. Sub-region Map with Overlapping Values of Irrigated Lands, Warm Water Fish, & Cold Water Fish

and fish across the watershed (Figure 17). Early in the process we decided that final products should be accessible to a broad range of stakeholders and presented in formats that are easily understood and applied as well as easy to see how different strategies can be accomplished in different places to benefit the watershed as a whole system. As such, the team developed what we referred to as "external" and "internal"-facing products. The "internal" products include the vulnerability assessment, summaries and maps, and the climate filter for prioritizing strategies.

The "external" educational and outreach materials consist, primarily, of seven strategy summary documents, and seven value summary documents that include spatially explicit information for each of the strategies (Figure 18). The strategy summary documents were developed by identifying the five strategies that were prioritized across values for the full watershed, and highlighting where those strategies make sense on the landscape; how implementing the strategies changes across ownership bounds or at distinct reaches of the watershed; and highlighting additional opportunities and barriers. For each of the value summaries, the Team identified the top strategies and created an accessible document that helps people with a value-focus identify the top climate informed strategies for that value, as well as reach and ownership-specific opportunities for implementation.

FRONT **BACK**



WARM WATER FISH

Drought resilience strategies:

- Expand populations
- Maintain & restore riparian vegetation
- Promote landscape connectivity
- Identify & protect climate refugia
- Maintain & enhance hydrologic processes

SHARED GOALS

Stakeholders identified the following goals for warm water fish in the Mancos Watershed:

- Keep key warm water fish species from becoming federally listed as threatened or endangered species
- Improve habitat quality (flows, temperature) and connectivity (including movement of fish to refugia)

CLIMATE CONSIDERATIONS

The primary climate impacts that these strategies will help address are:

- Reduced spring high flows and summer low flows
- Increased frequency of extreme drought
- Reduced habitat connectivity
- Fire and subsequent debris flows/sedimentation

SUMMARY & CONSIDERATIONS

In Colorado, three sensitive warm water fish are found throughout the Upper Colorado River drainage. Within the Mancos River all three warm water fish are found in the middle and lower reaches. Warm water fish are highly vulnerable with summer low flows, extreme drought, and habitat connectivity presenting the largest concern. Adult bluehead sucker are most often found in swift, high gradient streams; larval fish inhabit near-shore, low velocity habitats (Childs et al. 1998). Riffles and pools support algae and macroinvertebrates that are consumed by bluehead suckers (Sigler and Sigler 1996). Bluehead sucker occupy warm to cool streams (20˚C) with rocky substrates (Sigler and Sigler 1996; Bestgen 2000). Flannelmouth sucker are opportunistic benthic feeders. Adults occupy deep riffles and runs as well as deep, murky pools with sparse vegetation (McAda 1977; Sigler and Sigler 1996; Bezzerides and Bestgen 2002), while young fish are typically found in quiet, shallow riffles and near-shore eddies (Childs et al. 1998). Roundtail Chub adults use eddies and pools near areas with strong currents and boulders (CPW 2015), while juveniles are most frequently found in quiet, shallow backwaters (Brouder et al. 2000). Larvae prefer low velocity backwaters, young-of-the-year occupy shallow, low velocity habitats, and juveniles occupy pools (Bestgen et al. 2011).

These recommendations were produced in 2020 by members of the Mancos Watershed Group with funding from the Bureau of Reclamation. Read the full report at: www.mancoscd.org.

WARM WATER FISH

MAINTAIN AND RESTORE RIPARIAN VEGETATION

Maintain and enhance high quality riparian habitat at stream edge

Tactic: Reconnect the floodplain through small, hand-built structures that raise the water table

Tactic: Remove invasive plant species and restore with natives well-suited for future climate conditions

PROMOTE LANDSCAPE CONNECTIVITY

Improve connectivity within river mainstem and with tributaries

Tactic: Install fish ladder/passage for migrating species

Tactic: Locate spawning tributaries

Tactic: Maintain flows to allow connectivity to tributaries during critical times

Improve diversions to promote flows, prevent entrainment, allow fish passage

Tactic: Increase riffles

EXPAND WARM WATER FISH POPULATIONS

Increase population size and number of populations in order to maintain a viable population

Tactic: Stock native warm water fish above the town of Mancos into areas that have a suitable temperature range

IDENTIFY AND PROTECT CLIMATE REFUGIA

Prioritize sites that have the ability to maintain a viable population under future climate

Tactic: Identify, protect, and restore refugia sites

MAINTAIN AND ENHANCE HYDROLOGIC PROCESSES

Improve groundwater retention

Tactic: Encourage beaver re-colonization where appropriate

Tactic: Slow down surface runoff using a variety of human-built structures (e.g., beaver analogs, worm ditches, etc.)

Figure 18. Sample of Strategy Documents. Full copies of each are included in the Appendix.

Both documents were designed to provide a foundation for the next step toward implementation, whether that's identifying the best location, answering outstanding research or logistical questions, or securing funding.

Project results will be disseminated at multiple scales: locally through multiple MSI, MCD and CNHP websites, printed reports, and meetings with Mancos Watershed Group and specific partner groups, including the Dolores Watershed and other opportunities that transboundary user groups (e.g., meetings with multiple agencies, states, and stakeholders).

11. DISCUSSION

The goal of the project was to develop a repeatable and scalable drought resilience process that integrates sound climate science and rigorous scientific processes with on-the-ground stakeholder feedback to identify and prioritize climate-informed strategies for key values. By completing this process through an iterative and collaborative approach, we engaged stakeholders and managers and empowered them to prioritize climate-informed strategies for building drought resilience for multiple values in the watershed. The structure for this process was designed to stimulate dialogue, and spur deeper and more informed thinking about the pending impacts of climate change on a very vulnerable watershed.

While the strategies that were developed are by no means comprehensive, the process is designed to be scalable and repeatable, both by land and resource managers in the Mancos Watershed, and other watersheds.

Of note is the time it took to complete this process, and the opportunity to find efficiencies and reduce the time and resources required. In some ways, this process underscores the need to move slowly in order to move fast: by laying critical groundwork and foundation around climate vulnerabilities, managers can now move forward with that knowledge base in place and have ideas about resources that can help them stay current. However, in watersheds or with groups where the climate science and impacts are already relatively well understood, this process could likely be streamlined and occur much more quickly. As with all resource concerns and climate-informed decisions, these prioritized strategies will require ongoing review and revision or updates.

Alongside the priority strategies outlined in this document and the Appendix, managers will need to consider place-and goal-based nuances before pursuing implementation. For example, when it comes to addressing and prescribing treatments in ponderosa pine, thinning may make sense as a drought resilience strategy, but only if the forest has a diverse age structure and other management objectives, such as Lewis's woodpecker or other sensitive species, have been considered.

This effort has already inspired the pursuit of implementation projects. As we neared completion of this WaterSMART "Prioritized Drought Resilience Framework" effort, key stakeholders and early adopters were already working together to integrate findings from this project into grants to secure implementation funding for climate-informed strategies that were prioritized through the five-step decision framework. In 2020, the Mancos Watershed Group obtained funding for a Stream Management Planning effort that will build upon these strategies for a holistic approach to river health. In parallel, private landowners and resource managers from the Ute Mountain Ute Tribe undertook a coordinated effort to design a suite of groundwater retention strategies that could be implemented, monitored, and used for demonstration purposes across ecosystem and landownership types. This coordinated pursuit of funding for strategies that will mitigate both the social, economic, and ecological impacts of drought is illustrative of the success of the project.

CITATIONS

Abatzoglou, J.T., D.J. McEvoy, and K.T. Redmond, in press. The West Wide Drought Tracker: Drought Monitoring at Fine Spatial Scales, *Bulletin of the American Meteorological Society*

Alder, J. R. and S. W. Hostetler, 2013. USGS National Climate Change Viewer. US Geological Survey http://www.usgs.gov/climate_landuse/clu_rd/nccv.asp doi:10.5066/F7W9575T.

Allen, C.D., M. Savage, D.A. Falk, K.F. Suckling, T.W. Swetnam, T. Schulke, P.B. Stacey, P. Morgan, M. Hoffman, And J.T. Klingel. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective. Ecological Applications 12:1418–1433.

Anderson, R. M. and G. Stewart. 2007. Fish-Flow Investigation: II. Impacts of stream flow alterations on the native fish assemblage and their habitat availability as determined by 2D modeling and the use of fish population data to support instream flow recommendations for the sections of the Yampa, Colorado, Gunnison and Dolores Rivers in Colorado. Colorado Division of Wildlife Special Report No. 80, DOW-R-S-80-07. Fort Collins.

Arno, S.F. 2000. Fire in western forest ecosystems. Chapter 5 in Brown, J.K. and J.K. Smith, eds. Wildland fire in ecosystems: effects of fire on flora. Gen.Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Barrett, J.W., P.M. McDonald, F. Ronco Jr, and R.A. Ryker. 1980. Interior ponderosa pine. In: Eyer, F. H., ed. Forest cover types of the United States and Canada. Washington, DC: U.S. Department of Agriculture, Forest Service: 114-115.

Beatty, R.J., F.J. Rahel, and W.A. Hubert. 2009. Complex influences of low-head dams and artificial wetlands on fishes in a Colorado River tributary system. Fisheries Management and Ecology 16:457-467.

Bezzerides, N. and K. Bestgen. 2002. Status review of roundtail chub Gila robusta, flannelmouth sucker Catostomus latipinnis, and bluehead sucker Catostomus discobolus in the Colorado River basin. 2002. Colorado State University Larval Fish Laboratory, Fort Collins, CO.

Bjornn T.C. & Reiser D.W. 1991. Habitat requirements of salmonids in streams. Bethesda, MD: American Fisheries Society Special Publication 19, 83–138.

Brown, P.M. and R. Wu. 2005. Climate and disturbance forcing of episodic tree recruitment in a southwestern ponderosa pine landscape. Ecology 86:3030-3038.

Carter, J.G., V.A. Lamarra, and R.J. Ryel. 1986. Drift of larval fishes in the upper Colorado River. Journal of Freshwater Ecology 3:567-577.

Childs, M.R., R.W. Clarkson, and A.T. Robinson. 1998. Resource use by larval and early juvenile native fishes in the Little Colorado River, Grand Canyon, Arizona. Transactions of the American Fisheries Society 127:620-629.

Colorado Water Trust. 2011. Mancos River Basin Instream Flow Report. Prepared for the Mancos Conservation District by Amy Beatie and Zach Smith, Colorado Water Trust.

Covington, W.W. and M.M. Moore. 1994. Southwestern ponderosa forest structure: changes since Euro-American settlement. Journal of Forestry 92: 39–47.

Crausbay, S. D., et al. 2017: Defining Ecological Drought for the Twenty-First Century. Bull. Amer. Meteor. Soc., 98, 2543–2550, doi.org/10.1175/BAMS-D-16-0292.1

Decker, K., Fink, M. & Rondeau, R. (2017). Triangulation in climate change vulnerability assessment: examples from Colorado, USA. Regional Environmental Change. 1-9. 10.1007/s10113-017-1190-9

Douglas, M.R., M.E. Douglas, M.W. Hopken. 2009. Population Genetic Analysis of Bluehead Sucker [Catostomus (Pantosteus discobolus] Across the Species' Range. Online at http://www.fws.gov/southwest/es/NewMexico/documents/ZBSESD/Douglas_et_al_2013.pdf

Friggens, M.M. and C.K. Woodlief. 2015. Final Report: Synthesis of aquatic climate change vulnerability assessments for the Interior West. Rocky Mountain Research Station, Albuquerque, NM.

Holden, P.B. and L.W. Crist. 1981. Documentation of changes in the macroinvertebrate and fish populations in the Green River due to inlet modification of Flaming Gorge Dam. Contract No. 0-07-40-S1357 for Water and Power Resources Service. Bio/West, Inc., Logan, UT.

Holthe E., E. Lund, B. Finstad, E.B. Thorstad, and R.S. McKinley. 2005. A fish selective obstacle to prevent dispersion of an unwanted fish species, based on leaping capabilities. Fisheries Management and Ecology 12, 143–147.

Hopken, M.W., M.R. Douglas, M.E. Douglas. 2013. Stream hierarchy defines riverscape genetics of a North American desert fish. Molecular Ecology (2013) 22, 956–971.

Hostetler, S.W. and Alder, J.R., 2016. Implementation and evaluation of a monthly water balance model over the U.S. on an 800 m grid. Water Resources Research, 52, doi:10.1002/2016WR018665.

Kaye M.W., C.A. Woodhouse and S.T. Jackson. 2010. Persistence and expansion of ponderosa pine woodlands in the west-central Great Plains during the past two centuries. Journal of Biogeography 37:1668-1683.

Kerhoulas, L.P., T.E. Kolb, and G.W. Koch. 2013. Tree size, stand density, and the source of water used across seasons by ponderosa pine in northern Arizona. Forest Ecology and Management 289:425-433.

League, K. and T. Veblen. 2006. Climatic variability and episodic Pinus ponderosa establishment along the forest-grassland ecotones of Colorado. Forest Ecology and Management 228:98-107.

Lukas, J., J. Barsugli, N. Doesken, I. Rangwala, and K. Wolter. 2014. Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation. A Report for the Colorado Water Conservation Board. Western Water Assessment.

Mancos Conservation District. 2011. Mancos Watershed Plan. Collaborative plan developed and adopted by the Mancos Valley Watershed Group, a project of Mancos Conservation District. Mancos, CO.

Mast, J.N., T.T. Veblen, and Y.B. Linhart. 1998. Disturbance and climatic influences on age structure of ponderosa pine at the pine/grassland ecotone, Colorado Front Range. Journal of Biogeography. 25: 743-755.

McDonald, D.B., T.L. Parchman, M.R. Bower, W.A. Hubert, and F.J. Rahel. 2008. An introduced and a native vertebrate hybridize to form a genetic bridge to a second native species. Proc. Natl. Sci. USA. 105: 10842-10847.

Miller, W.J. and D.E. Rees. 2000. Ichthyofaunal surveys of tributaries of the San Juan River, New Mexico. Miller Ecological Consultants, Inc., Fort Collins, CO.

Muth, R.T. and D.E. Snyder. 1995. Diets of young Colorado squawfish and other small fish in backwaters of the Green River, Colorado and Utah. Great Basin Naturalist 55:95-104.

Nelson, R., M. Cross, L. Hansen, and G. Tabor. 2016. A three-step decision support framework for climate adaptation: Selecting climate informed conservation goals and strategies for native salmonids in the northern U.S. Rockies. Wildlife Conservation Society, EcoAdapt, Center for Large Landscape Conservation. Bozeman, MT, USA. http://rmpf.weebly.com/cold-water-ecosystem-management-tool.html

Osmundson, D.B. 1999. Longitudinal variation in fish community structure and water temperature in the upper Colorado River: implications for Colorado pikeminnow habitat suitability. Final Report for Recovery Implementation Program, Project No. 48. U.S. Fish and Wildlife Service, Grand Junction, CO.

Ptacek, J.A., Rees, D.E. and Miller, W. J. 2005. Bluehead sucker (Catostomus discobolus): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region, Fort Collins, Colorado.

Rangwala, I., & J. R. Miller. 2010. Twentieth Century Temperature Trends in Colorado's San Juan Mountains, Arctic, Antarctic, and Alpine Research, 42:1, 89-97, DOI: 10.1657/1938-4246-42.1.89

Ray, A.J., J. Barsugli, and K. Avery. 2008. Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation. Report to the Colorado Water Conservation Board.

Rees, D.E. and W.J. Miller. 2001. Habitat selection and movement of native fish in the Colorado River, Colorado. Miller Ecological Consultants, Inc., Fort Collins, CO.

Rehfeldt, G.E., N.L. Crookston, C. Saenz-Romero, and E.M. Campbell. 2012. North American vegetation model for land-use planning in a changing climate: a solution of large classification problems. Ecological Applications 22:119-141.

Reid, M. S., K. A. Schulz, P. J. Comer, M. H. Schindel, D. R. Culver, D. A. Sarr, and M. C. Damm. 1999. An alliance level classification of vegetation of the coterminous western United States. Unpublished final report to the University of Idaho Cooperative Fish and Wildlife Research Unit and National Gap Analysis Program, in fulfillment of Cooperative Agreement 1434-HQ-97-AG-01779. The Nature Conservancy, Western Conservation Science Department, Boulder, CO.

Romme, W., Allen C., Bailey, J., Baker, W., Bestelmeyer B., Brown P., Eisenhart, K., Floyd, L., Huffman, D., Jacobs, B., Richard F. Miller, Esteban H. Muldavin, Thomas W. Swetnam, Robin J. Tausch, Peter J. Weisberg, Historical and Modern Disturbance Regimes, Stand Structures, and Landscape Dynamics in Piñon–Juniper Vegetation of the Western United States, Rangeland Ecology & Management, Volume 62, Issue 3, https://doi.org/10.2111/08-188R1.1.

Romme, W.H., M.L. Floyd, and D. Hanna. 2009. Historical range of variability and current landscape condition analysis: South Central Highlands Section, Southwestern Colorado & Northwestern New Mexico. Colorado Forest Restoration Institute, Colorado State University, Fort Collins, CO.

Rondeau, R., B. Neely, M. Bidwell, I. Rangwala, L. Yung, K. Clifford, and T. Schulz. 2017a. Pinyon Juniper Landscape: San Juan River Basin, Colorado. Social-Ecological Climate Resilience Project. North Central Climate Science Center, Ft. Collins, CO.

Rondeau, R., B. Neely, M. Bidwell, I. Rangwala, L. Yung, K. Clifford, and T. Schulz. 2017b. Spruce-Fir Landscape: Upper Gunnison River Basin, Colorado. Social-Ecological Climate Resilience Project. North Central Climate Science Center, Ft. Collins, CO.

Shepperd, W.D. and M.A. Battaglia. 2002. Ecology, Silviculture, and Management of Black Hills Ponderosa Pine. General Technical Report RMRS-GTR-97. USDA Forest Service Rocky Mountain Research Station, Fort Collins, CO. 112

Smith, G.R. 1966. Distribution and evolution of the North American Catostomid fishes of Subgenus Pantosteus, Genus Catostomus. Miscellaneous Publications of the Museum of Zoology, University of Michigan, No. 129. University of Michigan, Ann Arbor, MI.

Theobald, D.M. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. Ecology and Society 10:32

Thompson, R.S., K.H. Anderson, and P.J. Bartlein. 2000. Atlas of relations between climatic parameters and distributions of important trees and shrubs in North America. U.S. Geological Survey Professional Paper 1650-A.

Thrasher, B., J. Xiong, W. Wang, F. Melton, A. Michaelis, and R. Nemani, 2013. New downscaled climate projections suitable for resource management in the U.S. Eos, Transactions American Geophysical Union 94, 321-323, doi:10.1002/2013EO370002.

Utah Division of Wildlife Resources [UDWR]. 2006. Range-wide conservation agreement and strategy for Roundtail Chub Gila robusta, Bluehead Sucker Catostomus discobolus, and Flannelmouth Sucker Catostomus latipinnis. Utah Division of Wildlife Resources, Publication No. 06-18, Salt Lake City, UT.

Ute Mountain Ute Tribe, 2020. Núchíú Ute Mountain Ute Tribe Climate Action Plan. A Collaboration of the Ute Mountain Ute Tribe Climate Change Adaptation Planning Working Group and Colorado State University.

Ute Mountain Ute Tribe. 2013. Mancos River Water Quality and Trends Assessment: 2011-2012. Prepared by C. Larrick and J. Ashmore, Ute Mountain Ute Tribe Environmental Program.

Vanicek, C.D. 1967. Ecological studies of native Green River fishes below Flaming Gorge Dam, 1964-1966. Ph.D. Thesis, Utah State University, Logan, UT.

White, J. 2016. "Mancos River Fisheries and Aquatic Health." Presentation to Mancos Resilience Workgroup, December 1, 2016.

Wilson Water Group. 2020. Mancos Watershed Drought Resilience Planning: Basin Characteristics and Model Development Final Report. Prepared for Mancos Conservation District.

Youngblood, A. P., and R. L. Mauk. 1985. Coniferous forest habitat types of central and southern Utah. USDA Forest Service, Intermountain Research Station. General Technical Report INT-187. Ogden, UT. 89 pp

APPENDIX

HISTORY OF PROJECTS IN THE MANCOS WATERSHED

CLIMATE MODELS SUMMARY TABLE

VULNERABILITY ASSESSMENT SUMMARIES + PRIORITY STRATEGIES

- Irrigated Lands
- Non-irrigated lands
- Riparian Habitat
- Warm-Water Fish
- Cold-Water Fish
- Pinyon-Juniper Woodlands
- Ponderosa Pine Forests

"DROUGHT AND CHANGE IN THE MANCOS WATERSHED" BOOKLET

Mancos Watershed - Promoting Long-term Sustainable Use and Protection

Introduction

In 2006 stakeholders in the Mancos Valley formed the Mancos Valley Watershed Group and worked together on developing the Mancos Watershed Plan, completing the report in 2011. The Watershed Plan became the guiding document for numerous on-the-ground projects and outreach activities in the watershed led by the Mancos Valley Watershed Group (now called the Mancos Watershed Group) and the Mancos Conservation District. The stakeholder group reconvened in 2015, and identified the need to update the knowledge base identifying accomplishments, data availability, information gaps, and priority issues.

The Mancos Watershed Plan has been the foundation document, identifying stakeholder concerns and defining goals. The Plan pointed towards the importance of irrigation efficiency projects, many of which have been completed. Subsequent studies and reports have built on information provided in the Plan.

This report is an overview identifying the flow of plans and projects completed or underway in the Mancos watershed, presented chronologically. Each section includes a brief summary paragraph and includes goals, outcomes, and gaps identified within each plan or project. The final section of the report is an overview of current activities in the Mancos Watershed, and a recap of data gaps and information needs.

Mancos Watershed Plan

Project lead: Mancos Valley Watershed Group

Report completed in 2011

A series of stakeholder meetings and studies coordinated by the Mancos Valley Watershed Group from 2006-2011 identified priority critical issues related to the Mancos River. These were: 1) the need to upgrade the aging, 19th century-vintage irrigation infrastructure; 2) the need to address historical levees; 3) the need to address the East Mancos River water-quality which had been identified as impaired for dissolved copper; and 4) concerns about impacts of low flows during late summer irrigation season on fish populations and riparian ecosystems.
The Group developed the Mancos Watershed Plan based on guidance provided by the US Environmental Protection Agency, including methods to develop an educational/informational component, to finance the work required, and monitoring methods to assess the effectiveness of the programs implemented.

Goals identified in the 2011 Mancos Watershed Plan:

1. Improve fishing, primarily from the confluence of the East Mancos River with the West Mancos River downstream.
2. Reduce the loading of dissolved copper from the East Mancos River either through reductions at the source, increasing assimilative capacity, or through dilution.
3. Work with irrigators/irrigation companies and landowners along the Mancos River to restore the functioning capacities of the river system.
4. Work with irrigators to rebuild diversion systems that are in need of constant maintenance and that have major impacts on river functions.
5. Improve the riparian ecosystem and thus the functioning capacity of the river.

6. Improve in-stream flows throughout the summer months through the town of Mancos and downstream when irrigation tends to dewater the river.

Projects and reports that informed development of the 2011 Watershed Plan:

- The *Mancos Valley Salinity: Hydrologic Study Report* (2004) assessed salinity contributions from the Mancos watershed to the Lower Colorado River Basin. This study quantified salt loading in the Mancos watershed using information documenting irrigated agriculture, geology, and soils, and streamflow and relevant constituent concentrations data obtained from various agency and tribal databases. Conclusions of the report resulted in the Mancos Valley's 2004 inclusion in NRCS salinity control program, contributing to the foundation of the Watershed Plan.
- The Ute Mountain Ute Tribe produced the report *Nonpoint Source Assessment for the Ute Mountain Ute Reservation of Colorado, New Mexico and Utah, 2005 Revision* (Clow and Daniel B. Steffens and Ass. Inc.), identifying non-source pollutants occurring in waters on tribal lands, and the sources of these pollutants. The primary recommendation was implementation of a non-point source pollution control program.
- Dr. Peter Stacey of the University of New Mexico used the Rapid Stream-Riparian Assessment method (RSRA) to complete the *Functional Assessment of the Mancos Watershed* (Stacey 2007), addressing Goals #1, 3, and 5 and providing information about the condition of the Mancos River's geomorphology, aquatic habitat, and riparian ecosystems.
- The Natural Resource Conservation Service's *Rapid Assessment of the Mancos Watershed* (2008) was an overview of the basin intended to guide conservation implementation by identifying where investments would best meet the needs and concerns of landowners, community organizations and stakeholders. The Assessment was a supporting document used in the development of the Watershed Plan and briefly summarizes concerns identified by the Mancos Conservation District, Ute Mountain Ute Tribe, and the National Park Service. These concerns were water resource management, noxious weed control, rangeland improvement, salinity, water conversions, and water quality in the East Fork of the Mancos River.
- A *Sampling and Analysis Plan* and a *Quality Assurance Project Plan* were completed by the Mancos Valley Watershed Group (2008), addressing Goals # 1 and 2, and functioning as guidelines for a water chemistry survey of the East Mancos River conducted by the Colorado Division of Mining and Reclamation in 2009. The survey replicated much of the work completed by the Water Quality Control Division in their 2006 TMDL for the East Mancos River.
- B.U.G.S. Consulting completed a *Sampling and Analysis Plan* (B.U.G.S. Consulting 2009) and *Benthic Macroinvertebrate Assessment of the Mancos River* (B.U.G.S. Consulting 2010). The purpose of the benthic macroinvertebrate assessment was to assess habitat quality, water quality, and biological integrity of the East Mancos, the Mancos River, and major tributaries to aid in improving understanding of deteriorated of fish populations, the impacts of metals to the biology of the river, and determine how far downstream those impacts are present, and establishes a baseline that can be used to evaluate natural trends or changes due to management activities, addressing Goal #1. The Sampling and

Analysis Plan was intended to serve as guidance and protocols for future macroinvertebrate sampling and analysis efforts on the Mancos River and tributaries, ensuring sampling repeatability and data quality.

- Mancos Conservation District contracted The Colorado Water Trust to provide *Mancos River Basin Instream Flow Report - Preliminary Evaluation of Flow Restoration Options* (2011), a report focused on Goal #6, assessing areas where water could potentially be obtained and left in the Mancos River to enhance in-stream flows.
- Colorado Division of Wildlife reviewed fish stocking and sampling of the Mancos River (Horn, 2011). The review is partial, but provides a baseline that can be used to evaluate natural trends or changes due to management activities of the East Mancos fish population, addressing Goal #1.
- The Mancos Conservation District inventoried more than 50 diversion structures, one step in support of Goal #4. The Watershed Plan contains an Appendix with detailed information about 12 diversion structures prioritized as candidates for reconstruction due to nearby head-cutting, bank-cutting drying of surrounding riparian area, and obstruction of fish passage.
- The San Juan National Forest developed a travel management plan to meet current and future anticipated needs for a variety of summer recreation opportunities and administrative demands. Goals of the plan were:
    - Improved management of public seasonal motorized vehicle use on a system of trails, roads, and areas;
    - Management of public motorized recreation in a way that meets the need of forest users while reducing soil erosion and impacts to wetlands, wildlife habitat, and cultural resources, and;
    - Respond to the goals and objectives outlined in the Amended San Juan Land and Resource Management Plan (Forest Plan, 1992) and San Juan/San Miguel Resource Management Plan (RMP, 1985).

Mancos Conservation District Projects

The following is a list of projects completed by the Conservation District prior to 2011 and identified in the 2011 Watershed Plan.

- Irrigation pipelines that carry approximately 30% of the irrigation water diverted in the valley are completed or in progress.
- Numerous conservation wildlife and on-farm irrigation projects including pipelines and irrigation equipment have also been undertaken. The total of the grant contributions for salinity control measures in the valley made by NRCS for the years 2004-2007 is $6M.
- The District was awarded $75,000 from the Colorado Water Conservation Board for restoration sites on two parcels of land: the Perry and Wolcott ranches. The projects took place on ranches that have been grazing cattle along the waterway for 50 to 60 years and over 2000 feet of stream reaches were restored.
- The District was awarded a grant to rebuild 3 diversion structures and to evaluate the potential for in-stream flows, primarily during the summer irrigation season when the river is dewatered in several reaches.

- Develop information and education program intended to enhance public understanding of and participation in Mancos Conservation District projects.

Implementation schedule for studies and management measures

The 2011 Mancos Watershed Plan included the following designed to address the Plan's goals. Current status is shown in *italics* below each bulleted item.

- Loading study designed to improve understanding of sources of contaminants in East Mancos River.
  Study of water quality in East Mancos River initiated in 2018.
- Depending on the results of loading study, implement a tracer study.
  Decision whether or not to implement tracer study pending results of current project.
- Restore reaches in valley impacted by historical levees (Stacey 2007) - Completed over the next 10 years, 1000 feet per year.
  Potential impacts on the river related to levees have not been addressed.
- Diversions 1-12 with riparian restoration and improving hydrogeomorphology - Completed over the next 12 years where 1 diversion is completed each year.
  The Mancos Conservation District has completed improvements on nine diversions in the Mancos Valley.
- Purchase water for instream flows - Get funding and willing sellers in place 2011 to 2014. Begin purchasing water in 2014. Continue purchases until the point where the river at the confluence of the East Mancos with the West Mancos is sufficiently dilute and the concentration of dissolved copper is below TMDL levels.
  No water has been purchased for instream flows.
- Reduce salinity loads - Install 1 sprinkler system to replace 20 acres of flood irrigation each year over the next 10 years
  Status unknown
- Reduce selenium, especially in Navajo Wash - Install 1 sprinkler system to replace 20 acres of flood irrigation each year over the next 10 years focusing on Navajo Wash
  Status unknown
- Close, improve and maintain roads in National Forest lands - Over the next 10 years close or improve 10 miles of degraded road each year
  Status unknown
- Reduce sediment loads from burn areas - Reseed 10 acres per year over the next 10 years.
  Status unknown
- Habitat rehabilitation in Mancos Canyon - Maintain/rebuild/monitor fencing that keeps cattle out of the riparian corridor within Mesa Verde National Park.
  Fencing complete.

The Mancos Watershed Plan identified a set of criteria to evaluate whether water quality improvement goals are met, and emphasized the importance of evaluating the effectiveness of implementation efforts. The Plan also included documentation of educational and informational projects completed, emphasizing the importance of continuing these in the future.

Mancos River Basin Instream Flow Report - Preliminary Evaluation of Flow Restoration Options

Project lead: Colorado Water Trust

Report completed in 2011

The 2011 *Mancos River Basin Instream Flow Report* was funded by the Mancos Conservation District and written by the Colorado Water Trust. The study addressed Mancos Watershed Management Plan's Goal #6 and examined options for balancing the needs of Mancos River water users with the desire to improve streamflows in the Mancos River Basin.

The report included a summary of water rights, a description and preliminary analysis of hydrology in the Mancos watershed, and addressed the following Mancos Valley Water Conservation Project goals:

- The reduction of salt in the Colorado River.
- The conservation of water lost through seepage and inefficient water application practices.
- The restoration of the Mancos River's riparian habitat.
- The establishment of an increase in the amount of water available to local properties.

Colorado Water Trust's recommendations:

- Examine potential for new instream flow appropriations.
- Examine potential for instream flow acquisitions.
- Continue efficiency projects.
- Consider other projects as appropriate such as eradication of phreatophytes as well as streambed and other modifications that may help improve the local system.

The Instream Flow Report described minimal guidelines for implementation each of the recommended streamflow protection and restoration measures, however the report identified the in-depth analysis would be required to go forward.

Mancos River Resilience Report

Project lead: Mountain Studies Institute

Report to be completed in 2019

The *Mancos River Resilience Report* was a collaborative effort of the Mancos River Restoration and Resilience Group, a sub-group of the Mancos Valley Watershed Group. The group identified a set of key values and used existing data for each of these to create a snapshot of the current state of the Mancos River. Values were agriculture, forest health, water quality, water quantity, and river health including fish, macroinvertebrates, and riparian ecosystems. Stakeholders and technical experts developed a set of questions identifying concerns and issues for each value.

All available data describing each value was gathered and summarized, information gaps were identified, and recommendations for future projects or studies were included in the report and are summarized below.

Agriculture

- **Land quality & quantity -** How much land is currently being used for agriculture and how is that land poised to change in the future?

        - Recommend compiling historic changes to parcel size and maintaining this information in a GIS database or spreadsheet enabling analysis of trends over time.
- **Irrigation efficiency -** How is irrigation consumptive use changing? And how efficient is our irrigation?
    - Improvements have been made to structures on six major diversions in the Mancos Valley, but a clear understanding of potential improvements on remaining structures is needed.
    - Map and survey diversion structures, specifically identifying places where efficiency and delivery can be improved.
    - Create a comprehensive map project of Mancos Valley irrigated lands.
- **Soil health -** Are soils in the Mancos River Valley healthy and functional?
    - Assess and monitor soil conditions in the Mancos Valley.

Forest Health

- **Wildfire risk -** What is the wildfire risk to communities and ecosystem values in the Mancos Watershed?
    - A weighted evaluation of what are significant resources that may be damaged by wildfire or post-fire flooding has not been done within the Mancos Watershed.
    - Post-fire recovery and succession has not been well studied within the areas of the watershed that have burned.
    - Fire regimes in grasses and shrublands are not well understood in the region.
- **Forest health: insects & disease -** How healthy are our forests?
    - Acquire annual stand-specific data gathered in the Mancos Watershed from Regional and National USFS databases.
    - How healthy is forest succession after large fires in the watershed?
    - Can public and private land management influence insect and disease outbreaks?

Water Quantity - Is there enough water to meet stakeholder needs?

- Establish and maintain streamflow gaging stations at key points on the Mancos River.
- Implementation of a flow monitoring network on the major diversions in the watershed.

Water Quality - Does the river's water quality support current and desired use needs?

- Address identified water quality impairments for the Mancos River.
- The National Park Service and Ute Mountain Ute Tribe have ongoing water quality monitoring programs on the Mancos River.
- The RiverWatch water quality monitoring program was operated from 2007 – 2009.

River Health

- **Fish** - Where do we have native fish and non-native/invasive fish?
    - What is the estimated abundance of each species in the sampled reaches? How and why has abundance been changing over time?
    - What is the age structure of fish species in sampled reaches? How has the age structure of fish in the Mancos River changed over time?
    - Where and how frequently does fish stocking occur? What are the stocking goals?
    - What are the most productive reaches in the Mancos Watershed for native fish? For game trout?
- **Macroinvertebrates** - What is the health of the macroinvertebrate communities in the river?

    - Data documenting benthic macroinvertebrate communities and habitat in the Mancos River is sparse and much of it is outdated. Reaches where MMI impairments have been identified should be priorities for future monitoring efforts.
    - What is causing (what is the source of) aquatic life impairments?
    - How can communication and data-sharing between agencies be improved?
    - Ensure all available data are included in future CDPHE analysis.
    - OPPORTUNITY: Co-locate benthic macroinvertebrate monitoring network with RiverWatch water quality monitoring sites.
- **Riparian ecosystem** - How healthy is the riparian system within the watershed?
    - Are cottonwoods and other native tree species regenerating along the river?
    - What flows in the Mancos River support establishment of cottonwood seedlings?
    - What conditions are needed for woody shrub and tree species recruitment?
    - How widespread are tamarisk, Russian olive, Siberian elm, and other invasive species in the watershed?
    - OPPORTUNITY: Co-locate RSRA sampling sites with RiverWatch water quality monitoring sites.

<u>Mancos Watershed Water and Drought Concern Gathering</u>

Project lead: Mancos Conservation District

Report to be completed in 2019

Mancos Conservation District's *Mancos Watershed Water and Drought Concern Gathering* project began in 2017, and was completed in 2019. The project used a survey to invite input from any and all water users, land owners, and stakeholders in the Mancos Watershed, asking for input on a variety of issues related to water and drought. Responses to the survey identified climate change and drought, lack of current storage and sound infrastructure, and water education as the highest priority water supply issues. Respondents suggested the best ways to address these issues would be through education, community building, and conservation. Participants stressed the importance of satisfying all user groups and expressed strong interest in being engaged in future meetings and discussions about water supply concerns.

<u>Mancos Watershed Drought Resilience Planning - Basin Characteristics and Model Development Report</u>

Project lead: Wilson Water Group

Report completed in 2019

In 2017 the Mancos Conservation District contracted Wilson Water Group (WWG) to support the *Mancos Watershed Drought Resilience Planning* effort through a project designed to develop and utilize decision support tools to describe current conditions of streamflow and consumptive use in the Mancos watershed, identify data gaps, and evaluate future alternatives. Project goals included:

- Documentation of Watershed Characteristics
    - Hydrology
    - Water Rights
    - Agricultural and Municipal Uses
- Update Decision Support System Tools
    - Quantify Existing Consumptive Uses

- Prepare for assessing drought resiliency options

WWG refined and used the State of Colorado's Colorado Decision Support System (CDSS) water rights allocation model to evaluate sources of diversion water, natural flow, and crop consumptive use for representative dry, wet, and average years of streamflow the Mancos River. Example scenarios including change in hydrology (two potential drought scenarios), increased reservoir storage capacity, and irrigation practices (unlined ditches and flood irrigation; piped and sprinklers) were explored. Important outcomes of the project were recognition of the high variability of flow and lack of long-term trends in the Mancos, and that doubling the size of Jackson Gulch Reservoir would only increase the consumptive use capacity by ~1,000 AF.

The Wilson Water Group's report included the following recommended additional data collection and potential model refinements for future drought resilience planning efforts:

- streamflow gages in the Mancos River Basin are critical for administering the river; possibly through reactivation of historic gages, or at locations of specific interest.
- The existing SNOTEL site is appropriate for forecasting runoff, and no additional sites are recommended.
- Jackson Gulch Reservoir Inlet Canal and the reservoir storage contents are well measured. It may be helpful to install a measurement device at the reservoir outlet in order to quantify the outlet canal seepage and losses.
- For future model refinement, it would be helpful to better understand lagged return flow timing from gated pipe and sprinkler irrigated fields, including field studies to measure the real-world conditions.
- For future model refinements, it would be helpful to delineate the ditch alignments. Open, unlined earthen canals could then be analyzed based on soil parameters in order to better estimate conveyance losses.

Prioritized Drought Resilience Framework

Project lead: Mountain Studies Institute

Report to be completed in 2020

The goal of the *Prioritized Drought Resilience Framework* is: to develop a repeatable and scalable decision support framework for prioritizing adaptation strategies to improve the drought resiliency of stream flows, livelihoods, and fisheries.

This project will:

- Work with managers and stakeholders to articulate shared, forward looking goals for people and conservation.
- Articulate key stressors and vulnerabilities under a suite of future scenarios (considering both climate and non-climate stressors) that impact river flows, livelihoods, and fisheries.
- Develop an integrated Decision Support Framework that helps resource managers to think critically about conservation objectives and document their decisions.
- Map vulnerabilities by sub-watershed to identify specific geographic areas within the watershed that are priorities for management and conservation investment in particular strategies.
- Identify specific actions to implement the chosen strategies.

- Collaborate with the SRLCC and the LCC network to disseminate the results of our work and to encourage widespread application in other high priority watersheds.

Summary of Current Activities and Steps Forward

Progress has been made on many of the studies and management measures recommended in the Mancos Watershed Plan. Numerous projects addressing irrigation efficiency in the Mancos Valley have been completed and more are planned. However, many of the goals identified in the Watershed Plan have been achieved only partially, and some not at all.

Several projects initiated for the purpose of addressing the Watershed Plan's goals, and identified gaps and needs are underway. These include Rapid Stream-Riparian Assessments, Riverwatch water quality and macroinvertebrate monitoring, and water temperature monitoring by the Mancos Conservation District. A study led by Mountain Studies Institute is looking at water quality, macroinvertebrates, and sources of potential contaminants in the East Mancos River.

Downstream from the Mancos Valley the National Park Service (NPS) monitors water quality, macroinvertebrates, and alluvial groundwater at two sites on the Mancos River in Mesa Verde National Park, and from 2016 to 2018 NPS completed surveys of current and historic channel morphology and riparian vegetation along the Mancos River in the park. The Ute Mountain Ute Tribe (UMUT) published *Mancos River Water Quality and Trends Assessment: 2011 – 2012* (Larrick 2013) presenting water quality and other data collected from waters throughout the Mancos watershed and continues their water quality and macroinvertebrate monitoring programs in the Mancos River.

Further work needs to be done addressing all of the goals stated in the Mancos Watershed Plan. The Mancos River Basin Instream Flow Report provided options for improving instream flows in the river, however further assessments will be necessary to understand minimum flows required to manage the river for multiple uses. Mancos Conservation District's community survey identified climate change and drought, lack of current storage and sound infrastructure, and water education as the highest priorities. The drought in 2018 caused prolonged drying of the river in many locations, reiterating the importance of addressing this issue.

The Mancos River Resilience Report identified numerous information gaps and needs, including the need to track and analyze changes in parcel size; identify and map places where water efficiency can be improved; the importance of evaluating potential wildfire related risks and potential damage (e.g. reservoirs, community, river health); a significant data gap in our understanding of soil health throughout the watershed; the need to improve our comprehensive understanding of the Mancos River's aquatic and riparian ecosystems; and the potential vulnerability of these to reduced flows in the river. Wilson Water Group's CDSS model could be further refined by adding 2018 and 2019 data.

Additional flow measurement stations would inform many goals identified by stakeholders. Most current studies of the Mancos River are being carried out independently by the various agencies. Use of compatible data collection methods and reporting throughout the watershed whenever possible would enhance the ability to address known issues and improve river health at a watershed scale.

The potential effects of drought and climate change could have significant impacts on agriculture, streamflow, and river health in the Mancos watershed. Steps towards understanding and planning for these are the focus of the Drought Resilience Framework and integrated into river management and improvement actions.

The Mancos Watershed Plan drafted in 2011 gave minimal attention to forest health or to the portion of the watershed on Ute Mountain Ute Tribal lands. It has been nearly ten years since the Watershed Plan was completed. Since that time new critical issues have emerged, such as changing land use patterns, drought, and climate change, pointing towards the need for revisiting and updating the Plan’s goals, encompassing the entire watershed.

Climate Scenarios for the Mancos Watershed Group

Note: These are changes during 2020-2050 relative to 1985-2015; hence these are changes on top of changes that have already occurred between 1985-2015 which saw at least a 2F warming across Colorado.

	Hot & Dry	Feast or Famine	Warm & Wet	Hot & Wet
	hadgem2-ao.1.rcp85	*cesm1-bgc.1.rcp85*	*gfdl-esm2m.1rcp45*	*canesm2.1rcp85*
Annual Temp increase F (C°)	3.9 (2.2)	2.6 (1.4)	1.9 (1.0)	4.0 (2.2)
Winter Temp increase F (C°)	6 (3.3)	3.0 (1.6)	1.4 (1)	4.5 (2.5)
Spring Temp increase F (C°)	2.5 (1.4)	1.9 (1)	3.4 (1.9)	4.1 (2.3)
Summer Temp increase (F) (C°)	3.5 (1.9)	2.3 (1.3)	1.8(1.0)	3.9 (2.2)
Fall Temp increase F (C°)	3.4 (1.9)	2.8	1.1 (0.6)	3
Annual Precipitation (%)	-13	2.0	16	3
Winter precipitation (%)*	-8	24	28	0
Spring precipitation (%)	-6	0	-17	6
Summer precipitation (%)	-18	9	20	17
Fall precipitation (%)	-11	-6	30	-8
Snowline/ Freezing Level	shifts up by 1800 ft	shifts up by 700 ft	shifts up by 400 ft	shifts up by 1300 ft
Summer monsoon	decrease by 18%	increase by 9%	increase by 20%	increase by 17%
Rain events	less frequent but more intense individual rain events	no change in frequency but increase in more intense rain events	slight increase in frequency as well as increase in more intense rain events	slight increase in frequency as well as increase in more intense rain events
Total Runoff	> 25% decrease	5% decrease	5% increase	5% decrease
Timing of peak spring runoff (earlier by how many days)	13 days	9 days	13 days	20 days
Spring Soil Water Storage (%)	-26	-8	-6	-27
Summer Soil Water Storage (%)	-60	-19	-23	-40
Spring Evaporitive Deficit (%)	70	24	35	59
Summer Evaportive Deficit (%)	23	8	5	13
Severe Drought years (like 2002) frequency	every 3-5 years	every 5-10 years	every 30-40 years	every 5-10 years

	Hot & Dry	Feast or Famine	Warm & Wet	Hot & Wet
Drought intensity and frequency	increase in intensity and frequency	moderate increase in intensity and frequency	little change in intensity moderate increase in frequency	moderate increase in intensity and frequency
# of days in heat waves (annual count of days with at least 6 consecutive days when TX>90th percnetile (eastern CO) (baseline days)	44	17	10	27
Growing season increase	increases by 2 weeks	increases by 2 weeks	increases by 1 week	increases by 3 weeks
Dust events	high frequency, large dust events every other year causing peak runoff to be 6 weeks earlier	large dust event following a dry year - large year to year fluctuations	same as current	high frequency, large dust events every other year causing peak runoff to be 6 weeks earlier
Fire frequency	greater fire frequency, especially in high elevation	fire risk during dry years is very high due to high fuel load from wet years	slightly worse than current	greater fire frequency, especially in high elevation
Fire season length	may widen by 1 month	increases by 2 weeks but large year to year fluctuations	same as current	may widen by 1 month
El Nino events	no change	Doubling of large El Nino events	no change	no change
Flood risk	flood less frequent than today but risk increases for big summer time rain events	flood frequency does not change, but risk increases substantially during the wet years	flood frequency increases and so does the overall risk	most increase of any of these scenarios
April SWE	-54%	3% increase	-5%	-52%

Note: The Climate Scenario Table was produced for the Social-Ecological Resilience of Colroado Project funded by North Central Climate Science Center (Rondeau et al, 2017). Dr. Imtiaz Rangwala, North Central Climate Science Center, and Renee Rondeau, Colorado Natural Heritage Program provided updates to the table through funding provided by US Bureau of Reclamation WaterSmart Grant and the Southern Rockies Landscape

CROSS-CUTTING STRATEGIES FOR DROUGHT RESILIENCE
in the Mancos Watershed

These strategies were developed through a multi-year and multi-stakeholder process. The primary values that stakeholders in the watershed chose to develop drought resilience strategies for were:

- **irrigated lands**
- **riparian habitat**
- **non-irrigated lands**
- **pinyon - juniper and ponderosa forests**
- **cold and warm water fish**

These are the top cross-cutting strategies across all of those values. See the full summary of drought resilience strategies for each value for more detailed strategies and tactics.

" I think about irrigation water. I think about snowpack. And maybe I think about how that's associated with the agricultural heritage and character of the Mancos Valley. The concern would be having water. Without irrigation water, this valley's done. "

" In 2002 and 2018, the river dried up at times. It no longer supports the species who need perennial water year-round. "

" All can say this: sometimes, you know, the way we used to use water isn't the best way to use it now. Not the most bang for our buck. "

TOP CROSS-CUTTING STRATEGIES:

- Promote research, education, and monitoring
- Promote landscape connectivity
- Maintain and enhance hydrologic processes
- Sustain fundamental functions of soil and water
- Maintain and restore riparian vegetation
- Reduce the risk and long-term impacts of severe disturbances
- Facilitate adjustments through community species transition
- Identify and protect climate refugia

These strategies are: ☑ Climate informed ☑ Feasible ☑ Scalable

CLIMATE VULNERABILITY SCORE:

HIGHLY VULNERABLE

Vulnerability factors include:

- **Winter and spring precipitation**
- **Growing season soil moisture and evapotranspiration**
- **Drought**
- **Summer monsoon precipitation**

Distribution

In the Mancos watershed, irrigated ranchlands consist of cleared and often planted hay meadows as well as fruit trees and other crops. They are generally found in the middle reach (the Mancos Valley) of the study area. Water for irrigation originates as snowmelt from the upper watershed and is piped through ditches. The water is applied via flood irrigation, center pivots, or side roll. The majority of irrigation takes place during June-August. Winter and spring moisture is critical for replenishing the reservoirs, streams, and rivers. Monsoonal rains are also an important factor and can alter the amount of irrigation needed.

PRIMARY USE OF IRRIGATED LANDS IN THE WATERSHED:

- Cattle grazing and production
- Hay production
- Fruit trees
- Crop production

VULNERABILITY ASSESSMENT SCORING: Across Four Climate Scenarios, 2050

This Mancos River watershed rank is based on the following key attributes: 1) Winter and spring precipitation, 2) Growing season soil moisture and evapotranspiration, 3) Growing season drought, and 4) Summer monsoon.

Winter precipitation: Deep soil moisture is replenished from winter and early spring moisture. Years with ample deep soil moisture are likely to produce good forage. We used winter precipitation as the impact assessment metric and how future climate scenarios depart from the 1985-2015 average. The Hot and Dry scenario is projected to incur a -6% decrease in winter precipitation, while the Hot and Wet remains the same as the historic average, the Feast or Famine and Warm and Wet scenarios both project an increase of 24% and 28% respectively.

Spring precipitation: Spring precipitation, especially as forage plants begin to grow, can ensure high quality forage that is important for determining summer livestock plans. We used spring precipitation as the impact assessment metric and how future climate scenarios depart from the 1985-2015 average. The

Warm and Wet scenario projects a -17% decrease and the Hot and Dry scenario is at a -6% decrease, while the other two scenarios, Feast and Famine and Hot and Wet, are either no change or slightly positive (0 and 6%, respectively). Spring temperatures rise in all scenarios, ranging from an increase of 2-4 F, the Feast or Famine and Hot and Wet scenarios may still result in a water deficit, i.e., the change in spring precipitation is not enough to offset the increase in spring temperature increases.

Growing season soil moisture deficit and summer evapotranspiration: Summer soil moisture is critical to forage productivity. Years with low soil moisture and high evaporative demand result in lower forage production. We used growing season soil moisture and summer evapotranspiration as the impact assessment metrics. All scenarios project a soil moisture deficit during the growing season, ranging from -13% to -43%. All scenarios project an increase in evapotranspiration, leading to a soil moisture deficit in most years, ranging from -6 to -15% compared to historic average. This results in a summer and growing season drying trend in most years which will be exacerbated during drought years.

Growing season drought: Extreme droughts such as 2002 and 2018 compound nearly all of the attributes that forage productivity relies on. Extreme droughts decrease spring and summer soil moisture required for forage productivity. We used the climate-water deficit maps (aka drought maps) for April-September to assess future extreme drought frequency. All but the Warm and Wet scenarios are likely to experience an increase in extreme drought frequency, ranging from a drought like 2002 occurring once every 3-5 years (Hot and Dry scenario) to once every 5-10 years.

Summer monsoon: Summer monsoons often produce a flush of high forage productivity. We used July-September precipitation as our impact assessment metric and its departure from the 1985-2015 historic average as a threshold. All but the Hot and Dry scenario is projected to incur an increase in monsoon precipitation, ranging from a 9-20% increase. While the potential increase in monsoon precipitation has a positive impact, the increase in summer temperatures is likely to negate any increase in precipitation. Basically, all but the Warm and Wet scenario is likely to not have enough additional moisture to compensate for the increase in temperatures (see summer evapotranspiration and soil moisture deficit).

SUMMARY:
Irrigated ranchlands are likely to have different impacts depending on which crop is being grown, however with projected increases in growing season temperatures and some loss of precipitation during the spring or summer, we can expect to have more years with higher irrigation needs compared to historic average.

Table 1. Climate vulnerability analysis: irrigated lands

Measurable Climate Indicator	Impact Assessment Metric	Thresholds for metric	Hot & Dry	Feast & Famine	Hot & Wet	Warm & Wet	Confidence Level
Growing season soil moisture	Soil Moisture	Departure from 30-year average	-43%	-13%	-33%	-14%	Low
Summer moisture deficit	Summer evapotranspiration	Departure from 30-year average	-15%	-12%	-6%	-12%	Low
Drought	Climate-water deficit maps April-Sep	Drought reduces plant productivity and extreme droughts require many years to recover	-3	-2	-2	0	High
Spring Precipitation	Spring Precipitation	Departure from 30-year average	-2	0	1	-3	Low
Monsoons	July-September Precipitation	Departure from 30-year average	-3	1	2	2	Low
Winter Precipitation	Winter Precipitation	Departure from 30-year average	-2	2	0	2	Low

IRRIGATED LANDS

Drought resilience strategies:

- Alter management to accommodate expected hotter and drier conditions
- Alter infrastructure to match new and expected conditions
- Create economic incentives to improve soil and water conservation
- Sustain fundamental functions of soil and water
- Manage farms and fields as part of a larger landscape

SHARED GOALS

Stakeholders identified the following goals for irrigated agricultural lands in the Mancos Watershed:

- Maintain livelihoods liked to agricultural lands
- Improve drought resilience
- Reduce impacts to riparian ecosystems from grazing and invasive species

CLIMATE CONSIDERATIONS

The primary climate impacts that these strategies will help address are:

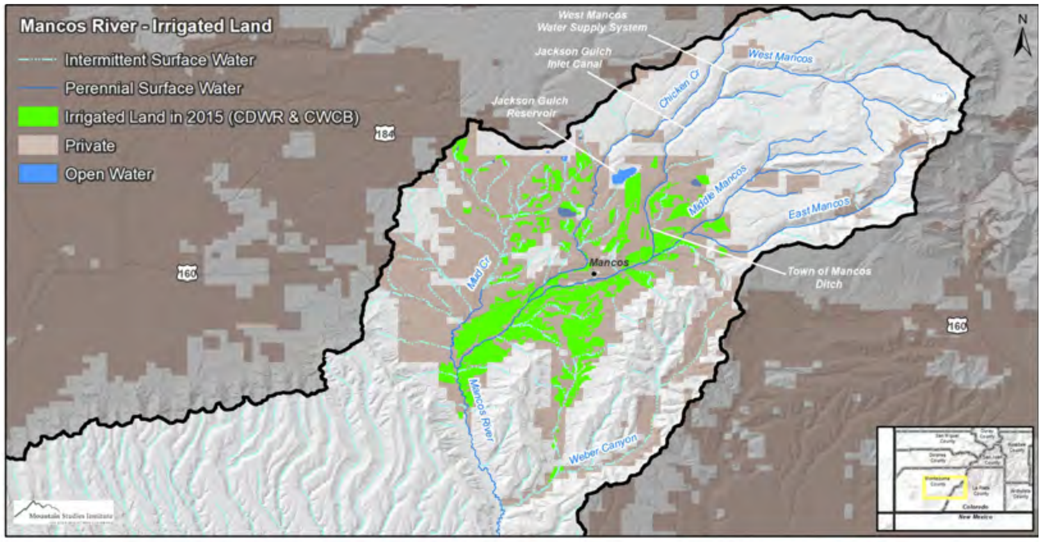
- Reduced winter and spring precipitation
- Growing season soil moisture deficit and summer evapotranspiration
- Growing season drought
- Decrease in summer monsoons
- Increase in summer temperatures

SUMMARY & CONSIDERATIONS

In the Mancos watershed, these irrigated ranchlands consist of cleared and often planted hay meadows as well as fruit trees and other crops. They are generally found in the middle section of the study area. The water for irrigation originates as snowmelt from the upper watershed and is piped through ditches. The water is applied via flood irrigation, center pivots, or drip irrigation. The majority of the irrigation takes place during June-August. Winter and spring moisture is critical for replenishing the reservoirs, streams, and rivers. Monsoonal rains are also an important attribute and can alter the amount of irrigation needed. Irrigated ranchlands are likely to have different impacts from future climate depending on which crop is being grown, however with projected increases in growing season temperatures and some loss of precipitation during the spring or summer, we can expect to have more years with higher irrigation needs compared to historic average.

These recommendations were produced in 2020 by members of the Mancos Watershed Group with funding from the Bureau of Reclamation. Read the full report at: www.mancoscd.org.

IRRIGATED LANDS



ALTER INFRASTRUCTURE TO MATCH NEW AND EXPECTED CONDITIONS

Expand or improve water systems to match water demand and supply, thus improving water use efficiences

Tactic: Develop small water storage (reservoirs)

Tactic: Improve ditch and water delivery systems

Restore water flow from slopes to valley bottom

Tactic: Restore/recontour ditches that have been placed into a pipe

ALTER MANAGEMENT ACCOMMODATE EXPECTED HOTTER AND DRIER CONDITIONS

Deficit irrigation (in extreme cases)

Tactic: Irrigation is only applied when drought would severly injure the plants and produce less than optimum harvest

Diversify crops; consider alternatives that may use less water and be more heat tolerant

Tactic: Incorporate drought/heat resilient crops

Tactic: Intercropping of root crops and trees

Improve return water flow to river during hay season

Tactic: Stagger hay cutting times

SUSTAIN FUNDAMENTAL FUNCTIONS OF SOIL AND WATER

Build simple structures for slowing and storing more water in the ground

Tactic: Install contour ditches along the contours of a field to receive surface flow runoff

Improve soil health and holding capacity; protect water quality

Tactic: Increase organic matter using cover crops and no-till operations.

CREATE ECONOMIC INCENTIVES TO IMPROVE SOIL AND WATER CONSERVATION

Increase carbon sequestration

Tactic: Use CRP or other programs to pay farmers to not till their lands, which increases carbon storage

MANAGE FARMS AND FIELDS AS PART OF A LARGER LANDSCAPE

Protect undeveloped land from being developed and subdivided

Tactic: Utilize existing tools (e.g., conservation easements and carbon credits, and develop new incentives.

CLIMATE VULNERABILITY SCORE:

HIGHLY VULNERABLE

Vulnerability factors include:

- **Winter and spring precipitation**
- **Growing season soil moisture & evapotranspiration**
- **Drought**
- **Summer monsoon precipitation**

Distribution

The non-irrigated lands in the Mancos Watershed consist of riparian areas, montane grasslands, Pinyon Juniper woodlands, Ponderosa pine woodlands, aspen forests and some alpine areas, ranging from high to low elevation. Winter and spring moisture are critical for replenishing the deep soil moisture that the forage requires for summer productivity. Monsoonal rains are also an important attribute and can ensure summer forage productivity.

SPECIES THAT DEPEND ON NON-IRRIGATED LANDS:

- Rocky Mountain Elk (Cervus canadensis nelson)
- Rocky Mountain Mule deer (Odocoileus hemionus)
- Feral livestock, horses, and burros

VULNERABILITY ASSESSMENT SCORING: Across Four Climate Scenarios, 2050

This Mancos River Watershed rank is based on the following key attributes associated with forage productivity: 1) Winter and spring precipitation; 2) Growing season soil moisture and evapotranspiration; 3) Drought; and 4) Summer monsoon precipitation.

Winter Precipitation: Deep soil moisture is replenished from winter and early spring precipitation. Years with ample deep soil moisture are likely to produce good forage. We used winter precipitation as the impact assessment metric and how future climate scenarios depart from the 1985-2015 average. The Hot and Dry scenario is projected to incur a -6% decrease in winter precipitation, while the Hot and Wet remains the same as the historic average; the Feast or Famine and Warm and Wet scenarios both project an increase of 24% and 28% respectively.

Spring precipitation: Spring precipitation, especially as forage plants begin to grow, can ensure high quality forage that is important for determining summer livestock plans. We used spring precipitation as the impact assessment metric and how future climate scenarios depart from the 1985-2015 average. The warm and wet scenario projects a -17% decrease and the hot and dry scenario is at a -6% decrease, while the other two scenarios, Feast and Famine and Hot and Wet are either no change or slightly positive (0 and 6%, respectively). Spring temperatures rise in all scenarios, ranging from an increase of 2-4° F, the Feast or Famine and Hot and Wet scenarios may still result in a water deficit, i.e., the change in spring precipitation is not enough to offset the increase in spring temperatures.

Growing season soil moisture deficit and summer evapotranspiration: Summer soil moisture is critical to forage productivity. Years with low soil moisture and high evaporative demand result in lower forage production. We used growing season soil moisture and summer evapotranspiration as the impact assessment metrics. All scenarios project a soil moisture deficit during the growing season, ranging from -13% to -43%. All scenarios project an increase in evapotranspiration, leading to a soil moisture deficit in most years, ranging from -6 to -15% compared to historic averages. This results in a summer and growing season drying trend in most years, which will be exacerbated during drought years.

Growing season drought: Extreme droughts such as 2002 and 2018 compound nearly all of the attributes that forage productivity relies on. Extreme droughts decrease spring and summer soil moisture required for forage productivity. We used the climate-water deficit maps (aka drought maps) for April-September to assess future extreme drought frequency. All but the Warm and Wet scenarios are likely to experience an increase in extreme drought frequency, ranging from a drought like 2002 occurring once every 3-5 years (Hot and Dry scenario) to once every 5-10 years.

Summer monsoon: Summer monsoons often produce a flush of high forage productivity. We used July-September precipitation as our impact assessment metric and its departure from the 1985-2015 historic average as a threshold. All but the Hot and Dry scenario is projected to incur an increase in monsoon precipitation, ranging from a 9-20% increase. While the potential increase in monsoon precipitation has a positive impact, the increase in summer temperatures are likely to negate any increase in precipitation. Basically, all but the Warm and Wet scenario are likely to not have enough additional moisture to compensate for the increase in temperatures (see summer evapotranspiration and soil moisture deficit).

SUMMARY:
Non-irrigated ranchlands are likely to have different impacts depending on which ecosystem they reside in; however with projected increases in growing season temperatures and some loss of precipitation during the spring or summer, we can expect to have more years with lower forage productivity compared to the historic average. Because these lands extend across a broad elevation band, our overall confidence level in the vulnerability score is low to moderate.

Table 1. Climate vulnerability analysis: non-irrigated lands

Measurable Climate Indicator	Impact Assessment Metric	Thresholds for metric	Hot & Dry	Feast & Famine	Hot & Wet	Warm & Wet	Confidence Level
Growing Season Soil Moisture	Soil moisture	Departure from 30-year average	-43%	-13%	-33%	-14%	Low
Summer Moisture Deficit	Summer evapotranspiration	Departure from 30-year average	-15%	-12%	-6%	-12%	Low
Drought	Climate-water deficit maps April-September	Drought reduces plant productivity and extreme droughts require many years to recover	-3	-2	-2	0	High
Spring Precipitation	Spring precipitation	Departure from 30-year average	-2	0	1	-3	Low
Monsoons	July-September precipitation	Departure from 30-year average	-3	1	2	2	Low
Winter Precipitation	Winter precipitation	Departure from 30-year average	-2	2	0	2	Low

NON-IRRIGATED LANDS

Drought resilience strategies:

- Alter infrastructure to match new and expected conditions
- Identify and protect climate refugia
- Promote landscape connectivity
- Sustain fundamental functions of soil and water

SHARED GOALS

Stakeholders identified the following goals for non-irrigated agricultural lands in the Mancos Watershed:

- Maintain production of forage for cattle and wildlife
- Increase resilience of forage during drought years
- Increase late-season production for forage
- Maintain culturally important species
- Maintain habitat connectivity for wildlife

CLIMATE CONSIDERATIONS

The primary climate impacts that these strategies will help address are:

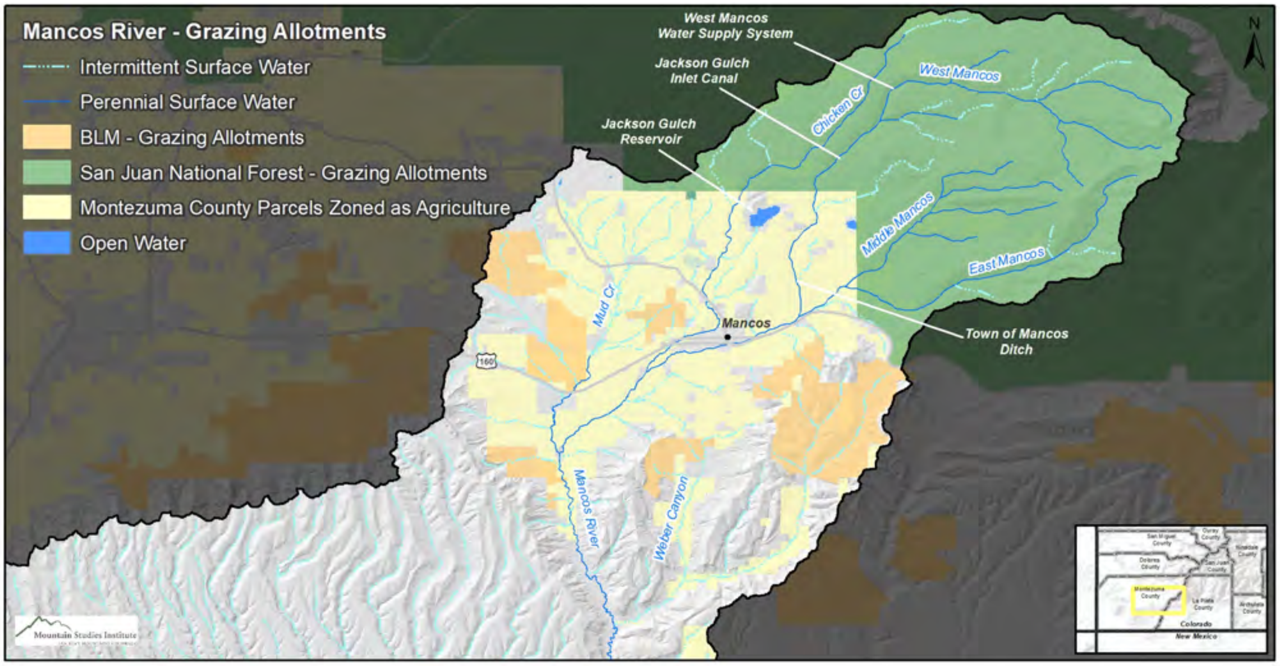
- Reduced winter snowpack due to higher winter temperatures
- Reduced spring and summer soil moisture
- Increased moderate and extreme drought intensity and frequency

SUMMARY & CONSIDERATIONS

The non-irrigated ranchland in the Mancos watershed consist of riparian areas, montane grasslands, Pinyon Juniper woodlands, Ponderosa pine woodlands, aspen forests and some alpine areas, ranging from high to low elevation. Winter and spring moisture are critical for replenishing the deep soil moisture that forage requires for summer productivity. Monsoonal rains are also an important attribute and can ensure summer forage productivity. Non-irrigated ranchlands are likely to experience different impacts depending on which ecosystem they reside in, however with projected increases in growing season temperatures and some loss of precipitation during the spring or summer, we can expect to have more years with lower forage productivity compared to the historic average. Because these lands extend across a broad elevation band, our overall confidence level in the vulnerability score is low to moderate.

These recommendations were produced in 2020 by members of the Mancos Watershed Group with funding from the Bureau of Reclamation. Read the full report at: www.mancoscd.org.

NON-IRRIGATED LANDS



ALTER MANAGEMENT TO ACCOMMODATE EXPECTED FUTURE CONDITIONS

Promote resilient cattle ranching strategies

Tactic: Encourage high-impact, short-term grazing

Tactic: Promote/identify desert-adapted cattle species

Reduce impacts from feral horses and cattle

Tactic: Utilize ethical treatments to reduce feral horses and cattle, especially in prioritized areas

Promote resilient crop types

Tactic: Native/heritage varietals

IDENTIFY AND PROTECT CLIMATE REFUGIA

Identify and protect climate refugia

Tactic: Identify places that will remain or become suitable (refugia)

Tactic: Protect/restore refugia

ALTER INFRASTRUCTURE TO MATCH NEW AND EXPECTED CONDITIONS

Provide water sources for livestock and wildlife

Tactic: Install rain catchment/guzllers for range and wildlife

PROMOTE LANDSCAPE CONNECTIVITY

Reduce habitat fragmentation

Tactic: Improve migration corridors

Tactic: Support privately owned ranchlands and reduce subdividing

SUSTAIN FUNDAMENTAL FUNCTIONS OF SOIL AND WATER

Promote carbon storage in soils

Tactic: Promote functioning and resilient native rangelands by maintaining a high biomass of native plants

Tactic: Restore abandoned fields with native/transition crops

CLIMATE VULNERABILITY SCORE:

HIGHLY VULNERABLE

Vulnerability factors include:

- **Winter snowpack**
- **Summer soil moisture deficit**
- **Growing season drought**
- **Timing and quantity of runoff**
- **Presence of cattle and feral horses**

RIPARIAN SPECIES:

- Narrowleaf cottonwood (Populus angusitfolia)
- Plains cottonwood (Populus deltoides)
- Coyote willow (Salix exigua)

Distribution

The riparian and wetland habitat of greatest concern for the Mancos watershed consist of narrowleaf and plains cottonwoods (narrowleaf, *Populus angusitfolia* and plains, *P. deltoides*) and willows, occurring around an elevation of 9,000 feet down to the junction with the San Juan River (middle and lower reaches). Riparian areas are found within the flood zone of the Mancos River and its tributaries. They often occur as a mosaic of multiple plant communities that vary from tree to shrub dominated. These areas are well-adapted to periodic flood disturbance and arid conditions. While the Mancos River mainstem mainly relies on mountain runoff for annual flows, some of the smaller tributaries may be supported by groundwater inflow and are often dry for some portion of the year. In general, the narrowleaf cottonwoods occur where temperatures are cooler, while the plains cottonwoods occur in warmer environments. These two species can hybridize. Narrowleaf cottonwood regenerates by either seeds or from root sprouts, while the plains cottonwood regenerates from seeds. Seed germination generally occurs following peak spring flooding events, for both species.

Habitat

In the Mancos watershed, this riparian system occurs below 9,000 feet, where some of the spring runoff can replenish the deep soil moisture, which is needed to withstand the hot summers. Winter moisture and spring runoff are key ecological attributes for cottonwood regeneration and survival. Cottonwood die-offs related to prolonged, intense drought have affected some stands in the Mancos River. Summer soil moisture deficits can cause dieback.

VULNERABILITY ASSESSMENT SCORING: Across Four Climate Scenarios, 2050

This Mancos River watershed rank is based on the following key attributes associated with the overall health of cottonwood 1) Winter snowpack, 2) Summer soil moisture deficit (evapotranspiration), 3) Growing season drought, 4) Timing and quantity of runoff, and 5) Presence of cattle and feral horses.

Winter snowpack: Spring high flows are critical to spring runoff as well as providing the deep soil moisture needed to withstand hot and dry summers. We used winter precipitation as the impact assessment metric, as well as how future climate scenarios depart from the 1985-2015 average. The Hot and Dry scenario is projected to incur a -6% decrease in winter precipitation, while the Hot and Wet remains the same as the historic average. The Feast or Famine and Warm and Wet scenarios both project an increase of 24% and 28% respectively.

Summer soil moisture deficit: Summer soil moisture is critical to the overall health of cottonwood trees. Years with low soil moisture result in dieback. We used summer evapotranspiration as the impact assessment metric. All scenarios project an increase in evapotranspiration, leading to a soil moisture deficit in most years, ranging from -6 to -15% compared to the historic average. This results in a summer drying trend in which droughts are likely to increase this soil moisture deficit.

Growing season drought: Extreme droughts like 2002 and 2018 compound nearly all of the stressors that cottonwoods experience. Extreme droughts decrease spring and summer low flows and they generally decrease the available growing season soil moisture required to survive the summer season. We used the climate-water deficit maps (aka drought maps) for April-September to assess future extreme drought frequency. All but the warm and wet scenarios are likely to experience an increase in extreme drought frequency, ranging from a drought like 2002 occurring once every 3-5 years to once every 5-10 years.

Timing and quantity of runoff: Cottonwood regeneration from seeds is episodic, thus not every year results in a good recruitment year. Under future climate scenarios, it still may be possible to experience good recruitment years, however the frequency may change. We are unclear how timing of runoff may impact recruitment (i.e. as peak runoff moves up by 3-4 weeks, do we expect cottonwoods to respond by producing seeds earlier to mimic this shift?). We have low confidence in our ability to assess this attribute. Additional literature review is in order.

Presence of cattle and feral horses: Young cottonwoods are susceptible to heavy browsing by cattle and feral horses, reducing the success of recruitment. Droughts exacerbate this problem because animals spend more time in riparian areas and less time in the uplands, due to lack of upland forage. We used the climate-water deficit maps (aka drought maps) for April-September to assess future extreme drought frequency. All but the Warm and Wet scenarios are likely to experience an increase in extreme drought frequency, ranging from a drought like 2002 occurring once every 3-5 years (Hot and Dry scenario) to once every 5-10 years.

SUMMARY:
Cottonwood vigor and regeneration is likely to decrease by 2050 as all impact assessment metrics, except for winter precipitation, project a negative impact on cottonwoods.

Table 1. Climate vulnerability analysis: riparian habitat

Measurable Climate Indicator	Impact Assessment Metric	Thresholds for metric	Hot & Dry	Feast & Famine	Hot & Wet	Warm & Wet	Confidence Level
Winter Snowpack	Winter Precipitation	Below average winter precipitation reduces runoff as well as groundwater recharge	-2	2	0	2	Moderate
Summer Soil Moisture Deficit	Summer Evapotranspiration	Departure from 30-year average	-15%	-12%	-6%	-12%	Moderate
Frequency of Extreme Growing Season Drought	Climate-water deficit maps April-Sep	Extreme droughts like 2002	-3	-2	-2	0	Moderate
Timing and Quantity of Runoff	Spring Temperature and runoff	Earlier runoff may be mismatched with seed/germination period, thus reducing germination	-3	-1	-3	-1	Low (for timing)
Drought	Climate-water deficit maps April-Sep	Droughts force animals to congregate in riparian areas	-3	-2	-2	0	High

ADDITIONAL FACTORS, INFORMATION, AND CONSIDERATIONS

Willows are also important plants in this area and while we did not specifically assess them, we believe that they have more resilience to future climate scenarios than cottonwoods, but that is not to say that they will not experience some decline. Willows are likely to be more resilient due to the ability to regenerate more rapidly and withstand browsing; however, extreme droughts may still impact willows.

RIPARIAN ECOSYSTEMS

Drought resilience strategies:

- ☑ Identify and protect climate refugia
- ☑ Maintain and restore riparian vegetation
- ☑ Maintain and enhance hydrologic processes and water quantity and quality
- ☑ Reduce the impact of biological stressors

SHARED GOALS

Stakeholders identified the following goals for riparian habitat in the Mancos Watershed:

- Increase resilience of riparian corridor
- Reduce impacts from grazing and invasive species
- Expand, restore, and connect ecological functions of the floodplain
- Restore cottonwoods and other culturally important riparian species
- Improve riparian corridor for rare or extirpated species

CLIMATE CONSIDERATIONS

The primary climate impacts that these strategies will help address are:

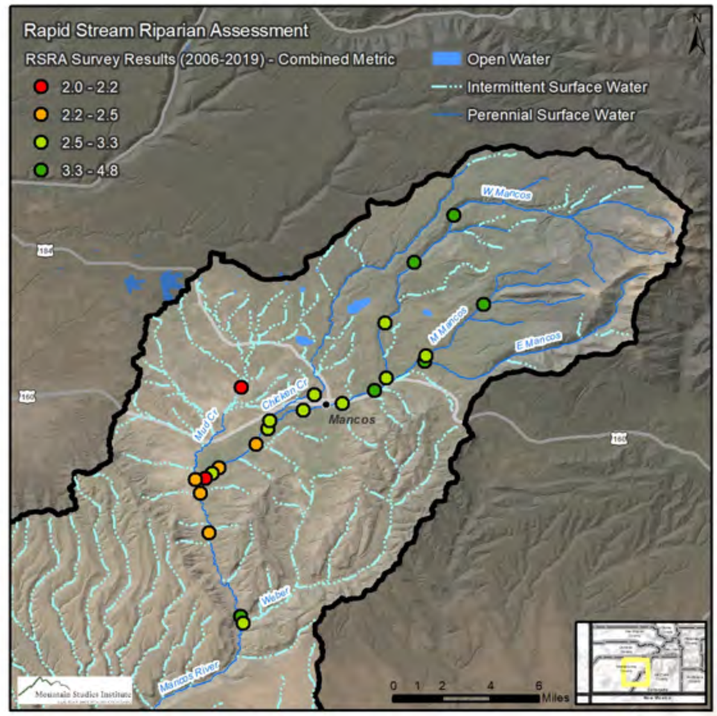
- Reduced winter snowpack due to rising temperatures
- Loss of growing season soil moisture due to higher evaporative demand
- Increased drought severity and frequency
- Fire and subsequent debris flows/sedimentation

SUMMARY & CONSIDERATIONS

The riparian and wetland habitat of greatest concern for the Mancos watershed consist of cottonwoods (narrowleaf, Populus angusitfolia and plains, P. deltoides) and willows, occurring around 9,000 ft down to the junction with the San Juan River at 4,400 ft (middle and lower reaches). Riparian areas are found within the flood zone of the Mancos River and its tributaries. They often occur as a mosaic of multiple plant communities that vary from tree to shrub dominated. These areas are well adapted to periodic flood disturbance and arid conditions. While the Mancos River mainstem mainly relies on mountain runoff for annual flows, some of the smaller tributaries may be supported by groundwater inflow and are often dry for some portion of the year. In general, the narrowleaf cottonwoods occur where the temperatures are cooler while the plains cottonwoods occur in warmer environments. These two species can hybridize. Narrowleaf cottonwood regenerates by either seeds or from root sprouts, while the plains cottonwood regenerates from seeds. Seed germination generally occurs following peak spring flooding events, for both species. Cottonwood vigor and regeneration is likely to decrease by 2050 as all impact assessment metrics, except for winter precipitation project a negative impact on cottonwoods.

These recommendations were produced in 2020 by members of the Mancos Watershed Group with funding from the Bureau of Reclamation. Read the full report at: www.mancoscd.org.

RIPARIAN ECOSYSTEMS



MAINTAIN AND ENHANCE HYDROLOGIC PROCESSES AND WATER QUANTITY AND QUALITY

Enhance linkages so that a functional corridor exists

Tactic: Increase groundwater retention and floodplain connectivity

Improve groundwater retention

Tactic: Encourage beaver re-colonization

Tactic: Slow the water down with multiple human-built structures, (e.g., beaver analgos, worm ditches, etc.

Maintain and enhance infiltration and water storage within wetlands, adjacent uplands, and groundwater recharge areas

Tactic: Restore sheet flows/improve infiltration

Tactic: Capture and store water across the landscape

Promote landscape connectivity

Tactic: Rewater abandoned oxbows and floodplains

REDUCE THE RISK OF BIOLOGICAL STRESSORS

Maintain and enhance wetland and riparian structure and function

Tactic: Remove invasive plant species

Manage herbivory to promote regeneration of desired species

Tactic: Reduce or eliminate impacts from feral horses and livestock

IDENTIFY AND PROTECT CLIMATE REFUGIA

Prioritize sites that have the ability to maintain a viable riparian corridor under future climate

Tactic: Develop maps that depict where climate refugia are likely to be, utilizing on-the-ground knowledge and modeling

Restore function to riparian areas that are at risk

Tactic: Restore refugia sites that are not functioning to their full potential by improving water retention and flow

MAINTAIN AND RESTORE RIPARIAN VEGETATION

Facilitate plant species' ability to move into new habitat that is the result of climate change

Tactic: Establish or encourage new mixes of native species in identified transition sites

Maintain and enhance wetland and riparian structure and function

Tactic: Plant native willows and cottonwoods within riparian corridor

CLIMATE VULNERABILITY SCORE:

HIGHLY VULNERABLE

Vulnerability factors include:

- **Spring high flows**
- **Summer low flows**
- **Summer temperature**
- **Frequency of extreme drought**

Distribution

In the Mancos watershed, these short-lived (4-6 years) cold-water fish mostly inhabit the headwater streams above the town of Mancos.

Habitat

In the Mancos watershed, these fish require cool, clear water in streams with well-vegetated, stable banks; deep pools, boulders, and logs.

COLD WATER FISH SPECIES:

- Mottled sculpin (Cottus bairdii)
- Rainbow trout (Oncorhynchus mykiss)
- Brown trout (Salmo trutta)

Stressors

Low flows, especially in summer and spring limits pools and decreases food resources; degradation of forest health from tree mortality and wildfire. There is very little chance that unoccupied headwater streams could support trout as the habitat is not suitable (i.e. as temperatures warm, the fish cannot migrate upstream).

VULNERABILITY ASSESSMENT SCORING: Across Four Climate Scenarios, 2050

This Mancos River watershed rank is based on the following key attributes: 1) Stream flows, 2) Stream temperature, and 3) Drought.

Winter precipitation: Spring high flows are critical to spawning in early April and require clean cobbles associated with riffles. We used April snow water equivalent (SWE) as the impact assessment metric and how future climate scenarios depart from the 1985-2015 average. The Hot and Dry and Hot and Wet scenarios are projected to incur a -54% and -52% SWE, while the Feast and Famine and Warm and Wet scenarios are projected to remain close to historic average.

Spring precipitation: Spring precipitation, especially as forage plants begin to grow, can ensure high quality forage that is important for determining summer livestock plans. We used spring precipitation as the impact assessment metric and how future climate scenarios depart from the 1985-2015 average. The Warm and Wet scenario projects a -17% decrease and the Hot and Dry scenario is at a -6% decrease, while the other two scenarios, Feast and Famine and Hot and Wet, are either no change or slightly positive (0 ad 6%, respectively). Spring temperatures rise in all scenarios, ranging from an increase of 2-4 F, the Feast or Famine and Hot and Wet scenarios may still result in a water deficit, i.e., the change in spring precipitation is not enough to offset the increase in spring temperature increases.

Summer low flows: These flows are important for survival, and years with low summer flows (i.e. 2002, 2012, and 2018) were detrimental to cold water fish. The riffles dry up and isolated pools are all that remain, thus reducing connectivity and access to additional food sources. We used August runoff as the impact assessment metric. The Hot and Dry and Hot and Wet scenarios are projected to incur a -34% and -14% reduction compared to the 1985-2015 average. The Feast and Famine and Warm and Wet scenarios are projected to remain close to historic average.

Summer temperature: The highest water temperatures occur in August and the optimal thresholds for Brook Trout is 50-59°F. Air temperature is correlated with water temperature, thus we used August mean maximum temperature as the impact assessment metric. Compared to the 1985-2015 historic average, all scenarios are projected to have August temperatures rising and likely to exceed the threshold in many years. The Hot and Dry and Hot and Wet scenarios increase by 4-5°F, while Feast and Famine rises 3°F and Warm and Wet increases by 1.5°F.

Frequency of extreme drought: Extreme droughts, such as 2002 and 2018, compound nearly all of the attributes that the fish need. Droughts decrease spring and summer low flows, generally increase the overall water temperature, and reduce the number of available low water pools and connectivity required for fish to survive. We used the climate-water deficit maps (aka drought maps) for April-September to assess future extreme drought frequency. All but the Warm and Wet scenarios are likely to experience an increase in extreme drought frequency, ranging from a drought like 2002 occurring once every 3-5 years (Hot and Dry scenario) to once every 5-10 years.

SUMMARY:
Cold water fish are highly vulnerable from reduced spring runoff and low summer flows, and elevated late summer stream temperatures, with extreme drought presenting the largest concern.

Table 1. Climate vulnerability analysis: cold water fish

Measurable Climate Indicator	Impact Assessment Metric	Thresholds for metric	Hot & Dry	Feast & Famine	Hot & Wet	Warm & Wet	Confidence Level
Spring high flows	April SWE	Departure from 30-year average	-54%	0	-52%	0	High
Summer low flows	August runoff	Departure from 30-year average	-34%	0	-14%	-1%	High
Summer Temperature	August Mean Max Temperature	Departure from 30-year average	-3	-2	-2	-1	High
Frequency of Extreme Drought	Climate-water deficit maps April-Sep	Droughts like 2002 are detrimental to flows and increased stream temps	-3	-2	-2	0	High

ADDITIONAL FACTORS, INFORMATION, AND CONSIDERATIONS

According to Jim White, Colorado Parks and Wildlife, the Mancos River trout are likely to be less vulnerable than the warm-water fish; however, they are still vulnerable to future climate scenarios. The ability for the cold-water fish to migrate to higher elevation stream reaches is low due to lack of suitable habitat, even if barriers were of no issue. This project would benefit from a future distribution model/map that incorporates the key impact assessment metric.

COLD WATER FISH

Drought resilience strategies:

- Identify and protect climate refugia
- Moderate base flow decreases
- Reduce uncertainty through research and monitoring

SHARED GOALS

Stakeholders identified the following goals for cold water fish in the Mancos Watershed:

- Maintain or improve existing cold water fish populations
- Improve habitat quality (flows, temperature) and connectivity (including movement of fish to refugia)

CLIMATE CONSIDERATIONS

The primary climate impacts that these strategies will help address are:

- Reduced spring high flows and summer low flows
- Increased frequency of extreme drought
- Reduced habitat connectivity
- Fire and subsequent debris flows/sedimentation

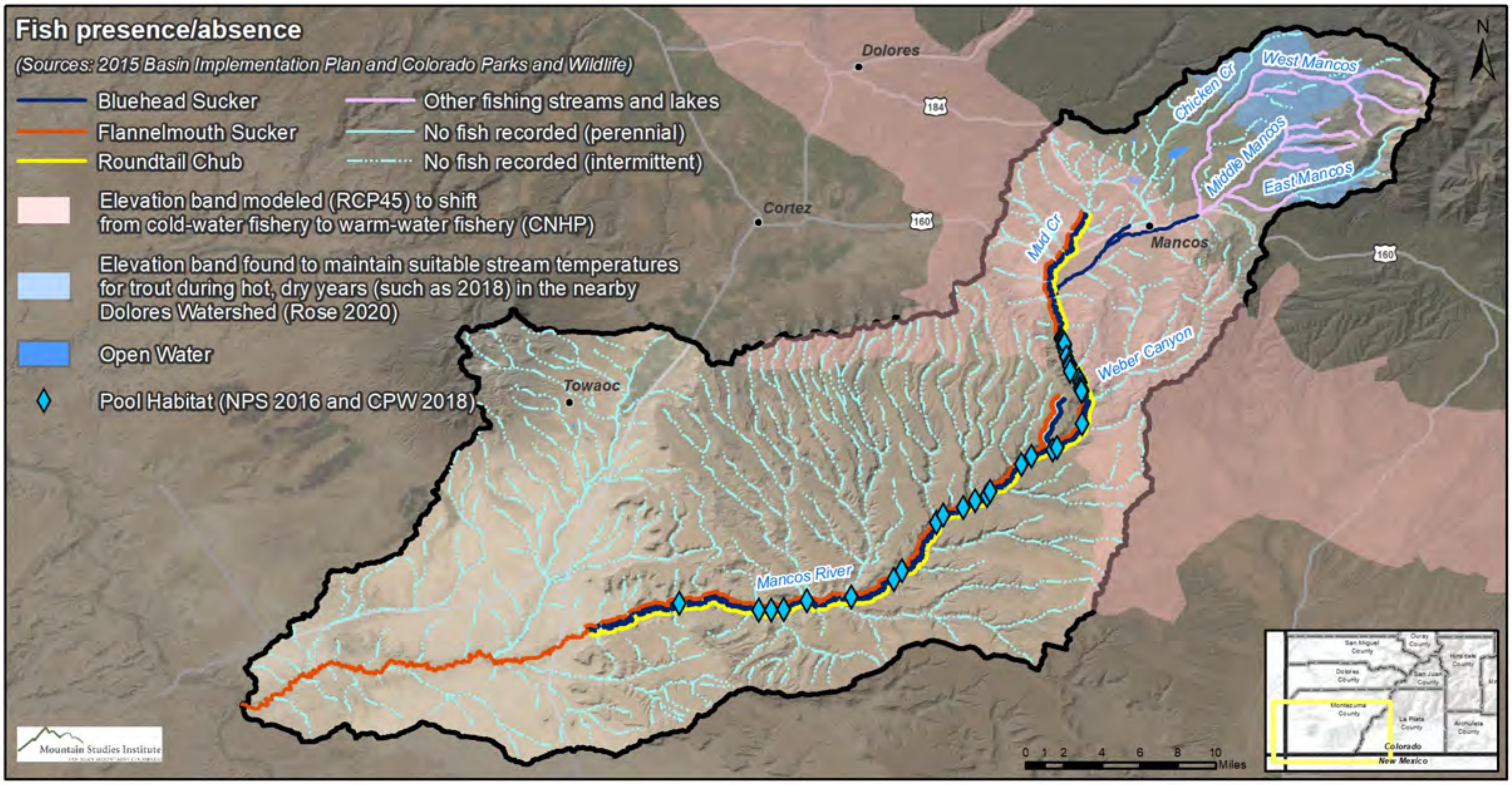
SUMMARY & CONSIDERATIONS

Cold Water Fish: Brook and Rainbow Trout, and Mottled Sculpin

In the Mancos watershed, these short-lived (4-6 years) cold-water fish mostly inhabit the headwater streams above the town of Mancos. These fish require cool, clear water in streams with well-vegetated, stable banks, deep pools, boulders, and logs. Low flows, especially in summer and spring, limit pools and decreases food resources. The Mancos River and tributaries are further threatened by degradation of forest health from tree mortality and wildfire. There is very little chance that unoccupied headwater streams could support trout as the habitat is not suitable (i.e. as temperatures warm, the fish cannot migrate upstream). Cold-water fish are highly vulnerable from reduced spring runoff and low summer flows, and elevated late summer stream temperatures, with extreme drought presenting the largest concern.

These recommendations were produced in 2020 by members of the Mancos Watershed Group with funding from the Bureau of Reclamation. Read the full report at: www.mancoscd.org.

COLD WATER FISH



IDENTIFY AND PROTECT CLIMATE REFUGIA

Identify and protect areas likely to remain climatically suitable over the long term

Tactic: Connect current populations with streams that have colder temperatures (the off-ramp concept)

Tactic: Look for opportunities for reintroductions to habitats likely to remain suitable over the long term

Tactic: Understand and map where groundwater inputs may buffer projected stream temperature increases

Protect and restore critical or unique habitats that buffer survival during vulnerable periods (i.e., seasonally or at particular life history stages)

Tactic: Protect/restore flood or thermal refugia and stream segments that are important connections

Tactic: Protect/restore off-channel habitats, spring brooks, and seeps important as early rearing environments

MODERATE BASE FLOW DECREASES

Increase natural water storage in groundwater aquifers

Tactic: Increase off-channel habitat and protect refugia in side channels

Tactic: Protect wetland-fed streams which maintain higher summer flows

Tactic: Reintroduce beaver and/or install artificial beaver-mimic dams where compatible with fish conservation goals

Restore or replicate stream flows

Tactic: Increase storage of water in floodplains by encouraging natural flooding and groundwater infiltration

REDUCE UNCERTAINTY THROUGH RESEARCH AND MONITORING

Improve systemic data collection and access across management and political boundaries

Tactic: Initiate and/or expand collaborative data collection and sharing to ensure climate change research on trout occurs at appropriate scales

CLIMATE VULNERABILITY SCORE:
HIGHLY VULNERABLE

Vulnerability factors include:

- **Spring high flows**
- **Summer low flows**
- **Frequency of extreme drought**
- **Habitat connectivity**

SPECIES OF WARM WATER FISH:

- Bluehead Sucker (Catastomus descobolus)
- Flannelmouth sucker (Catostomus latipinnus)
- Roundtail Chub (Gilia robusta)

Distribution
In Colorado, the three warm water fish are found throughout the Upper Colorado River drainage. The distribution map data is based on information provided in the Colorado Parks and Wildlife (2015) conservation assessment plan draft.

Habitat
In Colorado, adult bluehead sucker are most often found in swift, high gradient streams; larval fish inhabit near-shore, low velocity habitats (Childs et al. 1998). Riffles and pools support algae and macroinvertebrates that are consumed by bluehead suckers (Sigler and Sigler 1996). Bluehead sucker occupy warm to cool streams (20˚C) with rocky substrates (Sigler and Sigler 1996; Bestgen 2000). Flannelmouth sucker are opportunistic benthic feeders. Adults occupy deep riffles and runs as well as deep, murky pools with sparse vegetation (McAda 1977; Sigler and Sigler 1996; Bezzerides and Bestgen 2002), while young fish are typically found in quiet, shallow riffles and near-shore eddies (Childs et al. 1998). Roundtail Chub adults use eddies and pools near areas with strong currents and boulders (CPW 2015), while juveniles are most frequently found in quiet, shallow backwaters (Brouder et al. 2000). Larvae prefer low velocity backwaters, young-of-the-year occupy shallow, low-velocity habitats, and juveniles occupy pools (Bestgen et al. 2011). Within the Mancos Watershed, all three warm water fish are found in the middle and lower reaches of the Mancos River.

VULNERABILITY ASSESSMENT SCORING: Across Four Climate Scenarios, 2050

This Mancos River Watershed rank is based on the following key attributes: 1) Stream flows, 2) Drought, 3) Frequency of extreme drought, and 4) Habitat connectivity.

Spring High Flows: Spring high flows are critical to spawning in early April as warm water species require clean cobbles associated with riffles created during runoff. We used April snow water equivalent (SWE) as the impact assessment metric and how future climate scenarios depart from the 1985-2015 average. The Hot and Dry and Hot and Wet scenarios are projected to incur a -54% and -52% SWE, while the Feast and Famine and Warm and Wet scenarios are projected to remain close to historic averages.

Summer Low Flows: Summer flows are important for survival, and years with low summer flows (e.g. 2002, 2012, and 2018) were extremely detrimental to warm water fish. The riffles dry up and isolated pools are all that remain, thus reducing connectivity and access to additional food sources. We used August runoff as the impact assessment metric. The Hot and Dry and Hot and Wet scenarios are projected to incur a -34% and -14% reduction compared to the 1985-2015 average. The Feast and Famine and Warm and Wet scenarios are projected to remain close to historic average.

Frequency of Extreme Drought: Extreme droughts such as 2002 and 2018 compound the negative impacts from nearly all of the attributes that the fish need. Droughts decrease spring and summer low flows, increase the overall water temperature, and reduce the number of available low water pools and connectivity required to survive. We used the climate-water deficit maps (aka drought maps) for April-September to assess future extreme drought frequency. All but the Warm and Wet scenarios are likely to experience an increase in extreme drought frequency, ranging from a drought like 2002 occurring once every 3-5 years (Hot and Dry scenario) to once every 5-10 years in the Feast or Famine and Hot and Wet scenarios.

Habitat Connectivity: Connectivity is critical to fish persistence. As summers get hotter and instream water dries up, the connectivity declines. We used summer temperature, with a greater than 2° F increase as our metric. The Hot and Dry and Hot and Wet scenarios both are likely to incur at least a 3.5°F increase in average summer temperature, over the 1985-2015 average temperature. Feast and Famine is projected to incur a 2.3° F increase and warm and wet is likely to barely stay below the 2°F threshold at 1.8°F increase.

SUMMARY:
Warm water fish are highly vulnerable with summer low flows, extreme drought, and habitat connectivity presenting the largest concern.

Table 1.Climate vulnerability analysis: warm water fish

Measurable Climate Indicator	Impact Assessment Metric	Thresholds for metric	Hot & Dry	Feast & Famine	Hot & Wet	Warm & Wet	Confidence Level
Spring high flows	April S	Departure from 30-year average	-54%	0	-52%	0	High
Summer low flows	August runoff	Departure from 30-year average	-34%	0	-14%	-1%	High
Frequency of Extreme Drought	Climate-water deficit maps April-Sep	Extreme droughts like 2002	-3	-2	-2	0	High
Habitat Connectivity	Summer temperature	Greater than 2 F	-3	-1	-3	0	High

ADDITIONAL FACTORS, INFORMATION, AND CONSIDERATIONS

According to Jim White (pers. communication), Colorado Parks and Wildlife, the purity of the Bluehead and Flannelmouth suckers in the Mancos River are noteworthy. The purity is primarily due to the dam near the junction with the San Juan River, which prevents the White sucker from hybridizing with the native suckers. The Roundtail Chub appears to have a mixed purity rating in the Mancos River due to a mix with Rio Grande chub.

The warm-cold water transition zone in most years is near Mancos; some years it goes as high as Chicken Creek. Rainbow trout and Bluehead suckers have both been found in town.

WARM WATER FISH

Drought resilience strategies:

- ✓ Expand populations
- ✓ Maintain & restore riparian vegetation
- ✓ Promote landscape connectivity
- ✓ Identify & protect climate refugia
- ✓ Maintain & enhance hydrologic processes

SHARED GOALS

Stakeholders identified the following goals for warm water fish in the Mancos Watershed:

- Keep key warm water fish species from becoming federally listed as threatened or endangered species
- Improve habitat quality (flows, temperature) and connectivity (including movement of fish to refugia)

CLIMATE CONSIDERATIONS

The primary climate impacts that these strategies will help address are:

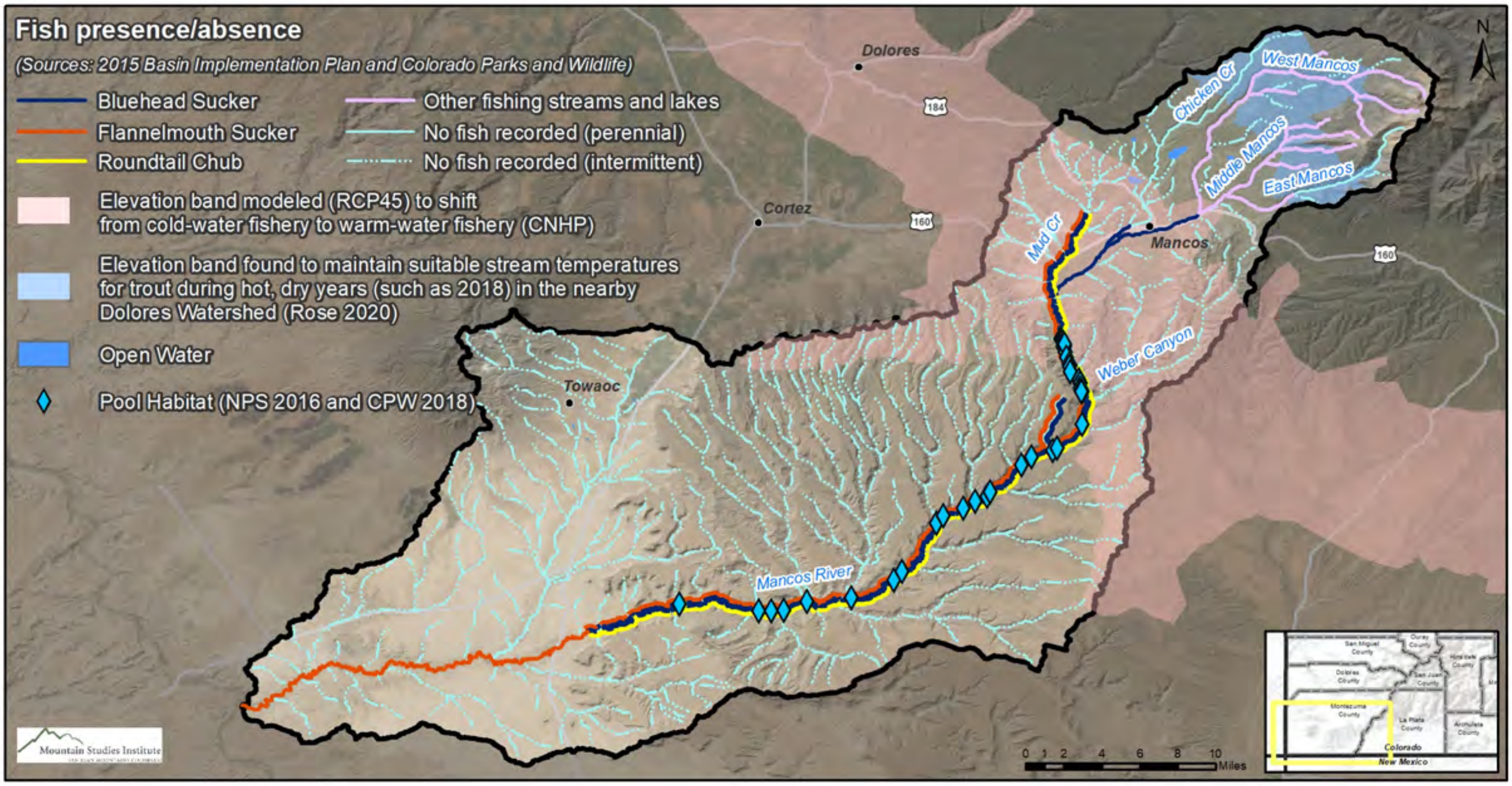
- Reduced spring high flows and summer low flows
- Increased frequency of extreme drought
- Reduced habitat connectivity
- Fire and subsequent debris flows/sedimentation

SUMMARY & CONSIDERATIONS

In Colorado, three sensitive warm water fish are found throughout the Upper Colorado River drainage. Within the Mancos River all three warm water fish are found in the middle and lower reaches. Warm water fish are highly vulnerable with summer low flows, extreme drought, and habitat connectivity presenting the largest concern. Adult bluehead sucker are most often found in swift, high gradient streams; larval fish inhabit near-shore, low velocity habitats (Childs et al. 1998). Riffles and pools support algae and macroinvertebrates that are consumed by bluehead suckers (Sigler and Sigler 1996). Bluehead sucker occupy warm to cool streams (20˚C) with rocky substrates (Sigler and Sigler 1996; Bestgen 2000). Flannelmouth sucker are opportunistic benthic feeders. Adults occupy deep riffles and runs as well as deep, murky pools with sparse vegetation (McAda 1977; Sigler and Sigler 1996; Bezzerides and Bestgen 2002), while young fish are typically found in quiet, shallow riffles and near-shore eddies (Childs et al. 1998). Roundtail Chub adults use eddies and pools near areas with strong currents and boulders (CPW 2015), while juveniles are most frequently found in quiet, shallow backwaters (Brouder et al. 2000). Larvae prefer low velocity backwaters, young-of-the-year occupy shallow, low velocity habitats, and juveniles occupy pools (Bestgen et al. 2011).

These recommendations were produced in 2020 by members of the Mancos Watershed Group with funding from the Bureau of Reclamation. Read the full report at: www.mancoscd.org.

WARM WATER FISH



MAINTAIN AND RESTORE RIPARIAN VEGETATION

Maintain and enhance high quality riparian habitat at stream edge

Tactic: Reconnect the floodplain through small, hand-built structures that raise the water table

Tactic: Remove invasive plant species and restore with natives well-suited for future climate conditions

PROMOTE LANDSCAPE CONNECTIVITY

Improve connectivity within river mainstem and with tributaries

Tactic: Install fish ladder/passage for migrating species

Tactic: Locate spawning tributaries

Tactic: Maintain flows to allow connectivity to tributaries during critical times

Improve diversions to promote flows, prevent entrainment, allow fish passage

Tactic: Increase riffles

EXPAND WARM WATER FISH POPULATIONS

Increase population size and number of populations in order to maintain a viable population

Tactic: Stock native warm water fish above the town of Mancos into areas that have a suitable temperature range

IDENTIFY AND PROTECT CLIMATE REFUGIA

Prioritize sites that have the ability to maintain a viable population under future climate

Tactic: Identify, protect, and restore refugia sites

MAINTAIN AND ENHANCE HYDROLOGIC PROCESSES

Improve groundwater retention

Tactic: Encourage beaver re-colonization where appropriate

Tactic: Slow down surface runoff using a variety of human-built structures (e.g., beaver analogs, worm ditches, etc.)

CLIMATE VULNERABILITY SCORE:

HIGHLY VULNERABLE

Vulnerability factors include:

- **Soil moisture**
- **Winter precipitation**
- **Frequency of extreme drought**

Distribution

In the Mancos River watershed, the pinyon-juniper woodland is found from approximately 4,900- 8,000 feet in elevation. Oak shrublands are often mixed within or adjacent to stands.

SPECIES FOUND IN PINYON-JUNIPER WOODLANDS:

- Pinyon pine (Pinus edulis)
- Utah juniper (Juniperus osteosperma)
- Rocky Mountain juniper (J. scopulorum)
- Pinyon jay (Gymnorhinus cyanocephalus)

Habitat

Pinyon pine (Pinus edulis) and juniper form the canopy. In western pinyon-juniper woodlands of lower elevations, Utah juniper (Juniperus osteosperma) is prevalent and Rocky Mountain juniper (J. scopulorum) may co-dominate or replace it at higher elevations. The understory is highly variable, and may be shrubby, grassy, sparsely vegetated, or rocky. Comer et al. (2003) separate Colorado's pinyon-juniper into four ecological systems: Colorado Plateau Pinyon-Juniper Woodland, Colorado Plateau Pinyon-Juniper Shrubland, Colorado Plateau Mixed Bedrock Canyon and Tableland, and Southern Rocky Mountain Pinyon-Juniper Woodland. Pinyon juniper has the highest number of obligate birds of any system, including the pinyon jay, which is declining at 4% per year.

Dynamics

Pinyon-juniper woodlands are influenced by climate, fires, insect-pathogen outbreaks, and livestock grazing (West 1999; Eager 1999). Although it is clear that the structure and condition of many pinyon-juniper woodlands has been significantly altered since European settlement (Tausch 1999), in recent years there has been an emerging recognition that not all of these woodlands are dramatically changed by anthropogenic influence. Increasing density of pinyon juniper woodlands and expansion into adjacent grassland or shrubland are well documented in some areas, but this is not a universal phenomenon in the western U.S. (Romme et al. 2009). Furthermore, the tree-dominated landscape characteristic of pinyon-juniper woodlands today is not necessarily representative of the typical landscape of the past few millennia (Tausch 1999). Romme et al. (2009) distinguish three pinyon-juniper types (persistent woodlands, savannas, and wooded shrublands), using characteristics of based canopy structure, understory, and disturbance history. Local site conditions may result in a fine-scale mixture of one type within a larger matrix of another type. The differences between these types have important implications for management actions, and efforts to maintain or restore natural processes in pinyon-juniper habitats. Both pinyon pine and juniper are fairly slow growing, and can live for hundreds of years, a life cycle that is well adapted to xeric habitats, but less suitable for quickly changing conditions. Although individuals of both species become reproductive after a few decades, most seed production is due to mature trees of 75 years of age or older (Gottfried 1992). Both species reproduce only from seeds, and do not resprout after fire. Cone production of mature pinyon pine takes three growing seasons, and the large seeds have a fairly short life span of 1-2 years (Ronco 1990). Juniper cones (often called berries) may require 1-2 years of ripening before they can germinate (Gottfried 1992). The smaller seeds of juniper are generally long-lived, surviving as long as 45 years. Birds are important dispersers of both pinyon pine and juniper seed (Gottfried 1992). The effects of fire in all types of pinyon-juniper depend in part on fuel provided by both canopy and understory, and by weather conditions during a fire (Romme et al. 2009). Sparse woodlands with little understory vegetation would typically have limited fire spread and little tree mortality. As tree density or understory cover (especially shrubs) increases, fire spread is facilitated, and tree mortality becomes more likely. Romme et al. (2009) concluded that spreading, low-intensity surface fires have historically had a limited role in this ecosystem, and that instead the dominant fire effect is mortality of most trees and top-kill of most shrubs within the burned area, regardless of tree or shrub size. At Mesa Verde National Park, where pinyon-juniper woodlands have burned in five large fires since 1930, trees have not yet re-established. It is not known why trees have not been successful in these areas, which are now occupied by shrubland (Floyd et al. 2000).

For many pinyon-juniper woodlands, climate fluctuation and insect or disease outbreak are more important in shaping stand structure than fire. Insect and disease mortality is a natural ongoing process, usually at a low level, but occasionally as more severe episodic outbreaks. Weather patterns may enhance patterns of mortality or recruitment, shifting stand composition and structure on a local or regional scale (Eisenhart 2004, Breshears et al. 2005, Shaw et al. 2005).

VULNERABILITY ASSESSMENT SCORING: Across Four Climate Scenarios, 2050

This Mancos River watershed rank is based on the following key attributes: 1) Soil moisture, 2) Winter precipitation, and 3) Frequency of extreme drought.

Soil moisture: Spring and summer soil moisture are critical for seed germination and seedling survival. We used the summer soil moisture as seedlings cannot survive if summer shallow soil moisture is low. All of the scenarios project a soil moisture deficit, ranging from -19% to -60%.

Winter precipitation: Winter precipitation is a good indicator for forest health as deep soil moisture is critical to tree survival and winter precipitation is the only season that replenishes the deep soil moisture. We used departure from 1985-2015 average winter precipitation as our impact assessment metric. Only the hot and dry scenario is projected to experience drier winters on average, while the other scenarios range from no increase to a 28% increase. It is important to note as winter temperatures increase, some of this additional winter moisture is likely to fall as rain and in addition, warm winters may allow the trees to photosynthesize, thus depleting soil moisture.

Growing season drought: Growing season drought increases fire risk as well as insect and disease events, which increases tree mortality. These growing season droughts increase the vapor pressure deficit, and evapotranspiration, which result in parched soils and vegetation. We used growing season climate water deficit model and departure from 1985-2015 average. All but the Warm and Wet scenarios are likely to experience an increase in extreme drought frequency, ranging from a drought like 2002 occurring once every 3-5 years (hot and dry scenario) to once every 5-10 years in the Feast or Famine and Hot and Wet scenarios.

SUMMARY:
Pinyon-Juniper Woodlands are at risk from increased drought and warming temperatures, resulting in increased tree mortality from fires and insects and disease. Regeneration is also a concern as summer shallow soil moisture is required for seedlings.

Table 1. Climate vulnerability analysis: pinyon-juniper woodlands

Measurable Climate Indicator	Impact Assessment Metric	Thresholds for metric	Hot & Dry	Feast & Famine	Hot & Wet	Warm & Wet	Confidence Level
Winter snowpack	Winter Precipitation	Below average winter precipitation reduces runoff as well as groundwater recharge	-2	2	0	2	Moderate
Summer soil moisture deficit	Summer Evapotranspiration	Departure from 30-year average	-15%	-12%	-6%	-12%	Moderate
Frequency of Extreme Growing Season Drought	Climate-water deficit maps April-Sep	Extreme droughts like 2002	-3	-2	-2	0	Moderate

ADDITIONAL FACTORS, INFORMATION, AND CONSIDERATIONS

It is important to note that pinyon trees are much more sensitive than juniper trees when it comes to their ability to withstand drought.

PINYON JUNIPER WOODLANDS

Drought resilience strategies:

- Maintain and enhance genetic diversity
- Facilitate native shrub establishment following stand-replacing fires
- Identify and protect climate refugia
- Reduce the risk and long-term impacts of severe disturbances
- Sustain fundamental ecosystem functions

SHARED GOALS

Stakeholders identified the following goals for pinyon juniper woodlands in the Mancos Watershed:

Protect and maintain a resilient landscape that:

- includes pinyon and juniper
- supplies people with ecosystem services, including clean water, biodiversity, recreation, tourism, traditional foraging, hunting, food and others.

CLIMATE CONSIDERATIONS

The primary climate impacts that these strategies will help address are:

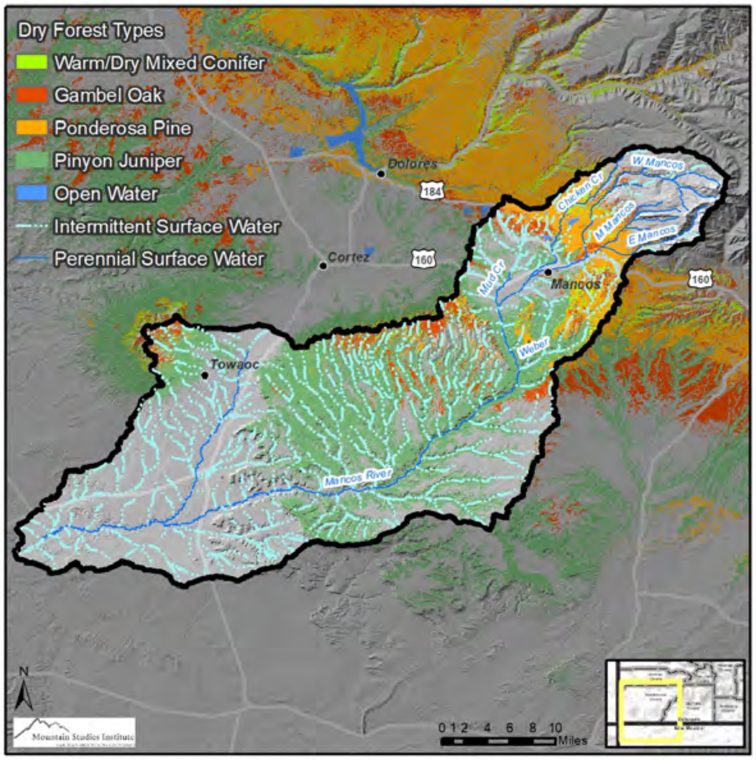
- Altered fire regime
- Reduced soil health
- Decreased stand resilience
- Altered species composition
- Tree mortality (fire, drought)

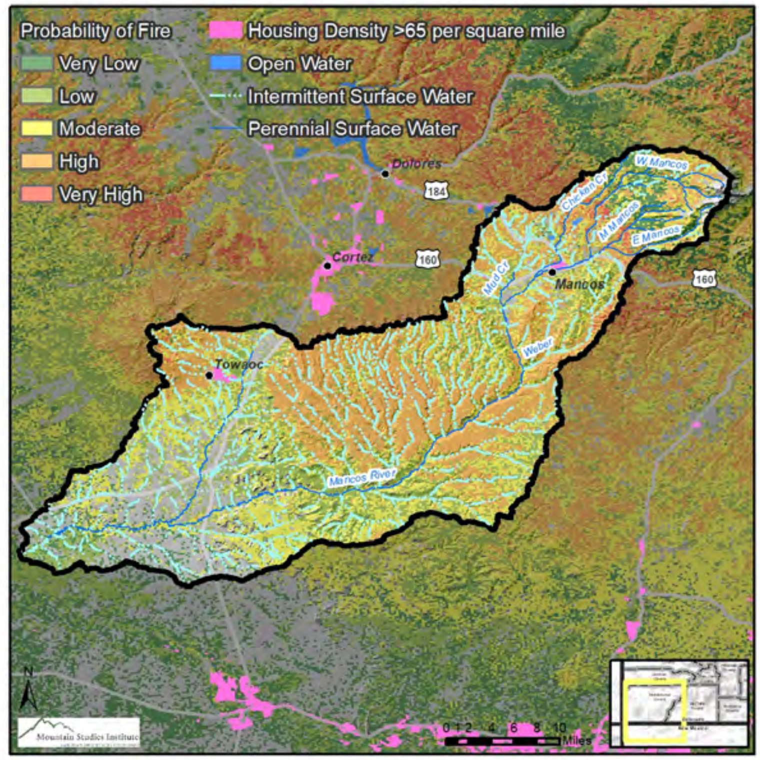
SUMMARY & CONSIDERATIONS

In the Mancos River watershed, the pinyon-juniper woodland is found from approximately 4,500– 10,000 feet in elevation. Oak shrublands are often mixed within or adjacent to stands. Habitat: Pinyon pine (Pinus edulis) and juniper form the canopy. In western pinyon-juniper woodlands of lower elevations, Utah juniper (Juniperus osteosperma) is prevalent and Rocky Mountain juniper (J. scopulorum) may codominate or replace it at higher elevations. The understory is highly variable, and may be shrubby, grassy, sparsely vegetated, or rocky. Comer et al. (2003) separate Colorado's pinyon-juniper into four ecological systems: Colorado Plateau Pinyon-Juniper Woodland, Colorado Plateau Pinyon-Juniper Shrubland, Colorado Plateau Mixed Bedrock Canyon and Tableland, and Southern Rocky Mountain Pinyon-Juniper Woodland. Pinyon-Juniper Woodlands are at risk from increased drought and warming temperatures, resulting in increased tree mortality from fires and insects and disease. Regeneration is also a concern as summer shallow soil moisture is required for seedlings and seed production requires multiple years of favorable conditions.

These recommendations were produced in 2020 by members of the Mancos Watershed Group with funding from the Bureau of Reclamation. Read the full report at: www.mancoscd.org.

PINYON JUNIPER WOODLANDS





SUSTAIN FUNDAMENTAL ECOSYSTEM FUNCTIONS

Decrease invasive species, especially in areas of importance

Tactic: Control invasives and non-natives

Limit soil disturbance

Tactic: Avoid disturbing the soils, especially from catastrophic fires and machines that compact the soil

FACILITATE NATIVE SHRUB REPLACEMENT FOLLOWING STAND REPLACING FIRES

Assist and allow transformation

Tactic: Guide changes in species composition at early stages of stand development, post-disturbance

Prepare for large fires

Tactic: Increase funding for stabilization projects (BAER & ES stabilization activities)

REDUCE THE RISK AND LONG-TERM IMPACTS OF SEVERE DISTRUBANCES

Establish fuel breaks to slow the spread of catastrophic fire

Tactic: Develop fire breaks that could limit catastrophic burns and, where necessary, reduce biomass

IDENTIFY AND PROTECT REFUGIA

Identify, prioritize, and maintain unique sites

Tactic: Identify areas likely to be climate refugia and manage for function and resilience

MAINTAIN AND ENHANCE GENETIC DIVERSITY

Promote genetic diversity

Tactic: Use climate-based seed transfer zones and local seed sources

CLIMATE VULNERABILITY SCORE:

HIGHLY VULNERABLE

Vulnerability factors include:

- **Summer drought**
- **Winter precipitation**
- **Winter temperature**
- **Soil moisture**

Distribution

In the Mancos River watershed, the Ponderosa Pine forests are found from approximately 6,500- 9,200 feet in elevation. Oak shrublands are often mixed within or adjacent to forest stands in the lower, warmer and drier elevations. At the higher wetter elevations, Douglas Fir and Aspen will create mixed conifer ecosystems.

Habitat

Ponderosa pine (Pinus ponderosa) is the predominant conifer; Douglas-fir, pinyon pine, and juniper may also be present in the tree canopy. The understory is usually a shrubby mix of common understory grasses.

Dynamics

Ponderosa pine is a drought-resistant and shade-intolerant conifer which often forms the lower treeline in the major mountain ranges of the western United States. Historically, ground fires and drought were influential in maintaining open-canopy conditions in these woodlands. With settlement and subsequent fire suppression, occurrences have become denser. Presently, many occurrences contain understories of more shade-tolerant species, such as Douglas-fir and/or white fir (Abies concolor) as well as younger cohorts of ponderosa pine. These structural changes have affected fuel loads and altered fire regimes. Presettlement fire regimes were primarily frequent (5-15 year return

SPECIES IN THE OVERSTORY:

- Ponderosa pine (Pinus ponderosa)
- Douglas-fir (Pseudotsuga menziesii)
- Pinyon pine (Pinus edulis)
- Juniper (Juniperus spp.)

SPECIES IN THE UNDERSTORY:

- Saskatoon serviceberry (Amelanchier alnifolia)
- Black sagebrush (Artemisia nova)
- Big sagebrush (Artemisia tridentata),
- Kinnikinnick (Arctostaphylos uva-ursi)
- Mountain mahogany (Cercocarpus montanus)
- Chokecherry (Prunus virginiana),
- Antelope bitterbrush (Purshia tridentata)
- Gambel oak (Quercus gambelii)
- Mountain snowberry (Symphoricarpos oreophilus)
- Bluebunch wheatgrass (Pseudoroegneria spicata)
- Species of needle-and-thread (Hesperostipa)
- Needlegrass (Achnatherum)
- Grasses Fescue (Festuca)
- Grama (Bouteloua)
- Muhly (Muhlenbergia)

intervals), low-intensity ground fires triggered by lightning strikes or deliberately set fires by Native Americans. With fire suppression and increased fuel loads, fire regimes are now less frequent and often become intense crown fires, which can kill mature ponderosa pine (Reid et al. 1999).

VULNERABILITY ASSESSMENT SCORING: Across Four Climate Scenarios, 2050

This Mancos River watershed rank is based on the following key attributes: 1) Summer drought, 2) Winter precipitation, 3) Winter temperature, and 4) Soil moisture.

Summer drought: Summer droughts increase the vapor pressure deficit, and evapotranspiration, which result in parched soils and vegetation. Tree mortality from either wildfires or insects and disease increase with summer droughts. We used summer climate water deficit model and departure from 1985-2015 average. The Hot and Dry scenario projects droughts such as 2002 and 2018 are likely to occur once every 3-5 years, while the Feast or Famine and Hot and Wet scenarios are projected to experience extreme droughts once every 10-30 years. The Warm and Wet scenario remains within our historic average.

Winter precipitation: Winter precipitation is a good indicator for forest health as deep soil moisture is critical to tree survival and winter precipitation is the best source that replenishes deep soil moisture. We used departure from 1985-2015 average winter precipitation as our impact assessment metric. Only the Hot and Dry scenario is projected to experience drier winters on average, while the other scenarios range from no increase to a 28% increase. It is important to note as winter temperatures increase, some of this additional winter moisture is likely to fall as rain and in addition, warm winters may allow the trees to photosynthesize, thus depleting soil moisture.

Winter temperature: The winter temperature impacts trees in multiple ways, e.g., higher winter temperatures increase the risk from insects and disease, as well as alter the type of moisture, with less snow and more winter rain as temperatures heat up. We used winter average temperature and its departure from the 1985-2015 average as our impact assessment metric and threshold. Winter temperatures are projected to rise in all scenarios; however, the Hot and Dry and Hot and Wet scenarios are the most extreme with a 5-6° F increase. The Feast or Famine scenario is projected to warm an additional 3° F, and the Warm and Wet an additional 1.5° F.

Soil Moisture: Spring and summer soil moisture are critical for seed germination and seedling survival. We used the summer soil moisture as seedlings cannot survive if summer shallow soil moisture is low. All of the scenarios project a soil moisture deficit, ranging from -19% to -60%.

SUMMARY:

Ponderosa Pine/Mixed Conifer are at risk from increased drought and warming temperatures, resulting in increased tree mortality from fires, and vulnerability to insects and disease. Regeneration is also a concern as summer shallow soil moisture is required for seedlings.

Table 1. Climate vulnerability analysis: ponderosa pine forests

Measurable Climate Indicator	Impact Assessment Metric	Thresholds for metric	Hot & Dry	Feast & Famine	Hot & Wet	Warm & Wet	Confidence Level
Summer Drought	Climate Water Deficit, Summer	Departure from 30-year average	-3	-1	-1	0	Moderate
Winter Snowpack	Winter Precipitation	Below average winter precipitation reduces runoff as well as groundwater recharge	-2	2	0	2	Moderate
Winter Temperature	Winter Average Temperature	Departure from 30-year average	-3	-2	-3	-1	Moderate
Soil Moisture	Summer soil moisture	Departure from 30-year average	-60%	-19%	-40%	-23%	Moderate

ADDITIONAL FACTORS, INFORMATION, AND CONSIDERATIONS

It is important to note that mature trees are capable of withstanding droughts and fires, however regeneration will be tied to the current climate.

PONDEROSA PINE

Drought resilience strategies:

- Facilitate community adjustments through species transitions
- Identify and protect climate refugia
- Maintain and enhance genetic diversity
- Reduce the risk and long-term impacts of severe disturbance
- Sustain fundamental ecological functions

SHARED GOALS

Stakeholders identified the following goals for pinyon juniper woodlands in the Mancos Watershed:

Protect and maintain a resilient landscape that:

- includes ponderosa pine
- supplies people with ecosystem services, including clean water, biodiversity, recreation, tourism, traditional foraging, hunting, food and others.

CLIMATE CONSIDERATIONS

The primary climate impacts that these strategies will help address are:

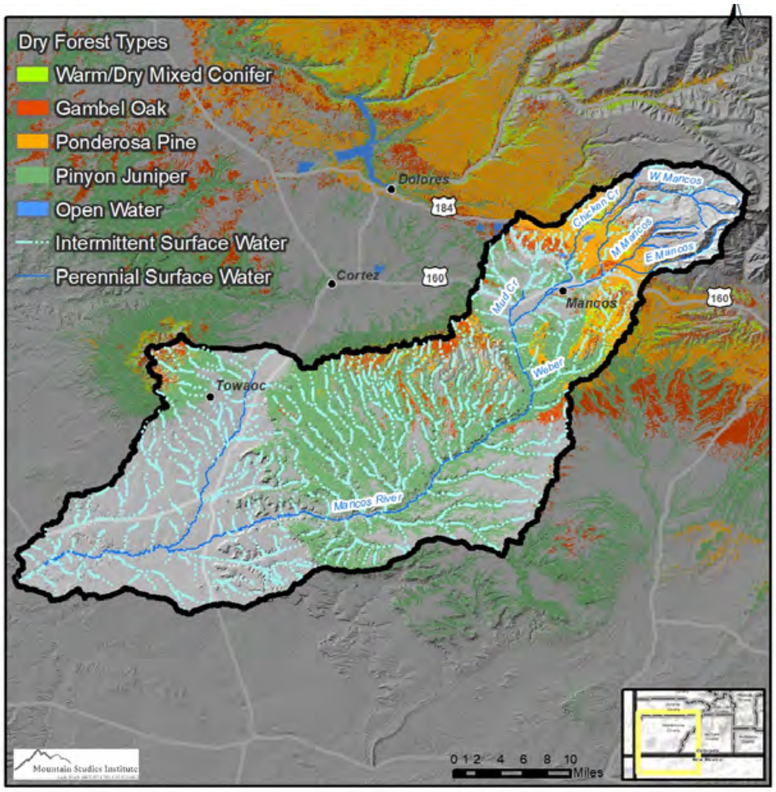
- Altered fire regime
- Reduced soil health
- Decreased stand resilience
- Altered species composition
- Tree mortality (fire, drought)

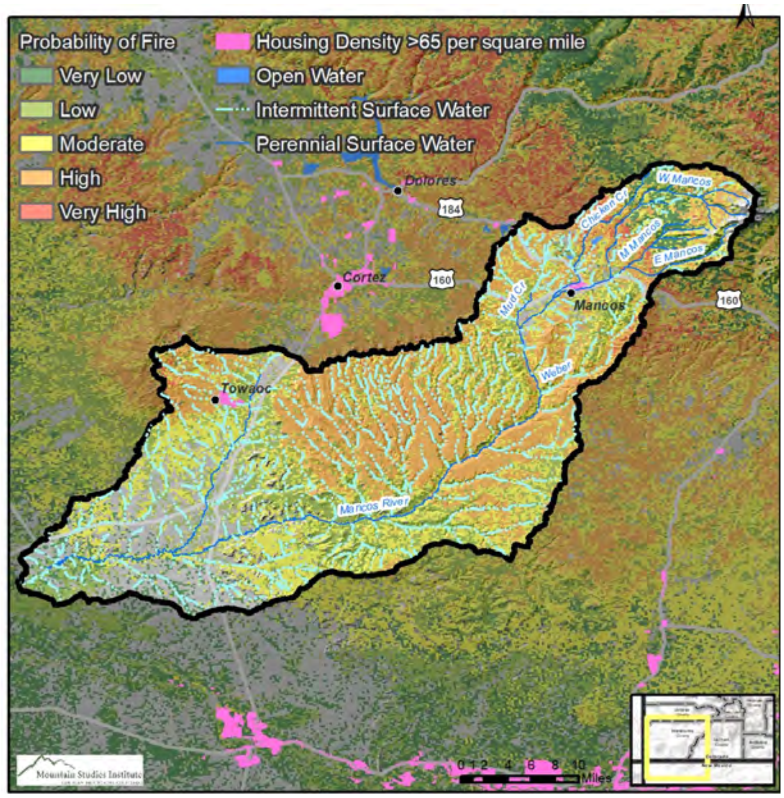
SUMMARY & CONSIDERATIONS

In the Mancos River watershed, the Ponderosa Pine/Mixed Conifer forests are found from approximately 6,750- 8,750 feet in elevation. Oak shrublands are often mixed within or adjacent to stands. Habitat: Ponderosa pine (Pinus ponderosa) is the predominant conifer; Douglas-fir (Pseudotsuga menziesii), pinyon pine (Pinus edulis), and juniper (Juniperus spp.) may also be present in the tree canopy. The understory is usually shrubby, with Utah servicebery (Amelanchier utahensis), black sagebrush (Artemisia nova), big sagebrush (Artemisia tridentata), kinnikinnick (Arctostaphylos uva-ursi), mountain mahogany (Cercocarpus montanus), chokecherry (Prunus virginiana), antelope bitterbrush (Purshia tridentata), Gambel oak (Quercus gambelii), and mountain snowberry (Symphoricarpos rotundifolisus) being common species. Bunchgrasses including bluebunch wheatgrass (Pseudoroegneria spicata) and species of needle-and-thread (Hesperostipa), needlegrass (Achnatherum), fescue (Festuca), muhly (Muhlenbergia), and grama (Bouteloua) are common understory grasses. Ponderosa Pine/Mixed Conifer are at risk from increased drought and warming temperatures, resulting in increased tree mortality from fires and insects and disease. Regeneration is also a concern as summer shallow soil moisture is required for seedlings.

These recommendations were produced in 2020 by members of the Mancos Watershed Group with funding from the Bureau of Reclamation. Read the full report at: www.mancoscd.org.

PONDEROSA PINE





FACILITATE COMMUNITY ADJUSTMENTS THROUGH SPECIES TRANSITIONS

Assist and allow transformation

Tactic: Promote pinyon-juniper trees where they already exist in ponderosa pine forests

Prepare for large fires

Tactic: Increase funding for stabilization projects (BAER & ES stabilization activities)

SUSTAIN FUNDAMENTAL ECOLOGICAL FUNCTIONS

Prevent uncharacteristic disturbance, especially on or near the trailing edge

Tactic: Allow fire to exist as low severity fires (use of PODs, Rx fire, and thinning)

Promote growth rates and resilience

Tactic: Increase funding for stabilization projects (BAER & ES stabilization activities)

Tactic: Thin overly dense tree stands and utilize controlled burns

REDUCE THE RISK AND LONG-TERM IMPACTS OF SEVERE DISTRUBANCES

Establish fuel breaks to slow the spread of catastrophic fire

Tactic: Develop fire breaks that could limit catastrophic burns and where necessary reduce biomass

IDENTIFY AND PROTECT REFUGIA

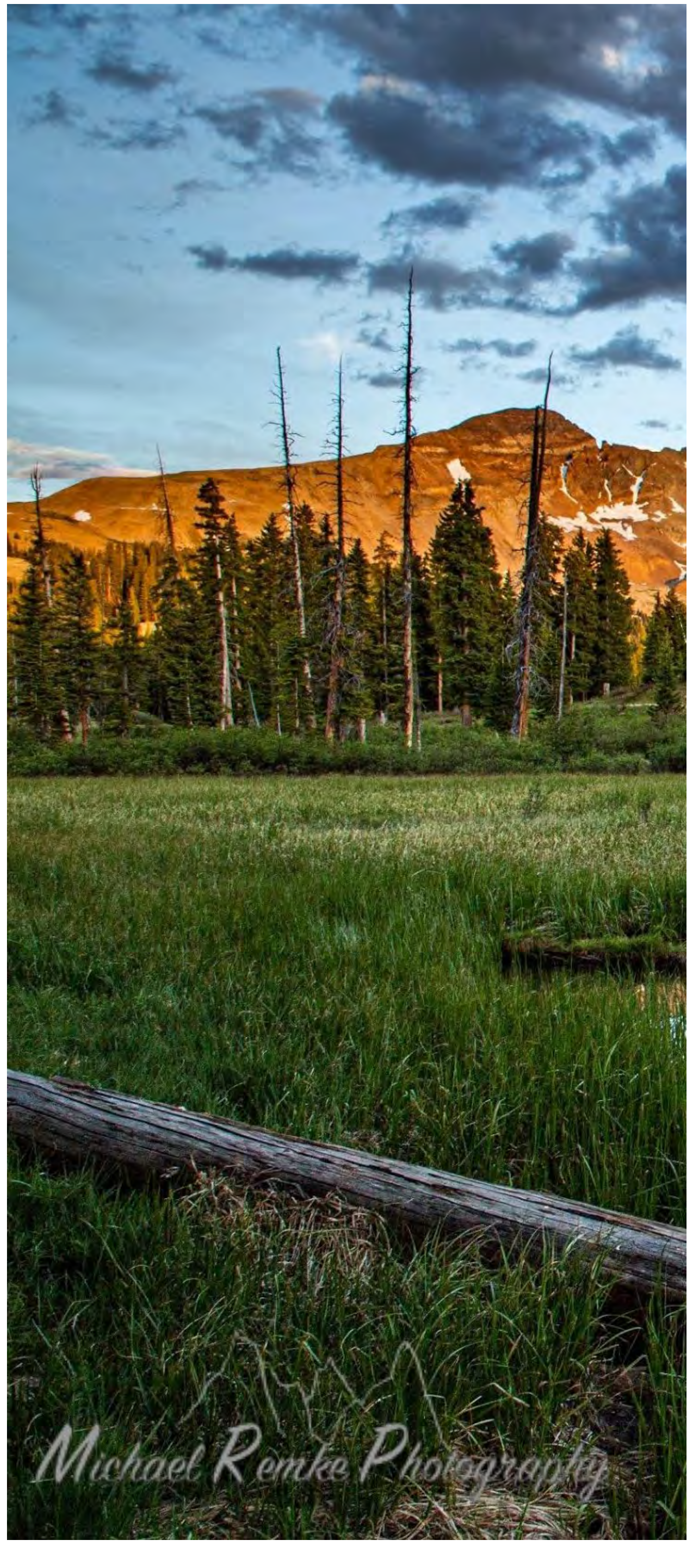
Identify, prioritize, and maintain unique sites

Tactic: Identify areas likely to be climate refugia and manage for function and resilience

MAINTAIN AND ENHANCE GENETIC DIVERSITY

Promote genetic diversity

Tactic: Use climate-based seed transfer zones and local seed sources.



Funding was generously provided by the Bureau of Reclamation WaterSmart Program, Southern Rockies Landscape Conservation Collaborative, Colorado Water Conservation Board Southwest Basin Roundtable, Colorado Non-point Source 319 Program, The Nature Conservancy, Wildlife Conservation Society, Temper of the Times Foundation, Mountain Studies Institute, and Colorado State University. The North Central Climate Adaptation Science Center produced and contributed foundational work for this effort. Because this work is ongoing, additional publications and materials can be found at www.mountainstudies.org/mancos or www.mancoscd.org.