UPPER YAMPA WATER CONSERVANCY DISTRICT

BEAR RIVER WILDFIRE READY ACTION PLAN

JANUARY 2025

UPPER YAMPA WATER
CONSERVANCY DISTRICT

JW associates

Otak

PROJECT DETAILS

This Plan and the supporting analysis and documents were prepared by JW Associates, in collaboration with Upper Yampa Water Conservancy District & Otak. This project was supported by a Wildfire Ready Watersheds grant from the Colorado Water Conservation Board.

To learn more about Wildfire Ready Action Plans, as well as the organizations collaborating in this project, please visit their websites:

- **Colorado Water Conservation Board, Wildfire Ready Watersheds** – www.wildfirereadywatersheds.com
- **JW Associates** – www.jw-associates.org
- **Otak, Inc.** - www.otak.com

Cover Page Photo Description: Yamcolo Reservoir with the Flattops Wilderness behind and blooming wildflowers in the foreground, June 2024.

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1 INTRODUCTION

1 A. Introduction to the Bear River Watershed and Water Supply

Yampa River Basin water, land, and resource managers and planners have long been aware of the threats that wildfire poses to their water supply. Nearly every local watershed and/or wildfire planning document acknowledges that post-fire erosional impacts to water supply and infrastructure are concerns for the basin communities. As the past several years of intense wildfires has amplified this message at the national level, Colorado State agencies have been incorporating watershed wildfire resiliency into statewide plans and objectives and developing the mechanisms necessary to fund it. Therefore, the UYWCD has convened a stakeholder group to complete a Wildfire Ready Action Plan (WRAP) for the Bear River Watershed.

The Upper Yampa Water Conservancy District (UYWCD), State of Colorado (State), and the Bear River Reservoir Company (BRRC) operate raw water supply and recreational reservoir facilities in the headwaters area of the Yampa River Basin. The headwaters watershed of the Yampa River is commonly referred to as the Bear River. The Bear River Watershed contains both public lands managed by the United States Forest Service (USFS-Routt National Forest), and several private land agricultural operations. A portion of the watershed is designated wilderness as part of the National Wilderness Preservation System (Flattops Wilderness).

1 A. Introduction to the Bear River Watershed and Water Supply

Stillwater Reservoir (BRRC) and Yamcolo Reservoir (UYWCD) are primarily agricultural water storage facilities. These reservoirs deliver all of their water storage to water users in Routt County, within the operational boundary of the UYWCD. Yamcolo reservoir also provides municipal and augmentation water storage for Yampa River basin water users. Bear Lake (also referred to as Upper Stillwater Reservoir) is operated by Colorado Parks and Wildlife (CPW) as a recreational facility. All three reservoirs (Map 1) are located above an elevation of 9,500', on National Forest System (NFS) lands. The town of Yampa is located at the downstream extent of the Bear River Watershed. The Town of Yampa's municipal water supply facility is located in the lowest portion of the watershed and is supplied by both direct diversion and infiltration galleries drawing from the main channel of the Bear River.

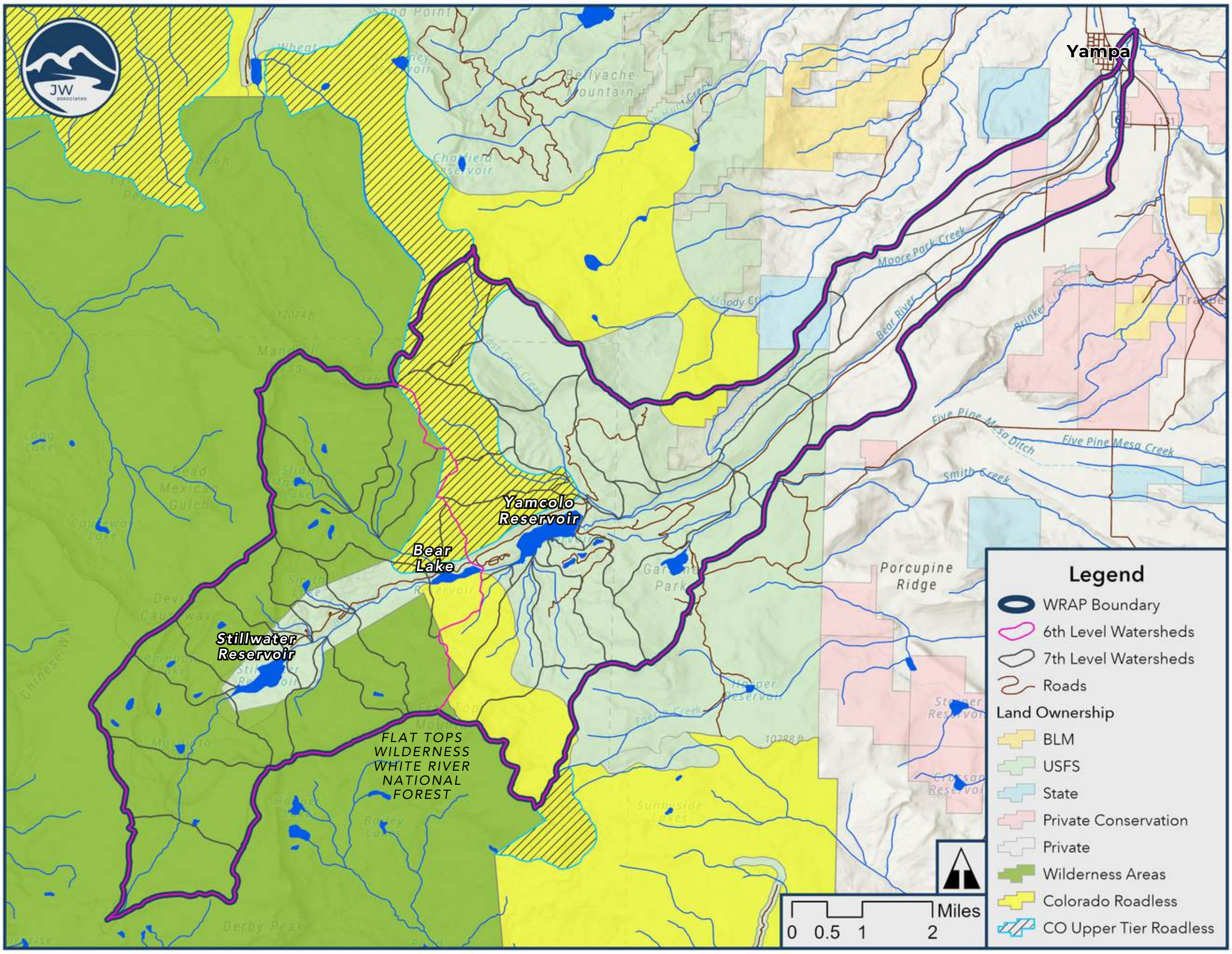
Throughout the west, a combination of overgrown forests, insect infestations, and climate change has led to an increasing frequency and severity of wildfires. Managers of surface water supply systems in forested watersheds must address potential impacts from these wildfires when planning for water security. Wildfires burn vegetation and alter soil properties, causing rainfall to run off the surface rather than soak into the soil. When combined with vegetation and root system losses due to burned surfaces, hillslopes can quickly erode. Consequently, rainfall on burned watersheds often produces floods that carry debris, sediment, ash, and contaminants into water sources. This has important implications for water supply infrastructure and the quality of source water. Sediments fill reservoirs, decreasing storage capacities; while debris, sediment, ash and contaminants lower water quality, and impede flow conveyance through agricultural irrigation infrastructure.

These kinds of impacts have been experienced in the immediate region. The Muddy Slide Fire started near Yampa on June 20, 2021 and burned 4,093 acres until fully contained on September 14, 2021. Post-fire impacts from this fire were typical of western fires and, as of 2024, are still being observed on the hillslopes and streams adjacent to the burn scar. Some of the notable observations include re-timing of the snow pack runoff, large debris flows, increased sediment inputs into the Yampa River and destruction of agricultural infrastructure.

The Bear River Watershed is a critical water-supply and is susceptible to wildfire. It received the highest priority classification for Watershed Protection in the Colorado State Forest Service (CSFS) 2020 Forest Action Plan (FAP). Areas identified as high priorities for Watershed Protection in the 2020 FAP represent priority areas where opportunities exist to improve and maintain water quality and quantity, improve resiliency of critical water infrastructure, and sustain or restore fundamental ecological functions for watershed health.

1 B. Geographic Scope of the WRAP

The WRAP watershed area is in both Routt and Garfield Counties. The Bear River has a 52 square mile basin and flows generally from southwest to northeast towards its confluence with Phillips Creek, where the two join to form the Yampa River. The Bear River Watershed is heavily forested and is characterized by high elevation mixed conifer, spruce-fir, and aspen forests, interspersed with montane meadows and wetlands (groundwater supplied) in the riparian corridors, with mostly aspen and shrublands at lower elevations. The Bear River Watershed includes two HUC-12 or 6th level watersheds. The Headwaters Bear River HUC-12 is entirely NFS lands. The Yamcolo Reservoir-Bear River HUC-12 is a combination of NFS lands, the Town of Yampa and private agricultural properties that rely on extensive surface irrigation infrastructure. Many of the private land irrigation systems originate in higher elevation, NFS lands.



Map 1. WRAP Project Area and Land Ownership

1 B. Geographic Scope of the WRAP

The Bear River Watershed considered for this plan contains the two 12-digit Hydrologic Unit Code (HUC-12) areas defined by the US Geological Survey (USGS) as:

> Headwaters Bear River, 140500010101 - 14,094 acres (22 square miles)
> Yamcolo Reservoir-Bear River, 140500010102 - 19,214 acres (30 square miles)

These 6th Level watersheds were then further sub-divided into 7th level (14-digit HUC) watersheds. The smaller analysis scale provides improved accuracy for the identification of areas that have higher hazards and lower resilience to wildfire impacts. The analysis is particularly useful in identifying specific reasons for the watershed resiliency rankings and subsequently target distinct projects that will improve both local and overall watershed resilience. The project area includes 35 7th level watersheds, covering 33,308 acres (Map 1).

2 STAKEHOLDER ENGAGEMENT

2 A. Vision, Goals & Objectives

The purpose of this project is to analyze conditions in the Bear River Watershed with the intent of improving long-term watershed resilience. The analysis is used to determine priorities and actions within identified target areas that would increase watershed resilience.

The vision, goals, and objectives of this plan were directed by a group of stakeholders, led by the Upper Yampa Water Conservancy District (UYWCD). When asked about their vision, goals, and objectives for this plan, feedback from the stakeholder group included the key ideas shown in the word cloud to the right.

2 A. Vision, Goals & Objectives

VISION

The vision for the Bear River Wildfire Ready Action Plan (WRAP) is to ready the critical water supply watersheds in the project area to withstand and be resilient to wildfires in a changing climate. These watersheds will be wildfire-ready through a combination of pre-fire actions and post-fire planning, as well as by working with the many stakeholders to ensure there is mutual understanding of roles and responsibilities for both pre-fire actions and post-fire response in the watersheds.

GOALS

- As a collaborative group, agree on what features make resilient or wildfire-ready watersheds, and with that, healthy forests, watersheds, and ecosystems in the Upper Bear River Watershed.
- Manage for a positive interaction with wildfire, rather than seeking its elimination as a disturbance component.
- Identify priority watersheds for pre- and post-fire actions.
- Identify specific pre-fire actions to move target watersheds towards more resilient conditions.
- Collaborate with stakeholders and other group efforts by sharing analysis and planning, integrating relevant data and specific small-scale watershed assessments.
- Incorporate watershed treatments that connect hillslopes with streams and reservoirs.
- Think outside the box with novel treatments and newer technology, such as Ponsse forest management equipment on steeper slopes, or combining forestry projects with low tech process based restoration (LTPBR) to utilize materials removed from the forests into stream projects.
- Adapt to and synthesize existing or planned projects in order to utilize funding efficiently and collaborate with partners doing work in similar areas.
- Include public education and community engagement as a pillar for the outcomes and practices specified in the plan.

MAIN OBJECTIVES

- Maintain stakeholder involvement through ongoing communication and integration of their ideas and planned projects.
- Create plans and identify funding for multiple specific watershed resilience projects in the next 2 years.
- For all projects completed, consider how to engage the public and add educational materials into the project budget.
- Build consensus with partners on a 5-year plan for continuing to accomplish identified watershed resilience projects.
- Annually track the progress of projects that move watersheds toward wildfire readiness.

STAKEHOLDERS

The Bear River Wildfire Ready Action Plan (WRAP) has initiated a stakeholder process that will continue beyond the completion of the WRAP. The Stakeholder Group includes a number of key agencies, groups, citizens, and other organizations (listed on the next page). The Stakeholder Group reviewed the formation of the plan and progress during three meetings over the last year.

2 B. Stakeholders

UPPER YAMPA WATER CONSERVANCY DISTRICT

- Andy Rossi
- Emily Lowell

COLORADO PARKS & WILDLIFE (CPW)

- Eric Vanatta
- Libbie Miller

UNITED STATES FOREST SERVICE (USFS)

- Jamie Statezny
- Sarah Hegg

BEAR RIVER RESERVOIR COMPANY

- Andi Schaffner
- John Redmond

TOWN OF YAMPA

- Sheila Symons

ROUTT COUNTY EMS

- Mo DeMorat

ROUTT COUNTY ROAD & BRIDGE DEPARTMENT

- Mike Mordi

ROUTT COUNTY ENVIRONMENTAL HEALTH

- Scott Cowman

COLORADO STATE FOREST SERVICE

- Carolina Manriquez

ROUTT COUNTY WILDFIRE MITIGATION COUNCIL

- Josh Hankes

ROUTT COUNTY CONSERVATION DISTRICT

- Lyn Halliday

NATURAL RESOURCES CONSERVATION SERVICE

- Cliton Whitten

UPPER YAMPA WATERSHED GROUP

- Lyn Halliday

COLORADO DIVISION OF WATER RESOURCES

- Mendi Figueroa

YAMPA FIRE PROTECTION DISTRICT

- Ky Cox

YAMPA VALLEY ELECTRICAL ASSOCIATION

- John Cromer

YAMPA VALLEY SUSTAINABILITY COUNCIL

- Tim Sullivan

FRIENDS OF THE YAMPA

- Jenny Frithsen

THE NATURE CONSERVANCY

- Jennifer Wellman

COMMUNITY AGRICULTURAL ALLIANCE

- Amber Pougiales

ROUTT COUNTY AGRICULTURAL EXTENSION

- Todd Hagenbuch

IRRIGATORS & PRIVATE LAND OWNERS

- Yamcolo Irrigation Association
- Jeff Clynke
- Rick Milway
- Jay Whaley
- Tyler Snyder
- Other individual stakeholders

Stakeholder meetings during the creation of the WRAP

Three Stakeholder Meetings were held during the WRAP process to inform and seek feedback from the stakeholder group. These meetings were held in Yampa and had a hybrid option for attendance. The meetings occurred on:

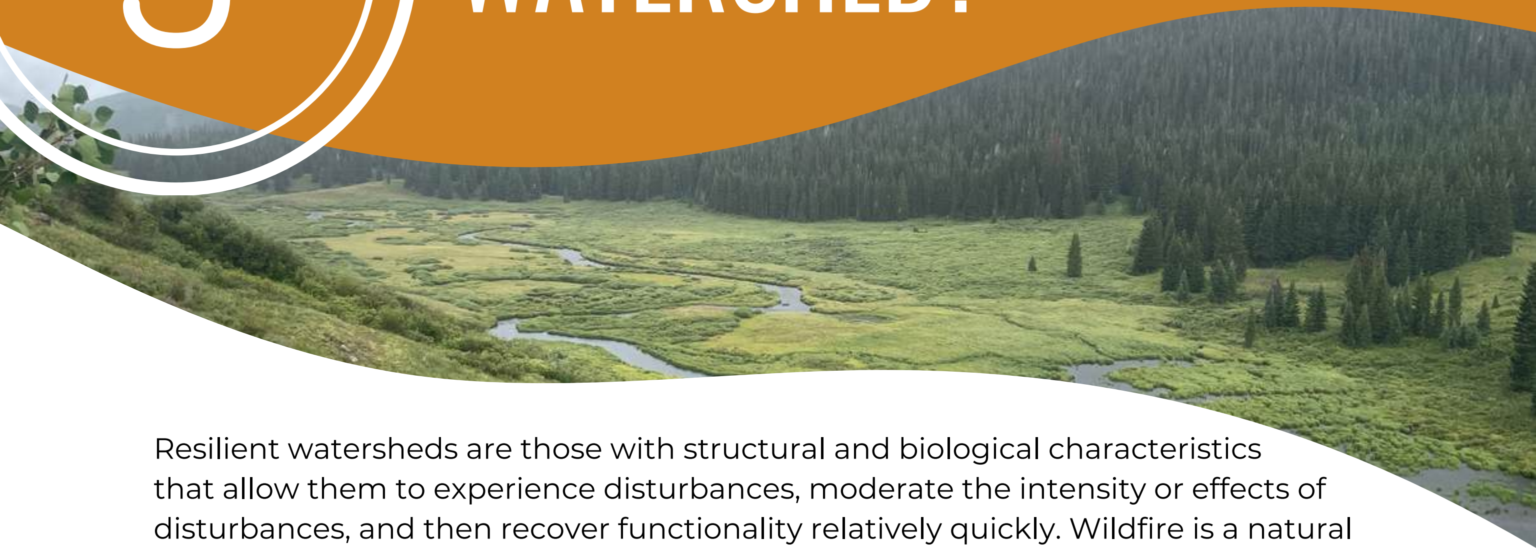
- December 12, 2023 (Goal Setting, Meeting #1)
- May 1, 2024 (South Routt Water Users Meeting)
- January 23, 2025 (Presentation of Results, Meeting #3)

Long-term stakeholder engagement following the creation of the WRAP

It will be important to secure a commitment among stakeholders to attend stakeholder meetings over the long-term. Creating a sub-committee to oversee progress with the WRAP implementation, or partnering with a local organization, will be critical for the long-term success of the project. The larger stakeholder group will become an important entity for holding institutional knowledge of the process and commitments. Other important on-going roles for this group include, but are not limited to

- Communicating project progress to the larger community
- Welcoming and disseminating information about the WRAP to new individuals as initial members revolve out
- Consistently reviewing the objectives to ensure current and future adherence to the goals and objectives laid out in the WRAP
- Reviewing changes in the watershed that could impact the WRAP
- Considering the need to update or revise the plan due to changes in the watersheds, impacts of climate change, wildfire in or adjacent to the watersheds, changes in forest health etc.
- Considering the need to update or alter the plan due to changes in agency direction

3 WHAT IS A RESILIENT WATERSHED?



Resilient watersheds are those with structural and biological characteristics that allow them to experience disturbances, moderate the intensity or effects of disturbances, and then recover functionality relatively quickly. Wildfire is a natural disturbance in these watersheds and is an important component of healthy ecosystem function. One goal of creating a resilient watershed is to manage for a positive interaction with wildfire, rather than its elimination as a disturbance component. By acting proactively, watershed managers can protect watersheds from existing and future stresses, such as wildfire and climate change, by understanding the characteristics that build watershed resilience. Management decisions can address the identified watershed resilience deficits to minimize impacts of disturbances to hydrologic systems, riparian zones, and the natural flux of water and sediment in streams.

3 A. Components of a Resilient Watershed

UPLANDS

Upland habitats maintain ecological characteristics that, when healthy and functioning properly, increase the likelihood that the watershed will withstand and recover from natural disturbances. Some of these characteristics include historical disturbance regimes, appropriate forest canopy cover and age structure, native vegetation, and healthy and diverse soils that support native vegetation, maximize infiltration and reduce runoff volume.

3 A. Components of a Resilient Watershed

Watershed uplands can significantly impact overall watershed resiliency. These areas are at risk from both natural and human caused disturbances such as wildfire, drought, insect and disease outbreaks, floods, development in the Wildland Urban Interface (WUI), land use and landscape fragmentation. If their functional ecological characteristics are compromised, the overall resilience of the watershed to disturbances may also decline, particularly if the watershed is experiencing multiple stresses.

Resilient Uplands in the Project Area

The vegetation types that make up the Forest Life Zones of the Bear River Watersheds have been analyzed using expected disturbance types to predict which vegetation patterns within each zone produce resilient conditions. An understanding of the variations in soils, aspect, local weather patterns, and disturbance history, provides insight into the types of vegetation expected to be found in resilient upland ecosystems. The analysis suggests a range of conditions that would be considered resilient within the current and future climate.

The lower elevations of Bear River are dominated by agricultural lands with some sagebrush and riparian areas dominated by cottonwood. The middle elevations contain some large patches of aspen between agricultural lands. The upper watersheds are dominated by spruce-fir with interspersed aspen woodlands. The highest elevations are alpine which are mostly grasslands, shrubs and rock.

Ecosystem Benefits & Services of Healthy Uplands

- Support biodiversity
- Sequester carbon
- Protect against invasive species
- Limit sediment delivery to receiving streams
- Provide services for human use, including:
  - natural resources
  - recreation
  - lands for agriculture & grazing

Diversity in vegetation and canopy closure in Coal Creek Watershed, within the WRAP project area. Photo: JW Associates, July 2024

The patterns of vegetation across the landscape are shaped by elevation, aspect, slope, soils (which are generally described by Forest Life Zones), and disturbances. Diverse patterns of vegetation and disturbances maintain the landscape in a varied and dynamic condition that can better withstand events such as fire, and insects and disease. Transition areas, especially aspen woodlands to the Subalpine Zone, are more diverse and aspen can remain a component within spruce and subalpine fir.

Fire regimes of the lower watershed are characterized by frequent, low severity fires. Higher elevations dominated by spruce-fir are more moist and support denser forests. These elevations are characterized by mixed severity fires in areas where openings or aspen woodlands exist, and stand replacement fire regimes that have long recurrence periods in areas of denser forest with fewer openings or pockets of aspen.

Why Resilient Uplands Function Better During & After Wildfire

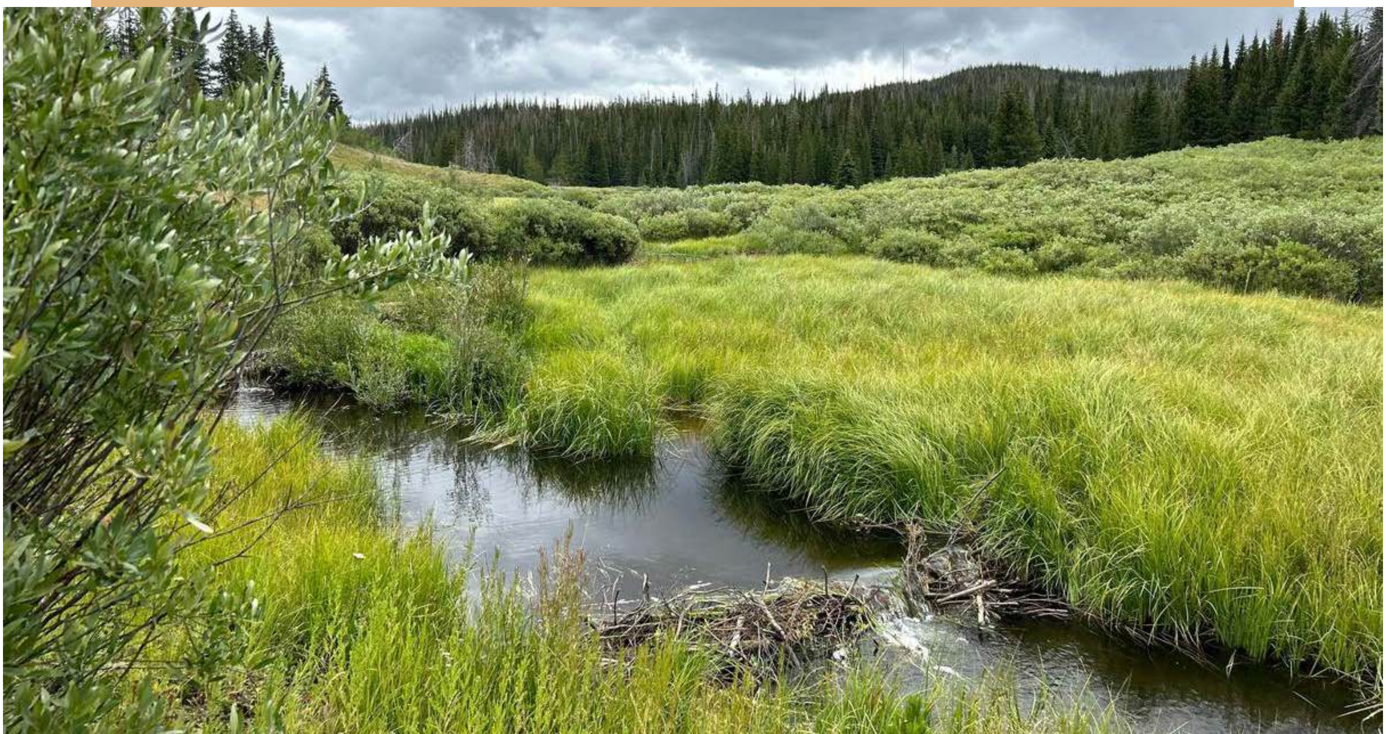
Diverse patterns of vegetation across a landscape provide opportunities for wildfire progress to slow and change behavior when there are openings or changes in species or density, such as a change from spruce-fir to aspen. When the wildfire slows or has less fuel to burn, the soil burn severity in those areas is reduced. Lower burn severity allows for a quicker recovery following the fire, including reduced overland flow, and erosion of hillslopes, which results in reduced peak flows and debris flow potential downstream.

INSTREAM & RIPARIAN AREAS

Riparian ecosystems are the connection point between the forested uplands and the river corridor. When riparian areas are functioning properly, their floodplains and vegetation can reduce negative impacts to downstream habitats and human infrastructure. If a stream's function and water quality is compromised, it is vital to to restore and maintain healthy, functioning wetlands where possible, re-connect the river to its floodplain, and improve the health of riparian vegetation.

Riparian areas include the vegetation communities that are influenced by the geomorphic and hydrologic processes of the river, such as bank zones, over-bank zones, and floodplain-upland transition zones of a floodplain. These areas are among the most biologically diverse and ecologically important habitats throughout the semi-arid west, providing important habitat for birds and other wildlife.

Riparian areas create cover for resident wildlife, and serve as the foundation for an entire food web of adjacent aquatic and upland systems. Throughout Colorado, the upper canopies of cottonwoods, aspen, blue spruce, and other mature trees commonly found in riparian areas provide important nesting habitat for bald eagles and other raptors. They also provide rookery habitat for great blue herons, and nesting habitats for owls and a variety of cavity nesting birds. Additionally, rare species such as the Preble's meadow jumping mouse, Colorado butterfly plant, and Ute ladies'-tresses orchid rely upon healthy riparian habitats for survival.



Beaver are working diligently in the lower Dome Creek meadow within the WRAP project area. However, the riparian vegetation is limited to small shrubs and willows. Improving the riparian vegetation here could uplift the entire ecosystem. Photo: JW Associates

Aquatic Habitat

Aquatic habitats are those that support a variety of vertebrates (i.e., fish, reptiles, and amphibians) and invertebrates (i.e., insects) whose reproductive cycles cannot be completed without water. Of all living things in a stream, insects are often considered a barometer for stream and watershed health. Similar to other biotic communities, stream insect communities increase in diversity with increases in physical and environmental diversity within their potential habitat. In Colorado streams, this diversity is provided by a variety of structural geomorphic features, such as overhanging banks, pools, riffles, runs, and steps. Physical and environmental diversity is provided by in-stream structures such as large boulders and woody debris, and organic inputs such as leaves, pine needles, and small woody debris. These structures influence temperatures and other water quality parameters.

Due to the profound impacts of riparian vegetation on stream health, including organic matter inputs and stream shading, there is an intimate relationship between riparian area health and the health of aquatic animals. The resilient condition of aquatic habitat is a condition that contains the structural diversity, water chemistry and biological diversity to maintain the expected aquatic life and to rebound back to that condition when affected by disturbances.

Stream Channel Form and Function

The form, or shape, and slope of stream channels changes over time depending on water flow (both instream and from tributaries), sediment movements, and biological factors such as riparian and aquatic vegetation and beaver activity. A natural stream can respond to changes in water and sediment by adjusting form in each direction vertically, laterally (meandering), and longitudinally. The ability to change channel and floodplain form helps to maintain healthy, diverse habitat structures including instream features such as riffles, pools, and bars, and floodplain features such as off-channel wetland/ponds and high-flow channels.

Sediment transport or erosion and deposition of sediments is the mechanism that creates river system changes in form. Generally, more water flow equates to more sediment transport, therefore peak flow events are responsible for creating the largest amount of change. Larger, perennial rivers typically move a notable amount of sediment annually or bi-annually, while smaller, ephemeral streams may only move sediment episodically during large flood events that may be associated with post-fire conditions.

Sediment Transport Balance

The expected response of river systems to disturbances can be predicted based on the sediment transport balance. If the amount of sediment entering a given section of river (a reach) is greater than the stream's capacity to transport sediment in the reach then net deposition is expected. If the amount of sediment entering a reach is less than the stream's capacity to transport sediment in the reach then net erosion is expected. The poorest river health conditions typically occur when net erosion creates downcutting, leading to homogenous habitat and disconnection from the surrounding floodplain.

The healthiest river conditions occur when the river system is in a state called dynamic equilibrium, with sediment transport, on-average, balanced. A dynamic equilibrium state will still have fluctuations of erosion and sedimentation but neither one dominates. River system health and associated sediment transport balance can look very different depending on river setting and size. For example, small headwater streams are naturally less mobile with changes that occur over longer time frames than larger streams.

Beaver Meadow Function & Benefits

Well-functioning beaver meadows provide benefits to river and floodplain health directly at their locations and also to surrounding uplands, the river system above the meadows and downstream reaches. Beaver meadows are most commonly located in lower gradient reaches with wider valley areas in mountainous streams. In these areas, beavers create a series of dams using mud, river rock, and branches. The dams back up water, spreading it across the adjacent floodplain. Well-functioning beaver meadows often have a high concentration of dams on multiple flow paths that can ultimately spread water across an entire river valley bottom. A compounding effect of beaver dams is to raise shallow groundwater tables creating a biological haven for aquatic, wetland, and riparian plants and animal species, ultimately adding to ecosystem functions that improve water quality.

Wetted meadows suppress the growth of conifers in the valley bottom, creating a break or buffer against the spread of a wildfire. When beaver are removed from an area, the stream will eventually follow a more direct flow path and the valley bottom will dry out.

Drier valley bottoms encourage the encroachment of upland species such as shrubs and conifers, which absorb remaining valley water, further lowering the groundwater table. As these more flammable species replace riparian vegetation, the likelihood of higher severity fires increase and the fire buffer at the stream is reduced.

Observations during wildfires have shown how beaver meadows can be resistant to burning and act as fire breaks between hillslopes. Additionally, a beaver meadow that is well-connected to its adjacent floodplain provides a natural sediment and debris trap and can attenuate post-fire flooding, reducing impacts on downstream ecosystems and human infrastructure.

Re-establishing beaver habitat through active encouragement of beaver populations or installation of BDAs, can be an effective tool to add resiliency to a watershed. However, there is a need to balance the added ecosystem functions with existing water supply infrastructure to avoid destabilizing existing beneficial uses.

Example of a beaver meadow that showed resistance to burning during a wildfire on Baugh Creek, Idaho. (Wheaton et. al 2019, Randall 2018)

3 A. Components of a Resilient Watershed

BENEFITS OF HEALTHY RIPARIAN AREAS AND FLOODPLAINS

- Provide a filtration system from adjacent upland areas, reducing sedimentation into waterways and the rate of soil loss from stream banks.
- Provide shade to streams which reduces in-stream temperatures
- Adds delivery of organic matter such as leaves and large woody debris to streams which also serve as a food source for many aquatic macroinvertebrates
- Enhance nutrient cycling
- Maintain higher base flows and dissipate flood energy
- Provide significant aesthetic value to residents and tourists who experience thousands of miles of riverine systems
- Produces natural resource, economic and recreational benefits

Why Resilient Riparian Areas Function Better During & After Wildfire

Riparian areas are commonly flooded. As long as that flooding is within the range of conditions that formed a stable system, the floodwaters function to maintain a healthy mosaic of plant community types that provide a great variety of resilience benefits. Healthy riparian areas show or provide resilience in the following ways:

- An ability to rebound quickly after most disturbances and under the majority of flood discharge frequencies, rebuilding its resilient functions.
- Floodplain roughness that helps reduce the risk of bank erosion or avulsions and floodplain scour during high magnitude events.
- Infiltration and/or water residence times in the floodplain that function to reduce the "flashiness" of a stream, thereby reducing downstream flooding.
- An ability for aquatic invertebrates to rebound quickly following natural disturbances. Healthy aquatic insect communities in turn have cascading positive impacts for a variety of aquatic and terrestrial wildlife.

ROADS

Roads can convert subsurface runoff to surface runoff and then route the surface runoff to stream channels in ditches, which can increase peak flows (Megan and Kidd 1972, Ice 1985, and Swanson et al. 1987). Therefore, watersheds with higher road densities have a higher sensitivity to increases in peak flows especially following disturbances such as wildfires.

Road stream crossings are especially critical locations where roads interact with streams. These crossings are typically a steel culvert with road fill around the culvert. Many, if not most, of older stream road crossings are critically undersized, especially in the case of post-fire or flood runoff. Undersized crossings can clog with debris and sediment which can lead to overtopping and road failure. Road crossing failures can cause large pulses of debris, sediment and streamflow downstream which can cause much more stream damage than if the crossing was not present.

Road Blowout in Cabin Creek in the East Troublesome Fire Area, 2022.

Photo: JW Associates

3 A. Components of a Resilient Watershed

Even if culverts are adequately sized, road erosion and the subsequent transport of sediments during high flow events can be a significant contributor to in-stream sediments. Forest roads are usually the largest source of long-term sediment in forested watersheds (Elliott 2000, MacDonald and Stednick 2003).

IMPACTS OF ROADS ON ECOSYSTEM HEALTH

- Reduce the width of a riparian corridor by occupying part of the valley bottom
- Increase disturbance of the stream bed & bank by increasing access for people
- Reduce infiltration of water
- Increase runoff & sediment input to the stream channel
- Alter the shape & stability of the channel

EXAMPLE RESILIENT WATERSHED CHARACTERISTICS

Uplands

- Healthy and diverse upland vegetation
- High wildfire hazard areas that are disconnected from other similar areas
- Mix of forest densities including meadows
- Good ground cover with native vegetation
- Wildfire behavior within natural disturbance regimes

Development

- Minimal impervious or compacted surfaces
- Low road density
- Trails designed to minimize erosion
- Well-designed stream/road and stream/trail crossings
- Well-designed storm-water management and erosion control BMPs with a monitoring plan
- Invasive weed prevention and eradication programs

In-Stream & Riparian Areas

- Natural stream flow regime, including peak and low flows
- Healthy riparian areas with native vegetation
- Intact and connected wetlands
- Functional floodplains connected to streams
- Water supply infrastructure that is designed and constructed to accommodate natural stream processes and long-term structural integrity.

3 A. Components of a Resilient Watershed

POST-FIRE WATERSHED IMPACTS

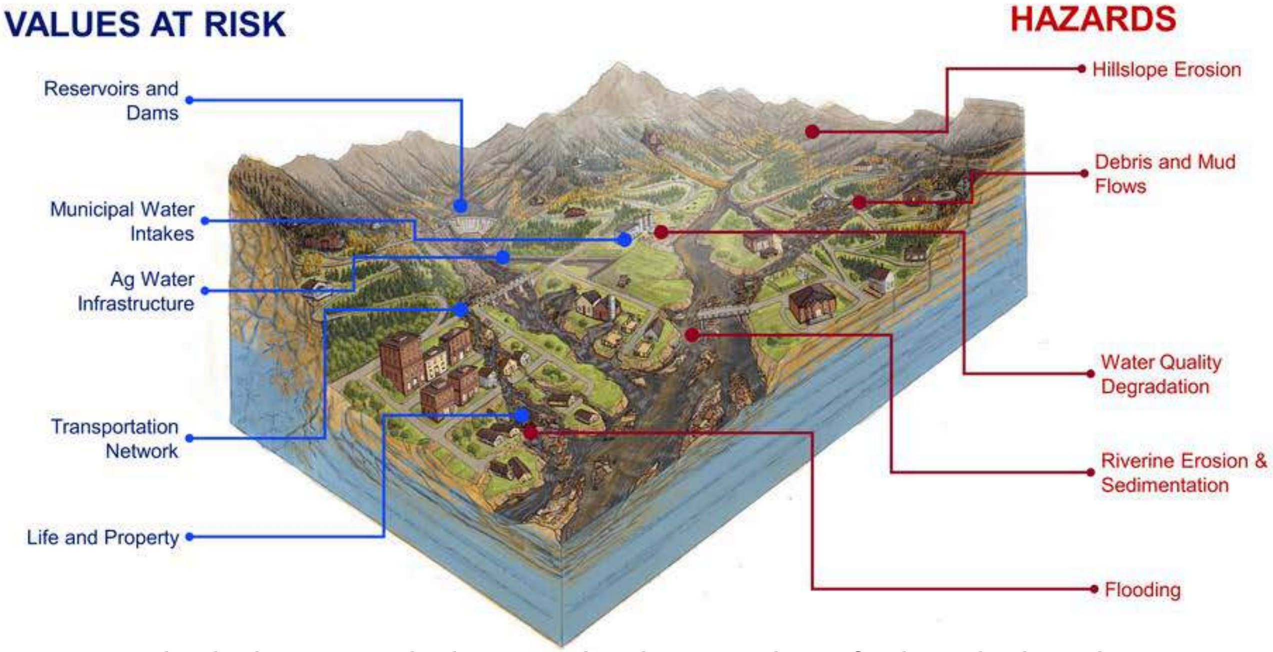


Figure 1. Graphic displaying typical values-at-risk and assocaited post-fire hazards. This is the foundation for performing a Wildfire Ready Action Plan (WRAP) under the WIldfire Ready Watersheds program. Credit: Maisie Richards. Graphic developed under CWCB WRW Program.

PROJECT OPTIONS TO CREATE MORE RESILIENT WATERSHEDS

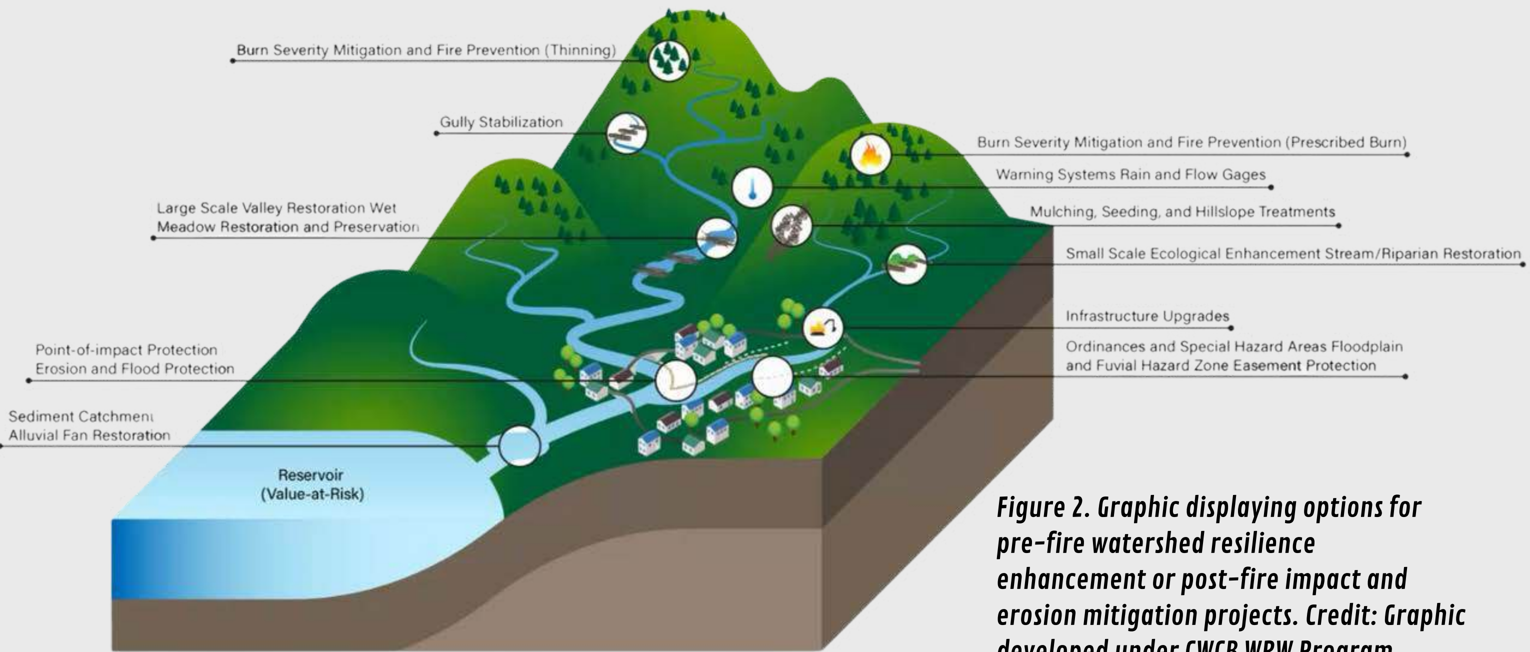


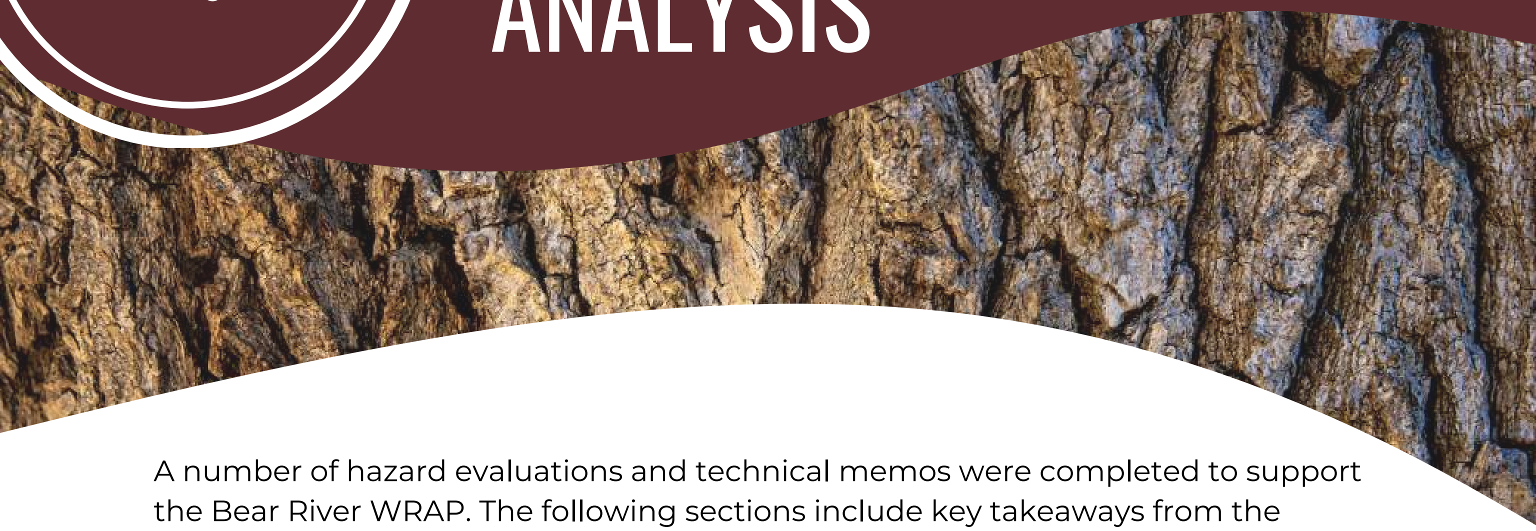
Figure 2. Graphic displaying options for pre-fire watershed resilience enhancement or post-fire impact and erosion mitigation projects. Credit: Graphic developed under CWCB WRW Program.

There are many ways to achieve resilient watershed conditions. Some suggested improvements are summarized in Table 1 below. Chapter 5 of this plan, *Pre-Fire Planning & Mitigation Activities*, describes more specific recommendations for the watersheds within the WRAP planning area in more detail.

Table 1. Management Actions to Improve Watershed Resilience

UPLANDS	IN-STREAM & RIPARIAN AREAS	DEVELOPMENT
• Encourage diversity of upland vegetation • Thin dense forest canopies • Create and maintain fuel breaks • Address beetle mortality • Treat and control non-native invasive plants species • Use prescribed fire as a primary or secondary treatment	• Remove conifers where they encroach in the floodplan • Encourage or plant native riparian vegetation, such as aspen, cottonwood, and willows • Treat and control non-native invasive plants species • Encourage or build in-stream structures, such as beaver dams and/or analogs or instream log dams, where such structures will not interrupt the continued use of existing water resource infrastructure	• Discourage or remove impervious or compacted surfaces • Build only necessary roads, decommission roads as possible • Improve stream/road and stream/trail crossings to be sized appropriately for post-fire peakflows, and allow for aquatic organism passage, where appropriate • Design and implement BMPs and an associated monitoring plan for storm-water runoff and erosion control • Encourage invasive weed prevention and eradication programs, especially along roads

4 POST-FIRE HAZARD AND SUSCEPTIBILITY ANALYSIS



A number of hazard evaluations and technical memos were completed to support the Bear River WRAP. The following sections include key takeaways from the individual assessments.

HAZARD EVALUATIONS COMPLETED:

1. Stream Conditions Assessment across the WRAP Project Area
    - Deliverable: Stream Conditions Assessment Technical Memorandum
2. Wildfire Modeling for the WRAP Project Area
3. Watershed/Wildfire Hazard Assessment on 7th Level Watersheds
    - Deliverable: Watershed Hazard Assessment Report
4. Pre- and Post-fire Hydrologic Modeling & Analysis
    - Deliverable: Hydrologic Analysis Technical Memorandum
5. Pre- and Post-fire Hydraulic Modeling & Analysis
    - Deliverable: Hydraulic Modeling & Analysis Technical Memorandum
6. Fluvial Hazard Zone Delineation & Analysis
    - Deliverable: Fluvial Hazard Zone Technical Memorandum
7. Post-fire Debris Flow Modeling & Analysis
    - Deliverable: Debris Flow Technical Memorandum
8. Post-Fire Susceptibility Analysis
    - Deliverable: Post-Fire Susceptibility Analysis Report & Mapping

4 A. Geologic & Hydrologic Context of the Project Area

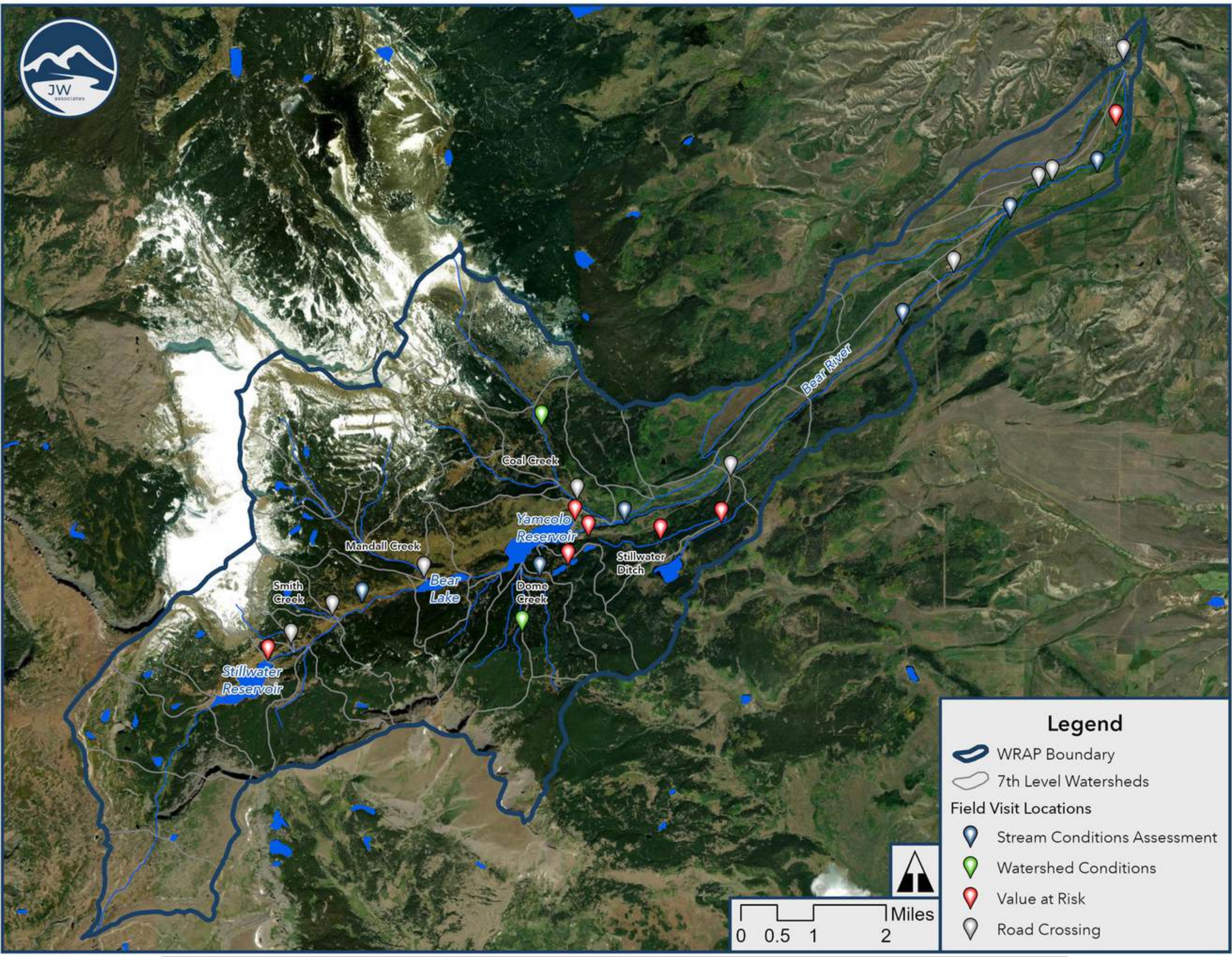
The Bear River has a 52 square mile basin and flows generally from southwest to northeast towards its confluence with Phillips Creek, where the two join to form the Yampa River. The basin is split between the Southern Rocky Mountains and Wyoming Basin physiographic provinces, and is located within the Level III Southern Rockies Ecoregion, which is further subdivided into four Level IV Ecoregions based on elevation. The zones include, from highest elevation to lowest: Alpine, Sedimentary Subalpine Forests, Sedimentary Mid-Elevation Forests, and the Foothill Shrublands.

The headwaters of Bear River are in the Routt National Forest starting in the Flat Tops Wilderness Area. As the river runs downstream it crosses into a Colorado roadless area. The lower portions of the watershed are primarily private agricultural lands. The watershed contains three reservoirs on the mainstem of the Bear River, from upstream to downstream: Stillwater, Bear Lake (Upper Stillwater), and Yamcolo.

Bear River has snowmelt driven hydrology, however that hydrology is modified by reservoir and agricultural operations. Bear River's floodplain flows through an alluvial valley, which has formed within a larger glacial valley. The valley is contained between glacial deposits, landslide deposits, the Mancos Shale formation, and historical Pleistocene terraces (Madole, 1991). Changes in confinement ratio generally increase gradually from upstream to downstream. This is important because rapid changes in confinement can lead to enhanced erosion or deposition. The Bear River mainstem below the confluence of Coal Creek is confined to partially-confined, while lower portions are unconfined.

4 B. Stream Conditions Assessment

A high-level stream conditions assessment was conducted as part of the Wildfire Ready Action Plan process. This assessment included a desktop effort, as well as a site visit to selected priority reaches within the Bear River Watershed. The goal of this assessment was to produce high-level documentation of existing watershed properties and physical conditions for specific stream reaches. More specific analyses of the Bear River system have been completed by others. The specific priority reaches selected for assessment were determined by the project team ahead of the site visit and included discrete locations along Bear River, as well as locations in Dome Creek, Smith Creek, and Mandall Creek (Map 2).



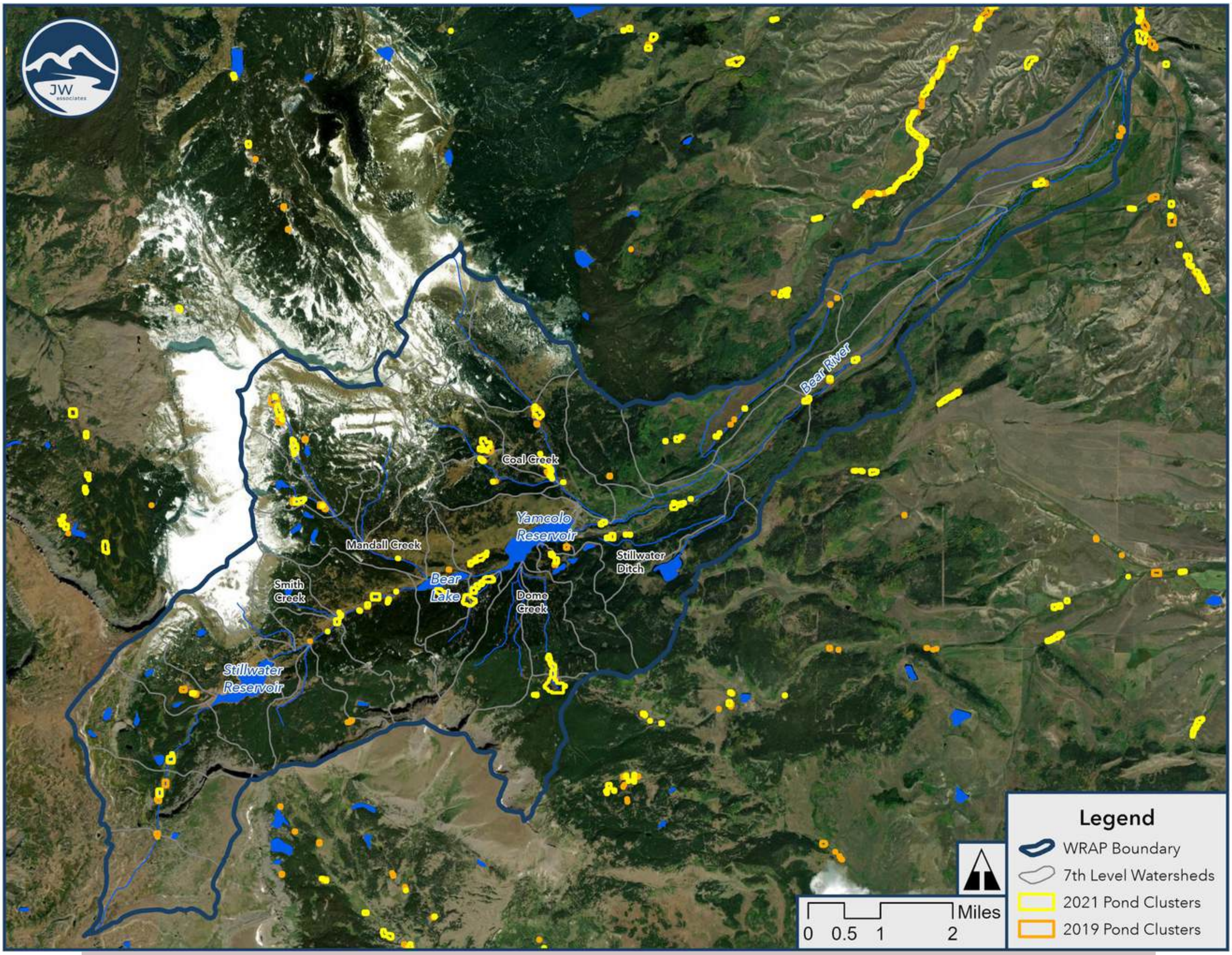
Map 2. Sites visited in the field, including those assessed for stream conditions

Bear River below the confluence with Coal Creek was selected as a priority reach due to the density of values at risk (including water and transportation infrastructure), and due to its proximity to the Town of Yampa. Dome Creek was selected because the contributing basin ranks highest for wildfire hazard due to dense contiguous spruce-fir stands, and its potential to contribute substantial amounts of sediment or debris flows into Yamcolo reservoir. Lastly, Mandall Creek and Smith Creek were selected because of their steep drainages that cross Forest Road 900, the major road in/out of the upper watershed. These locations all represent areas that may benefit from pre- and post-fire projects.

The assessment of Bear River was focused on the reach downstream of Yamcolo Reservoir, between the confluence of Coal Creek with Bear River and the town of Yampa. Bear River was also observed between Bear Lake (Upper Stillwater) and Stillwater reservoirs from Forest Road 900, while evaluating the Smith Creek and Mandall Creek tributaries. The Bear River corridor is heavily influenced by water and transportation infrastructure, including 14 road crossings and 25 diversion headgates between the Coal Creek confluence and the Town of Yampa. Downstream of the confluence with Coal Creek, Bear River is generally a sinuous, single-thread, channel, whose modern floodplain flows through an alluvial valley that formed within a larger glacial valley. The valley is contained between glacial deposits, landslide deposits, the Mancos Shale formation, and historical Pleistocene terraces (Madole, 1991). Bear River has an average reach slope of 2.2% and an approximate bankfull width of 20 feet between the confluence with Coal Creek and the Town of Yampa.

Areas observed during the site visit, and informed by a review of aerial imagery, were generally well connected to the floodplain, with a good riparian corridor (greater than or equal to two bankfull widths), with the exception of areas where land use impacts encroach upon the stream corridor. Based on the select assessment locations, Bear River appears to be a coarse-bedded stream with limited bedform diversity and limited in-stream large wood. These observations may be confirmed by detailed stream assessment completed by others. Between Bear Lake (Upper Stillwater) and Stillwater Reservoirs, the channel is also predominately single thread, although multiple flow paths are present within the existing beaver dam complexes. While there are some beaver complexes present, the density of these complexes may be lower than pre-European settlement, as the practice of commercial beaver trapping starkly reduced beaver populations throughout the Rocky Mountains and North America (Wohl, 2021). An increased density of these beaver complexes would likely further increase in-stream complexity (e.g., areas with multiple flow paths, healthier riparian corridor, large wood jams). Furthermore, the Colorado Beaver Activity Mapper (COBAM, 2023), hosted by the Colorado Natural Heritage Program, indicates a potential beaver dam density of over 3 dams per kilometer between Bear Lake and Stillwater Reservoir, which would amount to 11 total dams (currently, aerial imagery shows there are only 4 dams in this area).

Currently, the upper watershed sub-basins of the Bear River Watershed include many active or formerly active beaver meadows. Actively maintained beaver ponds have been catalogued statewide by the Colorado Natural Heritage Program (CNHP; COBAM, 2023) via remote sensing and can be seen in Map 3. As mentioned in Section 3A, beaver meadows provide extensive benefits to the surrounding watershed, slowing the flow of water and sediment and effectively serving as sponges during high flow events, ultimately enhancing watershed resiliency. Beaver meadows also provide fire breaks between hillslopes. Despite these ecological benefits, beaver activity can interfere with the proper functioning of road crossings and agricultural diversions, which has likely led to their removal from the lowest portions of Bear River.



Map 3. Yellow and orange polygons showing beaver ponds within Bear River Watershed mapped by CNHP remote sensing programs (COBAM, 2023).

Dome Creek, a tributary to Bear River flowing in from the south, with a contributing area of 2,641 acres (4.1 square miles), was identified as a priority watershed as it has a potential to deliver high sediment loads into Yamcolo reservoir. Aerial imagery reveals that there are several beaver dams within the reach, although CNHP mapping does not identify any beaver ponds in the Dome Creek priority reach (COBAM, 2023). The on-the-ground site visit confirmed approximately 8 to 10 beaver dams, as well as a lodge. Riparian vegetation, such as willow, is limited, especially on the northern side of the meadow. The reach average slope of the Dome Creek priority reach is approximately 1.4%, and bankfull width is approximately 6-8 feet wide, where undammed, which falls within the range to sustain beaver dams.

Beaver lodge present in Dome Creek but large vegetation is limited. Wildfire hazard is high in this watershed due to the dense Spruce fir which is visible on the hillslope. Photo: JW Associates, August 2024

Smith Creek and Mandall Creek are two steep tributaries that enter Bear River on the north side of the watershed, with contributing areas of 381 acres (0.6 square miles) and 3,998 acres (6.3 square miles), slopes of approximately 24% and 9%, and widths of approximately 6 feet and 8 feet, respectively (within the priority reaches). During high flow events, these steep tributaries have the potential to transport large quantities of sediment and debris, especially in a post-fire scenario. The culverts that allow these creeks to cross Forest Road 900 are both undersized, risking blockage by debris, overflow, and/or potential road damage during high flow events. The CNHP mapping identifies beaver ponds higher in the Mandall Creek sub-basin. Additionally, both Smith Creek and Mandall Creek have reaches identified by the Colorado Beaver Restoration Assessment Tool (BRAT; COBAM, 2023) as having the potential to sustain beaver dams (upstream of the Forest Road 900 crossing).

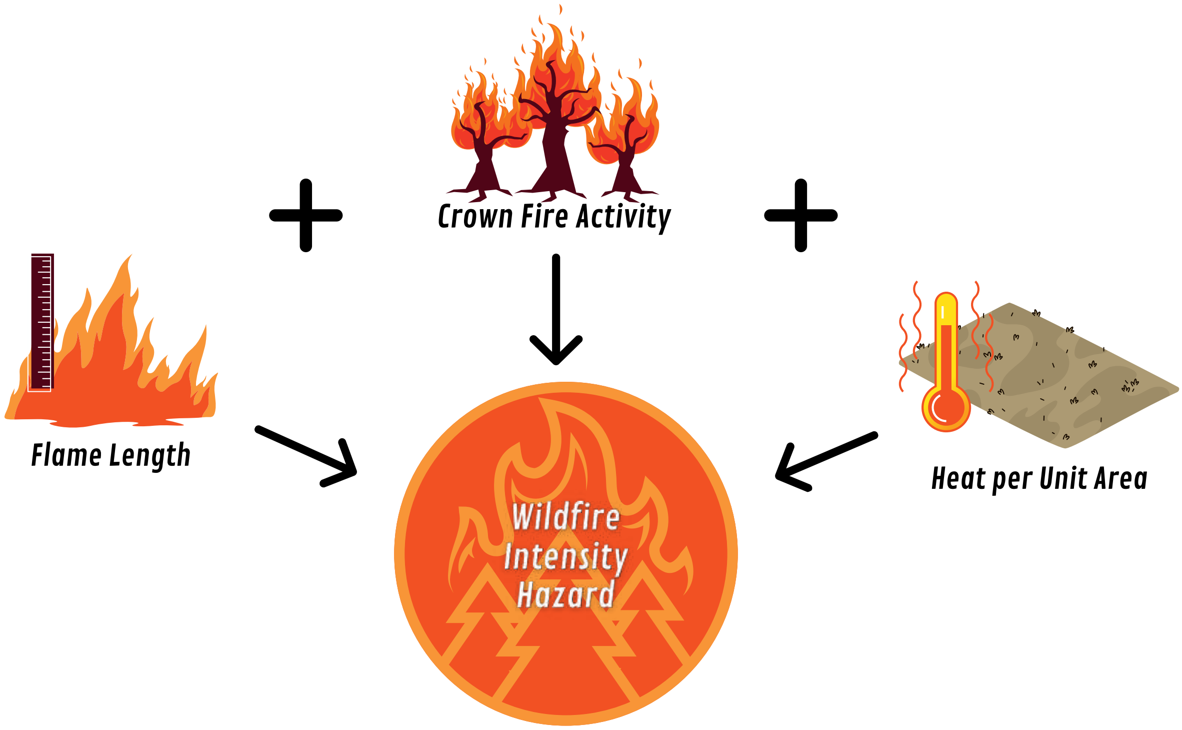
Smith Creek, below Forest Road 900 stream crossing, above confluence with Bear River. Photo: JW Associates, July 2024

Mandall Creek, below Forest Road 900 stream crossing, inflows directly into Bear Lake. Photo: JW Associates, July 2024

4 C. Wildfire Modeling

The wildfire intensity hazard analysis for this project used the Interagency Fuel Treatment Decision Support System (IFTDSS), an online implementation of the FlamMap fire mapping and analysis system (Finney 2006, Stratton 2006). The FlamMap analysis describes potential fire behavior for constant environmental conditions (weather and fuel moisture). FlamMap outputs and comparisons can be used to identify combinations of hazardous fuel and topography, aiding in prioritizing fuel treatments. FlamMap is widely used by the U.S. Forest Service, National Park Service, and other federal and state land management agencies in support of fire management activities. It should be noted that FlamMap does not calculate fire spread across a landscape.

LANDFIRE (2022) is the source for the basic data used in the wildfire modeling, including data for vegetation and topography. LANDFIRE covers all ownerships and is updated frequently, which are significant benefits of this data set. At the time of analysis, the latest update for LANDFIRE data was released in May 2023, and includes data collected through 2022.



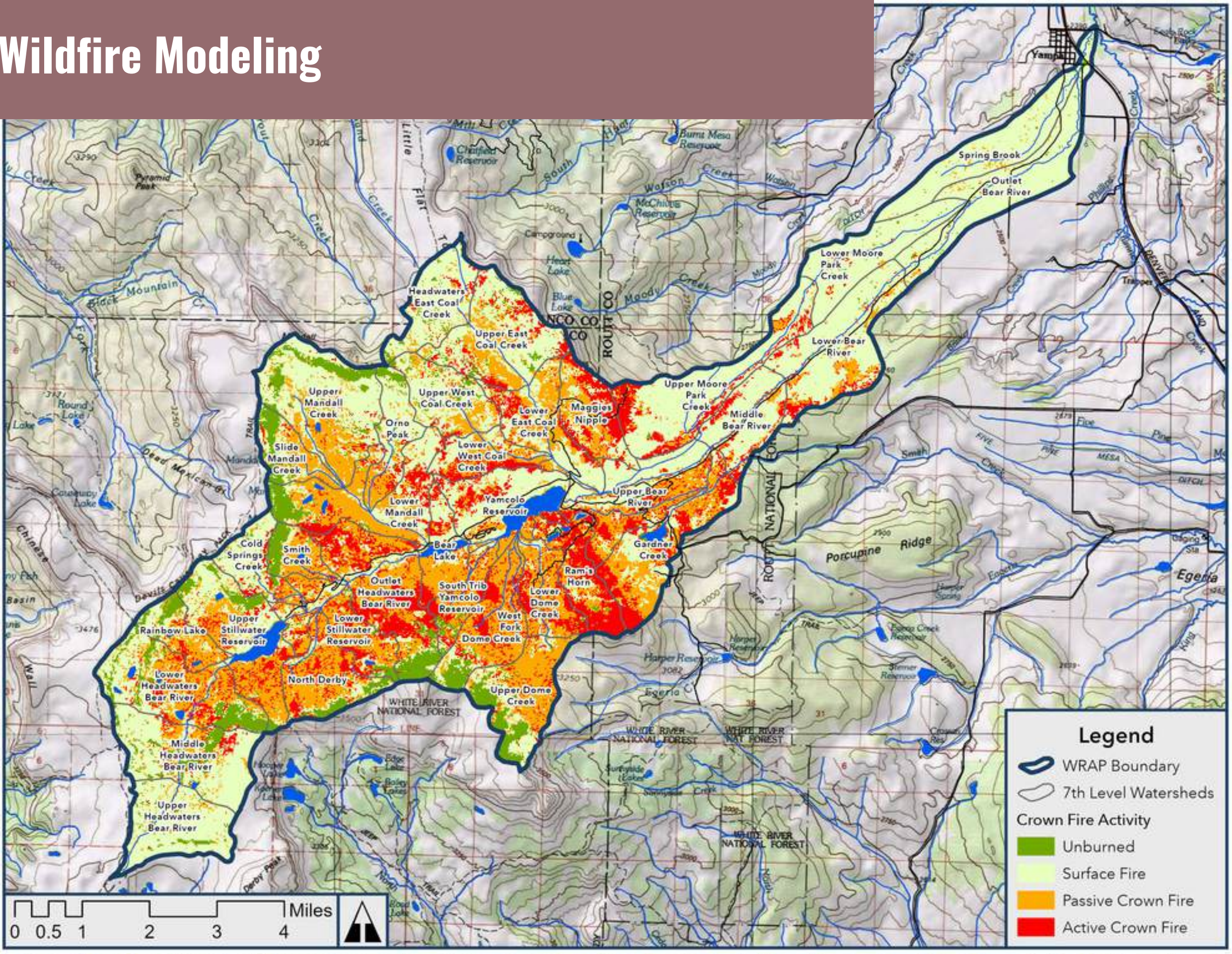
The fire behavior model outputs of Crown Fire Activity, Flame Length, and Heat per Unit Area were selected as the basis for the wildfire intensity hazard analysis. These factors were determined to be the most appropriate components for the analysis in the assessment area. The combination of these three output variables helps to identify the locations where wildfire will burn with both high intensity and high severity. Fire intensity is a measure of the heat output from the flames during burning, while fire severity is a measure of the overall impact the burn actually has on the ground conditions at the site, including post-fire soil conditions, erosion, and revegetation.

A number of recent wildfires in Colorado have involved areas with beetle-killed lodgepole pine, mixed conifer, and spruce-fir. It was found that the current FlamMap modeling does not adequately capture the extreme fire behavior observed in these areas. Therefore, some of the fuel modeling results in areas of beetle-killed spruce-fir and mixed conifer were adjusted to more accurately represent potential fire behavior in those stands. For more details on the wildfire modeling assumptions and inputs, see Appendix B of the Watershed Hazard Assessment, in the *Task 3 - Post-Fire Hazard Analysis* Deliverables.

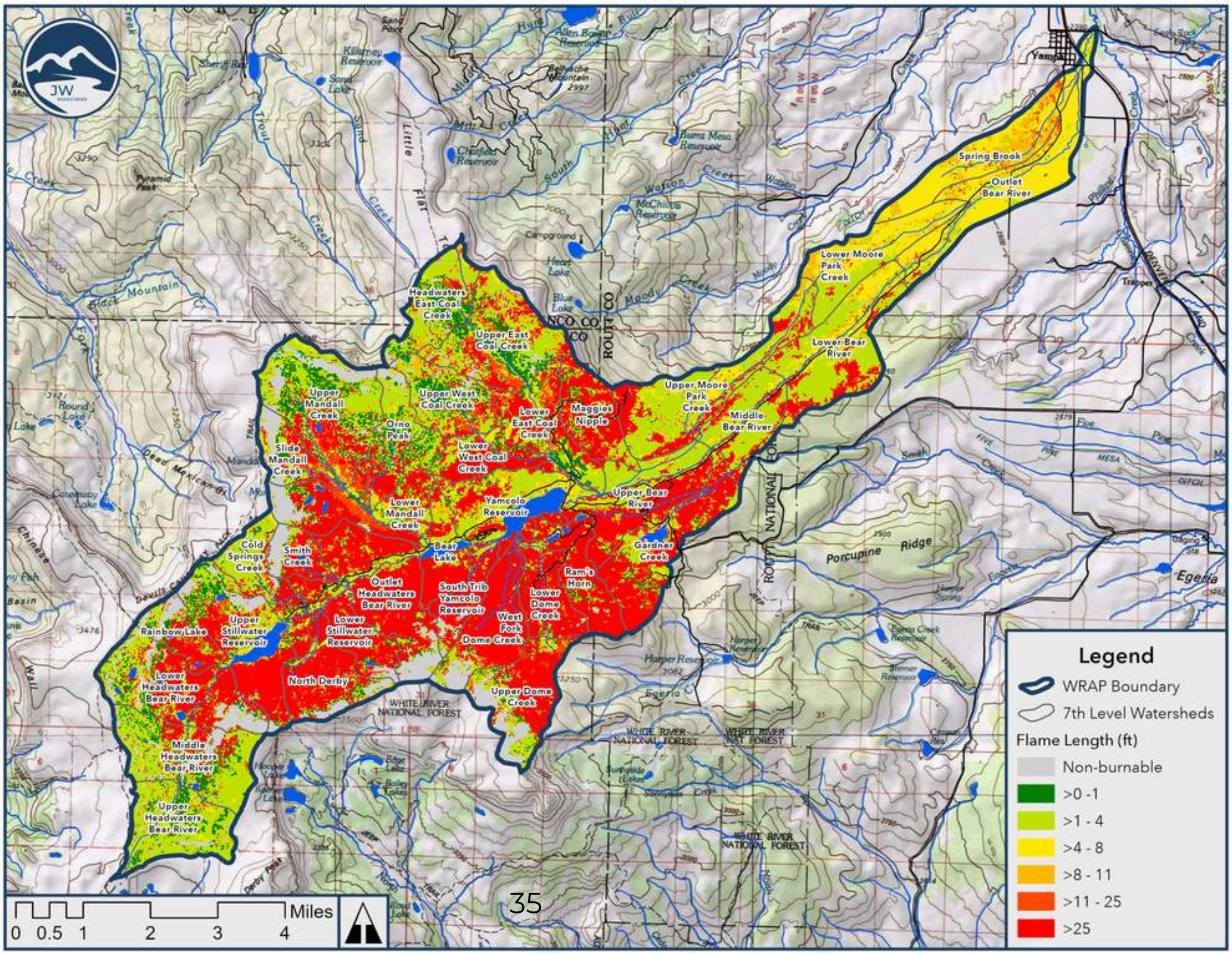
Maps 4, 5, and 6 show the results of the FlamMap modeling for Crown Fire Activity, Flame Length, and Heat per Unit Area.

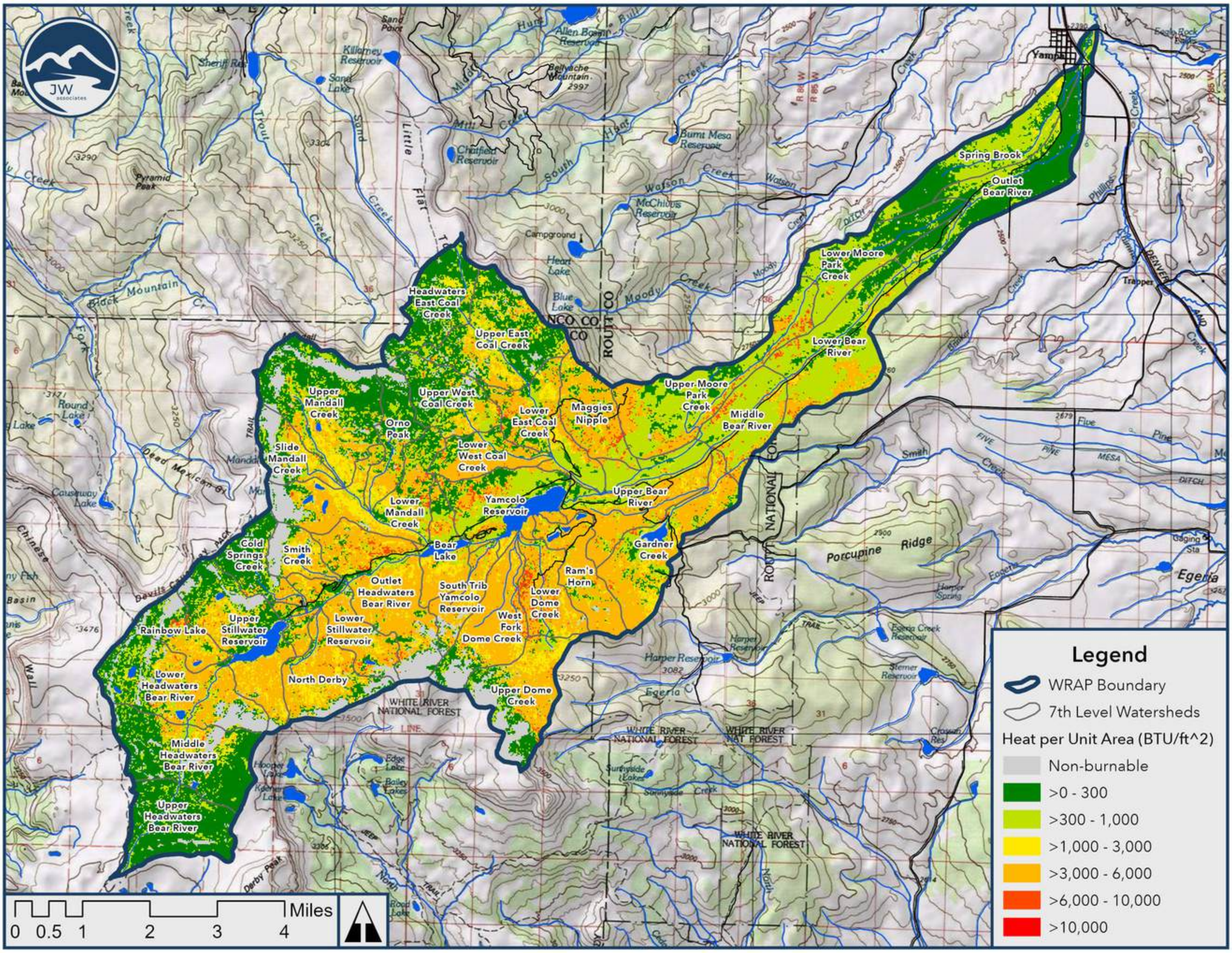
4 C. Wildfire Modeling

Map 4. Wildfire Modeling – Crown Fire Activity



Map 5. Wildfire Modeling – Flame Length





Map 6. Wildfire Modeling – Heat per Unit Area

4 D. Watershed/Wildfire Hazard Assessment

The 7th level (or HUC14) watersheds were delineated and analyzed with the goal of identifying hazards that may be targets of pre-fire or post-fire actions or other watershed protection measures. These watersheds were then grouped into roughly equal, ranked categories based upon the hazard components in the diagram to the right. Map 7 shows the results of this comparative assessment of relative hazard between the 7th level watersheds. For more detailed information, see the Watershed Hazard Assessment, in the *Task 3 - Post-Fire Hazard Analysis* Deliverables.

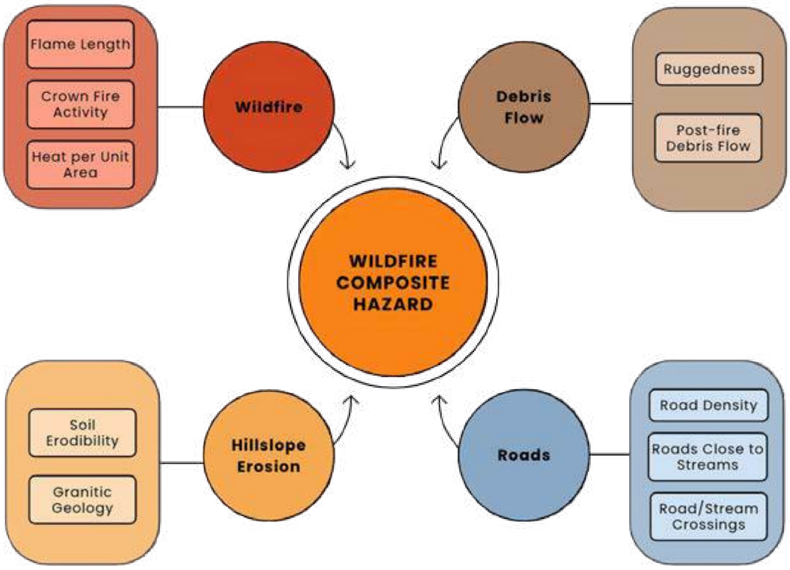
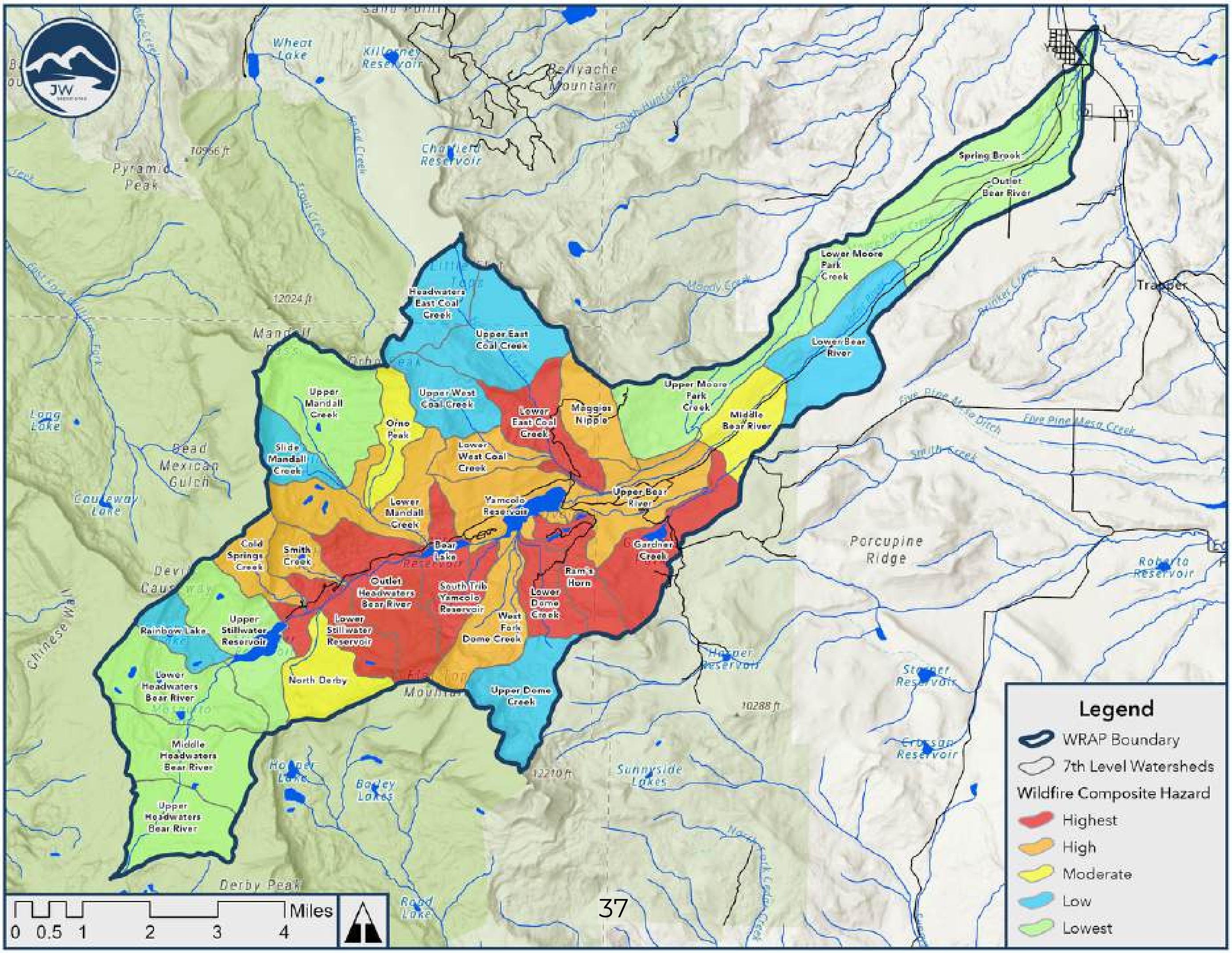


Figure 3. Wildfire Composite Hazard Components

Map 7. Wildfire Composite Hazard Ranking



The stress on ecosystems due to a changing climate is triggering a transformation of ecosystems at regional and local scales with varying speed and magnitude. Comer et al. (2019) has designed a framework to help identify which communities are at highest risk of climate change impacts and to provide a warning of future hazards. Components of this framework (at right) were used to comparatively assess potential climate change vulnerability between the 7th level watersheds. Map 8 shows the results of the analysis. For more detailed information, see the Watershed Hazard Assessment, in the *Task 3 - Post-Fire Hazard Analysis* Deliverables.

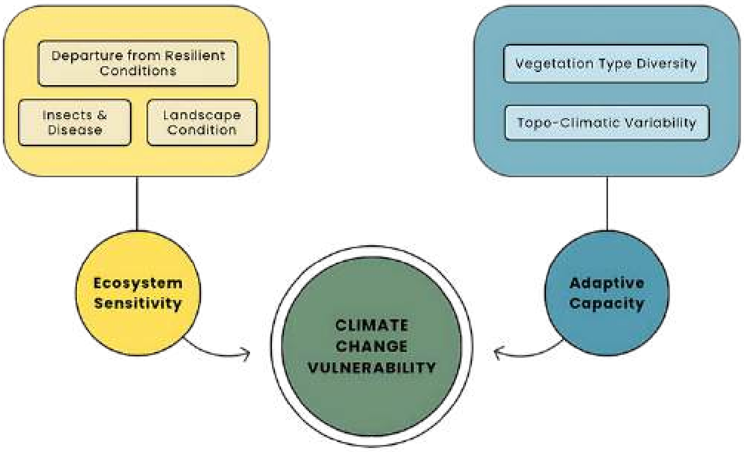
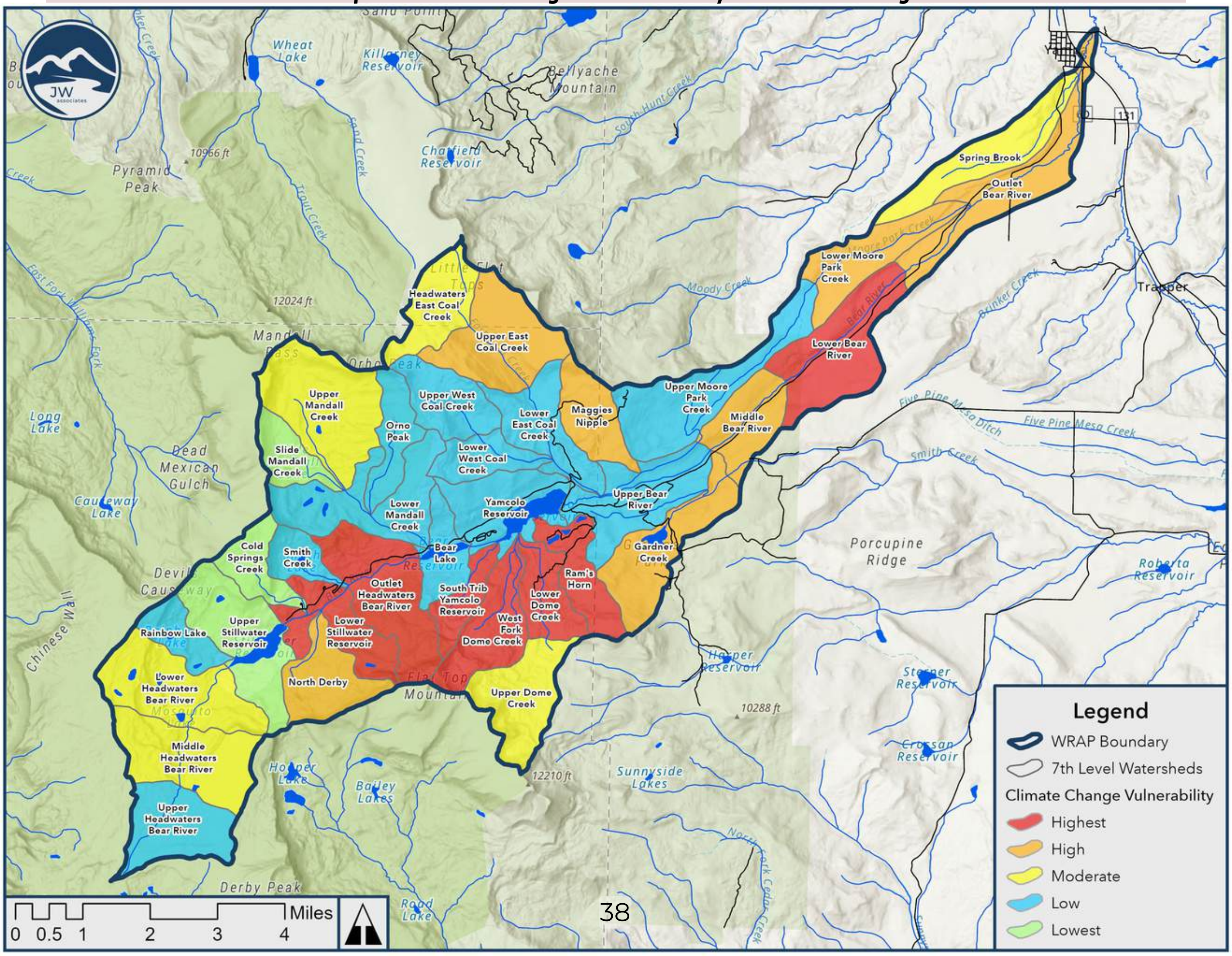


Figure 4. Climate Change Vulnerability Hazard Components

Map 8. Climate Change Vulnerability Hazard Ranking



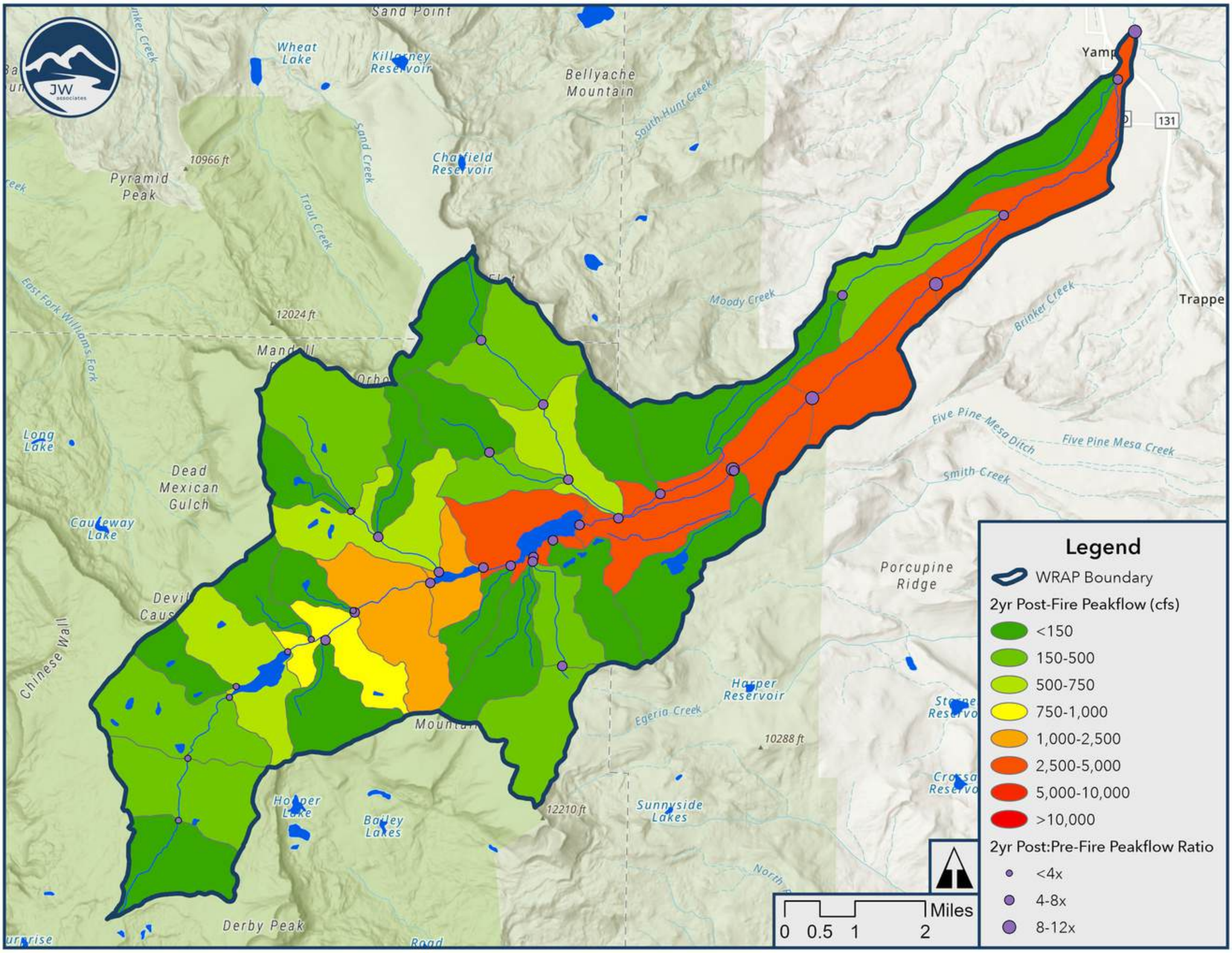
4 E. Pre- and Post-Fire Hydrologic Modeling & Analysis

The United States Geological Survey (USGS) created a method for estimating the post-fire peak discharge for watersheds before wildfire occurs (Moody, 2012). Using this analytical method, peak discharges are predicted for post-wildfire events using variables that can be modeled before the fire occurs. For this analysis, the USGS Level 2 method (Moody, 2012) was used which includes the predictor variables of rainfall intensity and difference normalized burn ratio.

The model was run for a triggering rainfall event intensity of: 2-year, 5-year, 25-year, 50-year, and 100-year storms across the analysis area. Peak discharges from rain events were calculated for watersheds that were delineated using pour point locations from each 7th level watershed. However, unlike the 7th level watershed analysis which separates each watershed as an individual unit, these watersheds include the entire watershed area above the pour point. In this way, the watersheds rainfall-runoff behavior builds on each other, starting with the uppermost watershed and working downstream.

For details on this methodology, reference the Hydrologic Analysis Technical Memorandum, in the *Task 3 - Post-Fire Hazard Analysis* Deliverables. The key results for the hydrologic model and analysis across the WRAP project area follow.

KEY RESULTS

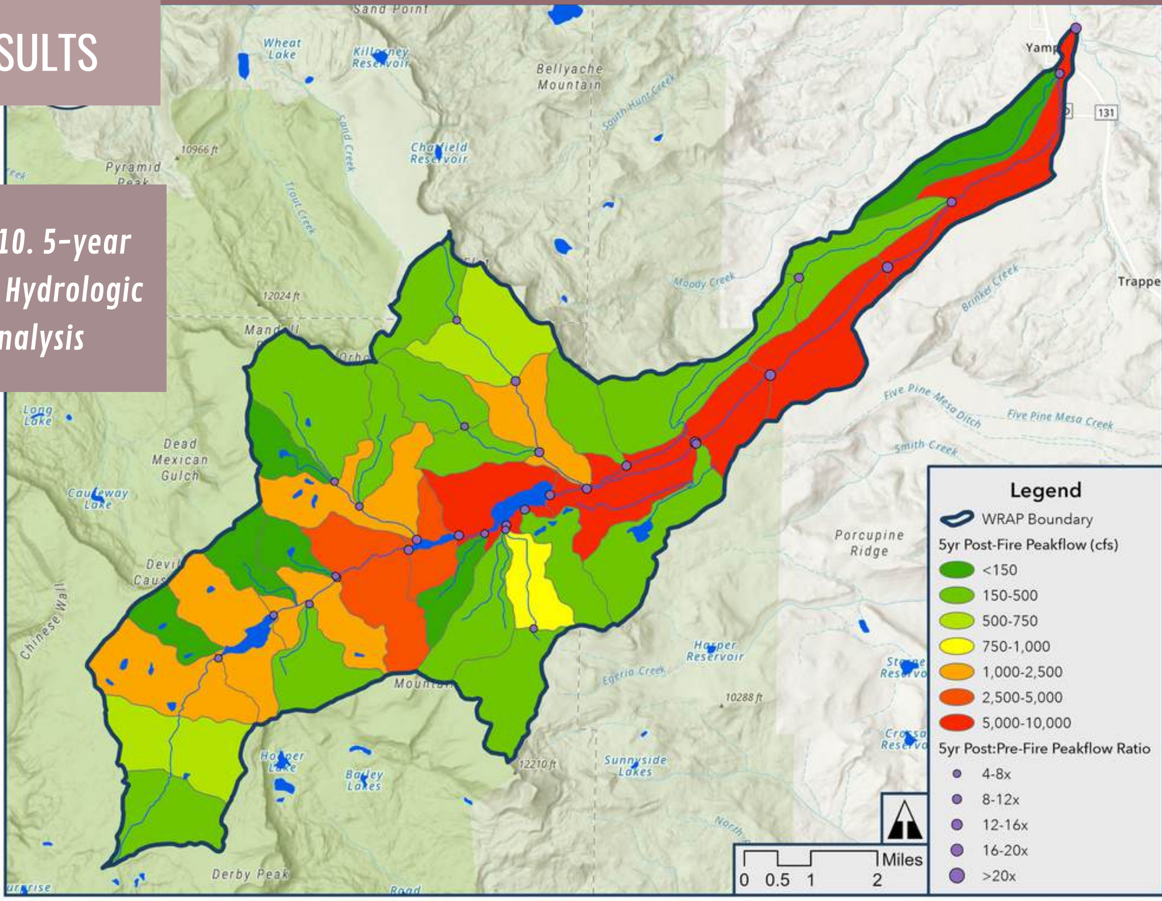


Map 9. 2-year Storm Hydrologic Analysis

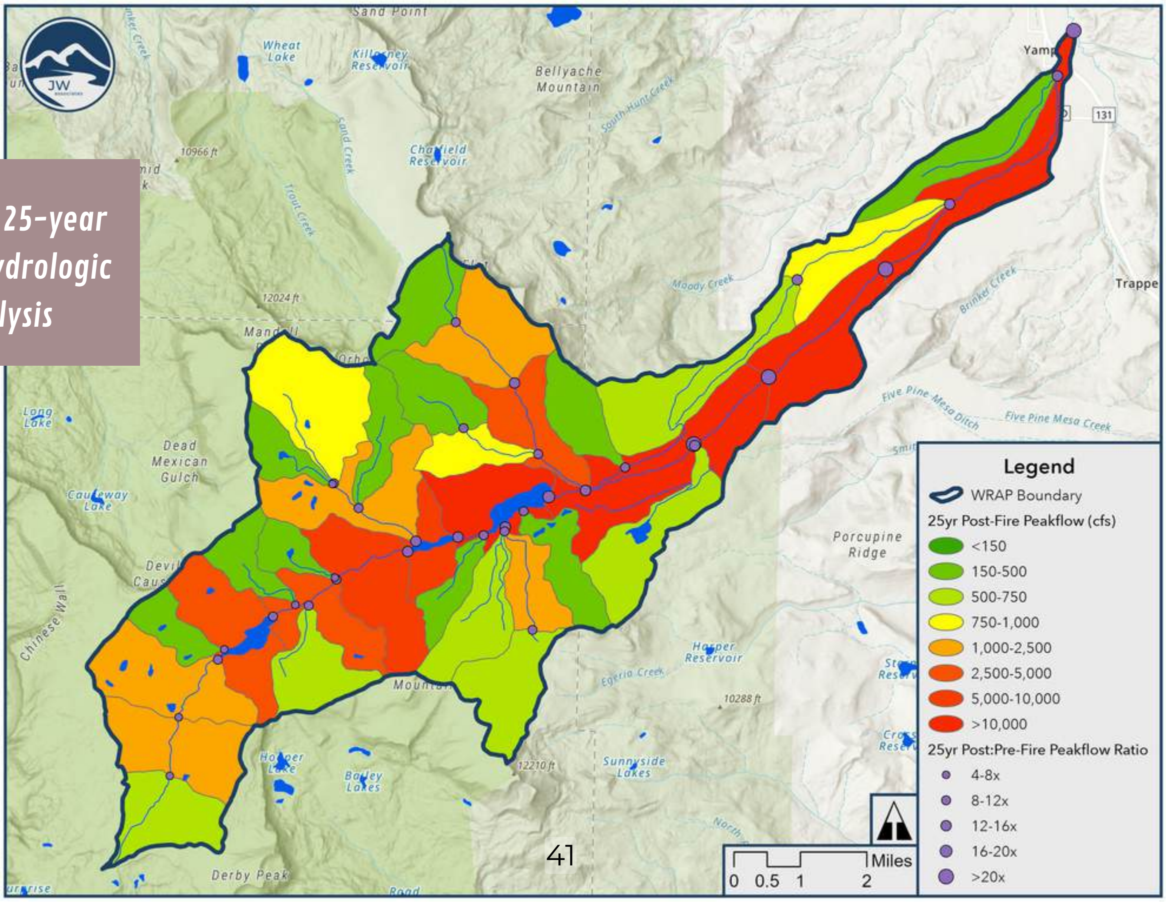
Post:Pre-Fire Peakflow Ratio:
In order to synthesize the pre- and post-fire peakflow data into comparable values across watersheds, the difference between the pre-fire peakflow and the post-fire peakflow for each design storm and watershed were calculated as a ratio, indicating the runoff multiplier to expect from a post-fire storm, relative to the same rainfall pre-fire.

KEY RESULTS

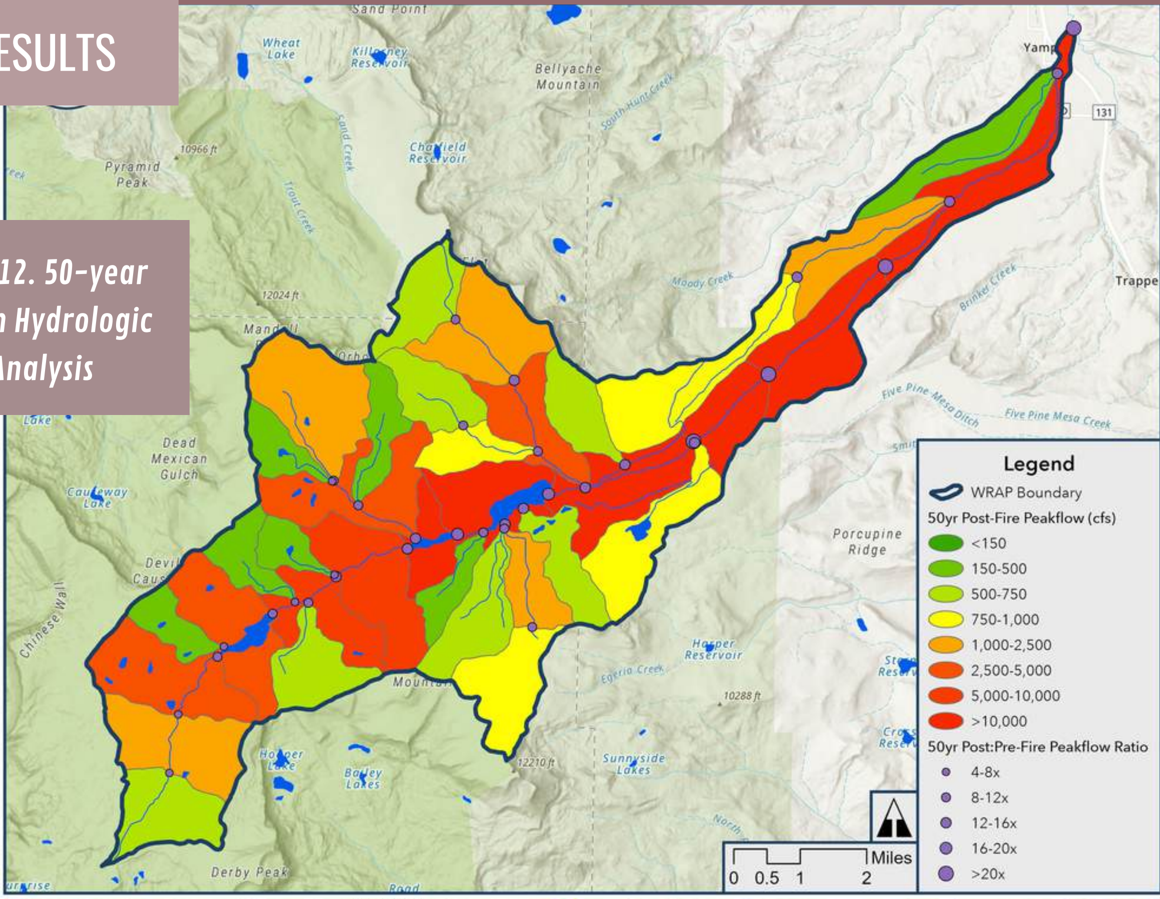
Map 10. 5-year Storm Hydrologic Analysis



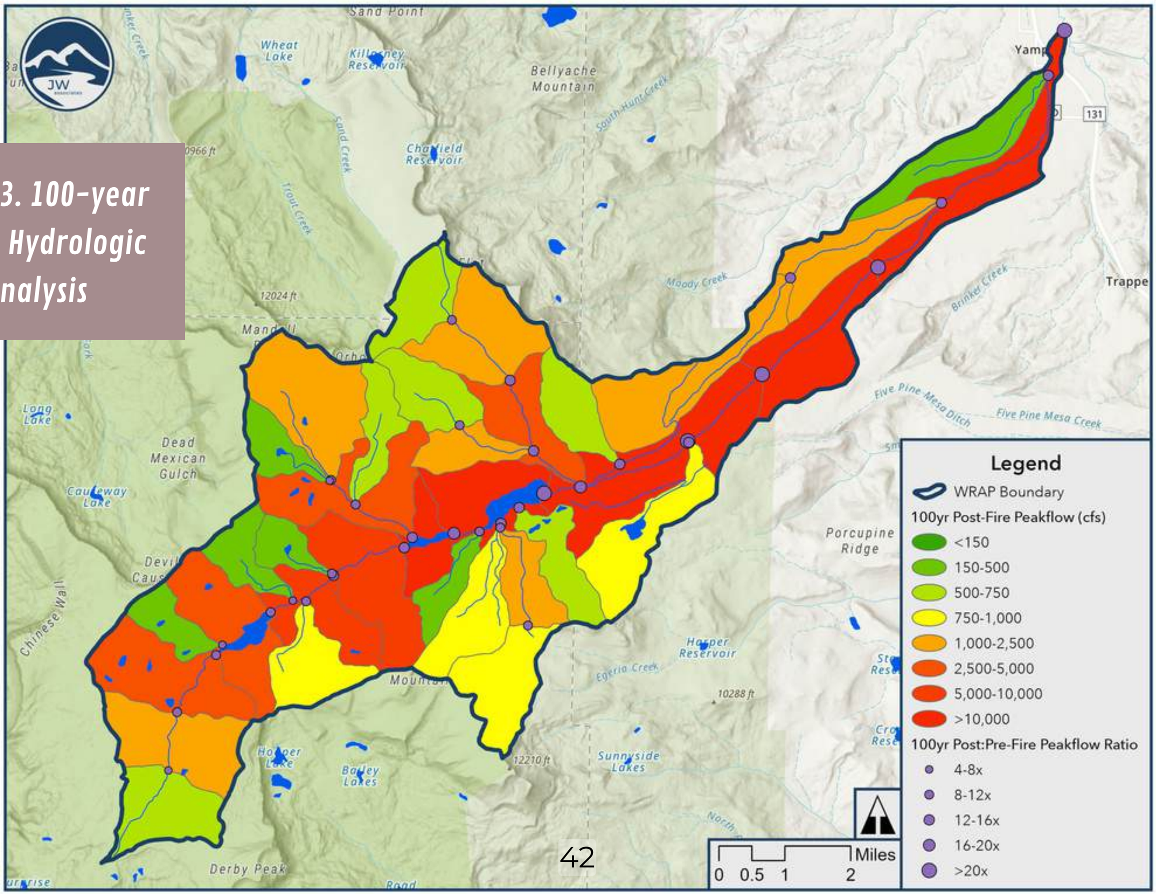
Map 11. 25-year Storm Hydrologic Analysis



KEY RESULTS



Map 12. 50-year Storm Hydrologic Analysis



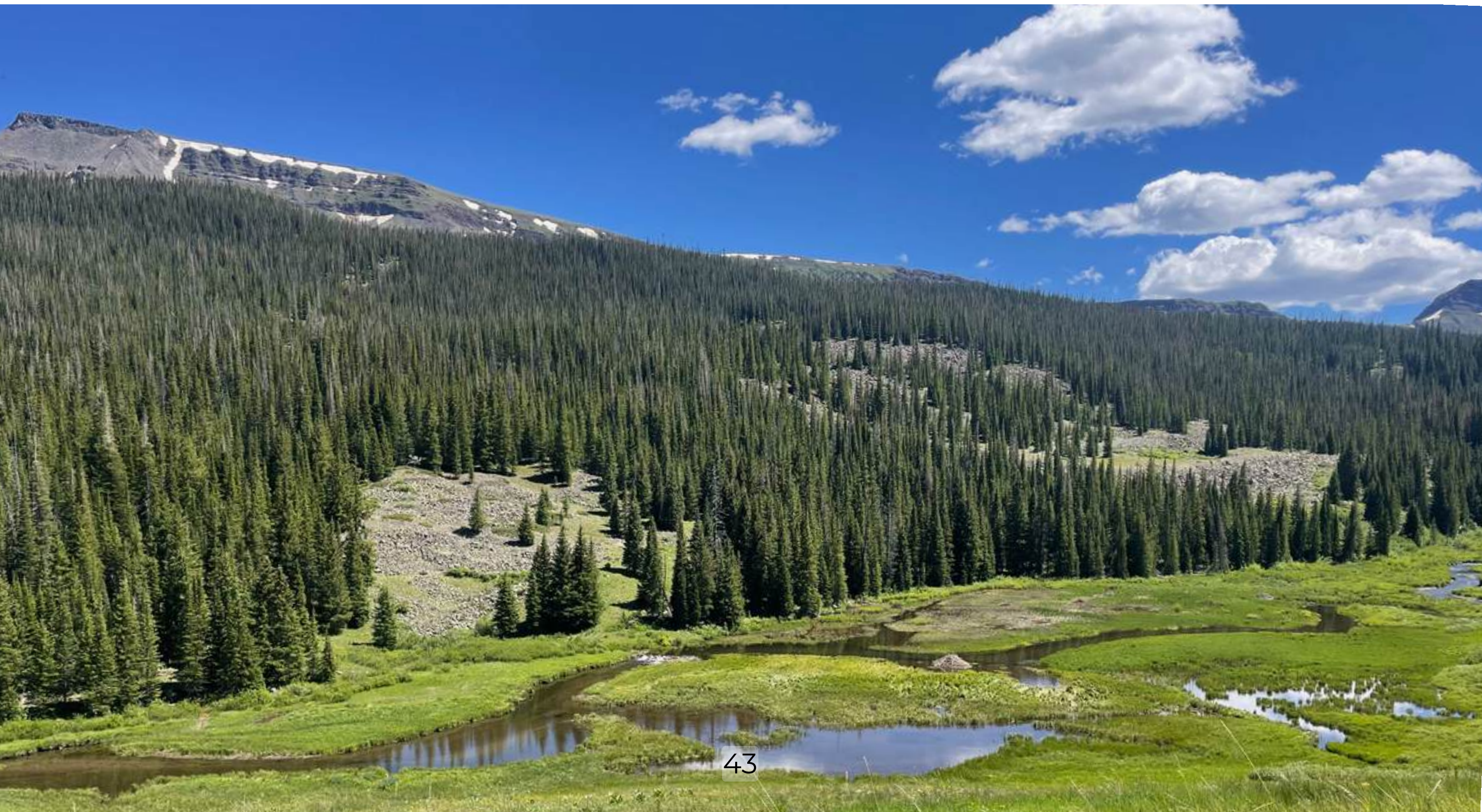
Map 13. 100-year Storm Hydrologic Analysis

4 F. Pre- and Post-Fire Hydraulic Modeling & Analysis

As part of the Bear River Wildfire Ready Action Plan (WRAP), a two-dimensional (2D) hydraulic analysis was completed to evaluate the impacts of post-fire hydrology in the Bear River corridor. This information will help inform mitigation strategies to protect infrastructure in the Bear River Watershed by identifying the potential for increased flooding risks and erosion under post-fire conditions.

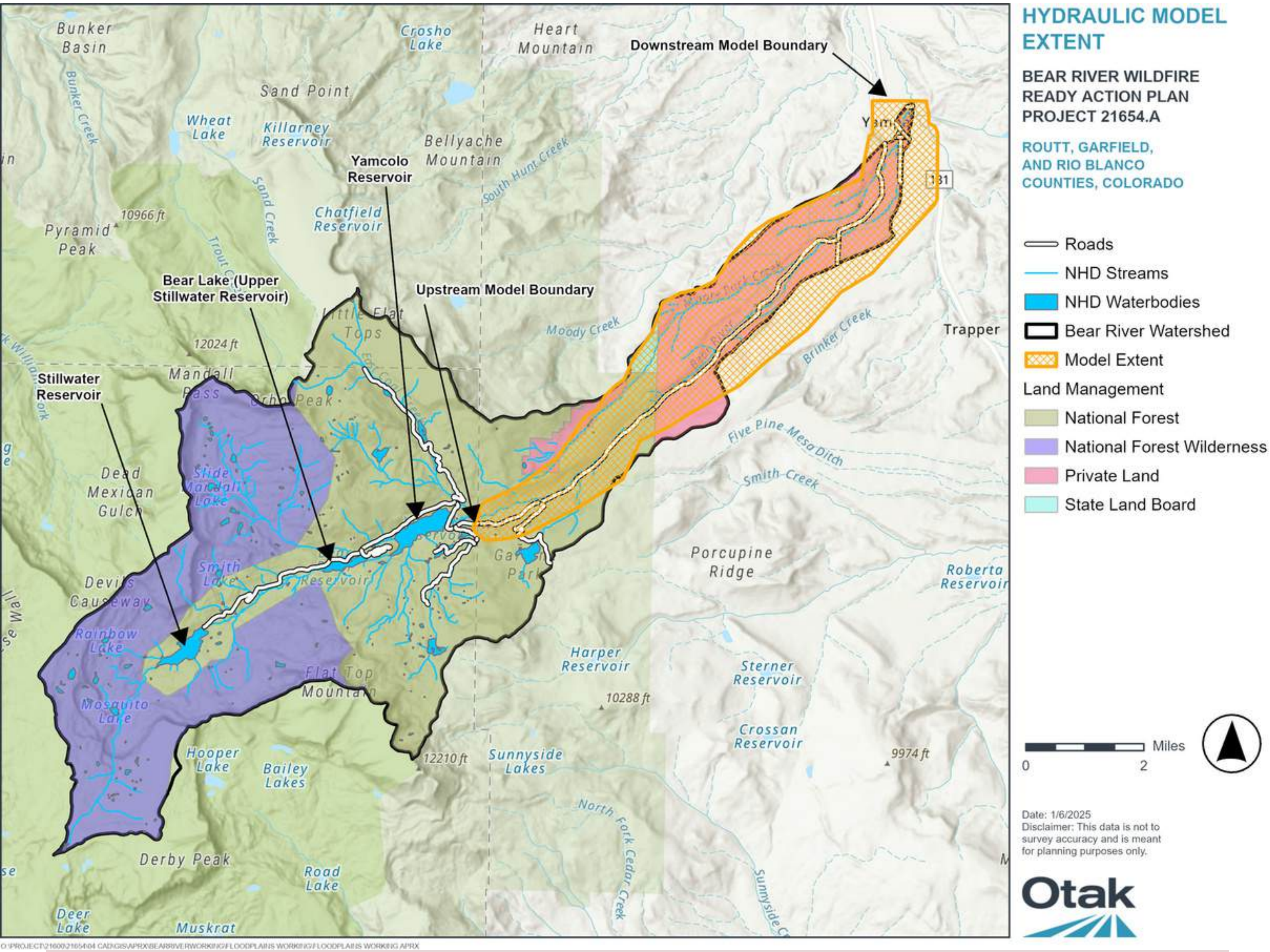
Hydraulic modeling was carried out using the US Army Corps of Engineers – Hydraulic Engineering Center's River Analysis System (HEC-RAS) version 6.3.1. A continuous existing conditions surface was created using LiDAR data from the Colorado Water Conservation Board (CWCB) Colorado Hazard Mapping & Risk Map Portal. This data originated from Routt County (Merrick & Co. 2016a), Garfield County (Merrick & Co. 2016b), and the Northwest Colorado Council of Governments (Sanborn Map Company, Inc., 2020). ArcGIS tools were used to combine these LiDAR surfaces into a single continuous surface covering the Bear River Watershed from the top of the basin downstream to the Town of Yampa. The hydraulic modeling analysis provided results for the upper sub-reach, middle sub-reach and lower sub-reach of the Bear River project area, for 2-, 5-, and 100-year post-fire storms, as well as the 100-year pre-fire event.

For details on this methodology, reference the Hydraulic Analysis Technical Memorandum, in the *Task 3 - Post-Fire Hazard Analysis* Deliverables. The key results for the hydraulic analysis across the WRAP project area follow.



MODELING EXTENT

The hydraulic model upstream boundary is just downstream of Yamcolo Reservoir at the confluence of the Bear River and Coal Creek; the hydraulic model downstream boundary extends just beyond Routt County Road 17, upstream of the confluence with Phillips Creek. The model domain and boundary locations are displayed in Map 14.



Map 14. Hydraulic Modeling Extent

KEY RESULTS

The upper sub-reach of the Bear River, extending from the upstream boundary at the confluence of Coal Creek and Bear River to just east of the US Forest Service Boundary, is largely confined by glacial and landslide deposits, with limited floodplain connectivity and minimal evidence of historic alluvial terraces. This sub-reach is very confined and steeper than the lower sub-reaches. The creek is largely contained in a narrow valley, which causes deep fast flows. The greatest opportunities for mitigating post-fire impacts in this upper sub-reach likely exist within the upper portions of the watershed, on lower order streams, rather than within the modeled portion of Bear River itself. The deep, fast flows through this confined sub-reach make many solutions, such as low-tech, process-based restoration (LTPBR), challenging to implement. Alternatively, LTPBR solutions could be implemented higher in the catchment to decrease the amount of sediment and debris being transported to the main channel. Other potential pre-disaster actions could include increasing the resiliency of the infrastructure within the corridor, such as increasing the capacity of bridges and upgrading diversion facilities with more robust infrastructure (e.g., gates, trash racks, and reinforced concrete).

The middle sub-reach extends from just east of the US Forest Service Boundary to the Town of Yampa Water Treatment Facility (WTF). This sub-reach is characterized by a slowly increasing floodplain width, contained by historic (Upper Pleistocene) gravel-bearing terraces. This sub-reach shows the floodplain gradually expanding along with the confining terraces. Unlike the upper sub-reach, the middle sub-reach has extensive floodplain connectivity, providing opportunities for flood attenuation and sediment storage during larger post-fire flood scenarios.

KEY RESULTS

Areas outside of the current pre-fire 100-year floodplain, and that experience shallow flooding during larger post-fire events, offer potential locations for regional mitigation efforts. These efforts could include increasing floodplain connectivity by strategic lowering of the terraces. Increasing floodplain connectivity would provide additional flood wave attenuation and sediment storage. The focus of mitigation efforts in this sub-reach should be on increasing floodplain connectivity and increasing the resiliency of the infrastructure, such as upgrading diversion facilities and increasing bridge capacities.

The third sub-reach extends from the Town of Yampa WTF to the downstream model boundary at Routt County Road 17. This sub-reach is similar to the middle sub-reach but less confined by the Pleistocene terraces; the floodplain continues to expand with higher floodplain flows moving east, out of the Bear River Watershed and into the Phillips Creek drainage. This sub-reach includes the Town of Yampa and ends just upstream of the confluence of Bear River and Phillips Creek, which form the Yampa River at their confluence. Like the middle sub-reach, this lower sub-reach has extensive floodplain connectivity, providing opportunities for flood attenuation and sediment storage during larger post-fire flood scenarios. Although this reach is lower in the watershed, which limits the benefits of mitigation for much of Bear River, mitigation could benefit the Town of Yampa and the Yampa River downstream of the confluence. The focus of mitigation efforts within this reach should be on increasing the resiliency of infrastructure, enhancing floodplain connectivity and storage, as well as protecting the Town of Yampa.

KEY RESULTS

Variable	100-year pre-fire	100-year post-fire	2-year post-fire	5-year post-fire
Max Depth (ft)	5	23	9	14
Avg Depth (ft)	2	7	3	4
Max Velocity (ft/sec)	13	25	16	19
Avg Velocity (ft/sec)	5	11	7	8
Max Shear (psf)	12	56	17	23
Avg Shear (psf)	2	10	4	6

Table 2. Upper Sub-reach Hydraulic Results

Variable	100-year pre-fire	100-year post-fire	2-year post-fire	5-year post-fire
Max Depth (ft)	8	15	9	11
Avg Depth (ft)	1	3	2	2
Max Velocity (ft/sec)	11	20	15	18
Avg Velocity (ft/sec)	3	6	4	5
Max Shear (psf)	10	31	19	33
Avg Shear (psf)	1	4	2	3

Table 3. Middle Sub-reach Hydraulic Results

Variable	100-year pre-fire	100-year post-fire	2-year post-fire	5-year post-fire
Max Depth (ft)	7	11	8	10
Avg Depth (ft)	1	2	1	1
Max Velocity (ft/sec)	10	16	12	12
Avg Velocity (ft/sec)	2	4	3	4
Max Shear (psf)	3	11	6	7
Avg Shear (psf)	1	2	1	2

Table 4. Lower Sub-reach Hydraulic Results

4 G. Fluvial Hazard Zone Delineation & Analysis

As part of the Bear River Wildfire Ready Action Plan (WRAP), Otak developed a Fluvial Hazard Zone (FHZ) Analysis utilizing the Colorado Water Conservation Board (CWCB) Colorado FHZ Delineation protocol (FHZ Protocol; Blazewicz et al., 2020). The intent of the FHZ mapping is to provide stakeholders and landowners with information and increased awareness of fluvial hazards beyond Federal Emergency Management Agency (FEMA) regulatory flood hazard maps. FHZ mapping incorporates fluvial hazards related to high flows, erosion of channel bed and banks, deposition of sediment and large wood, potential avulsions or realignment of channels, fan and tributary processes, and potential failure and retreat of adjacent hillslopes. This mapping will contribute to the WRAP by determining extent of possible fluvial hazards.

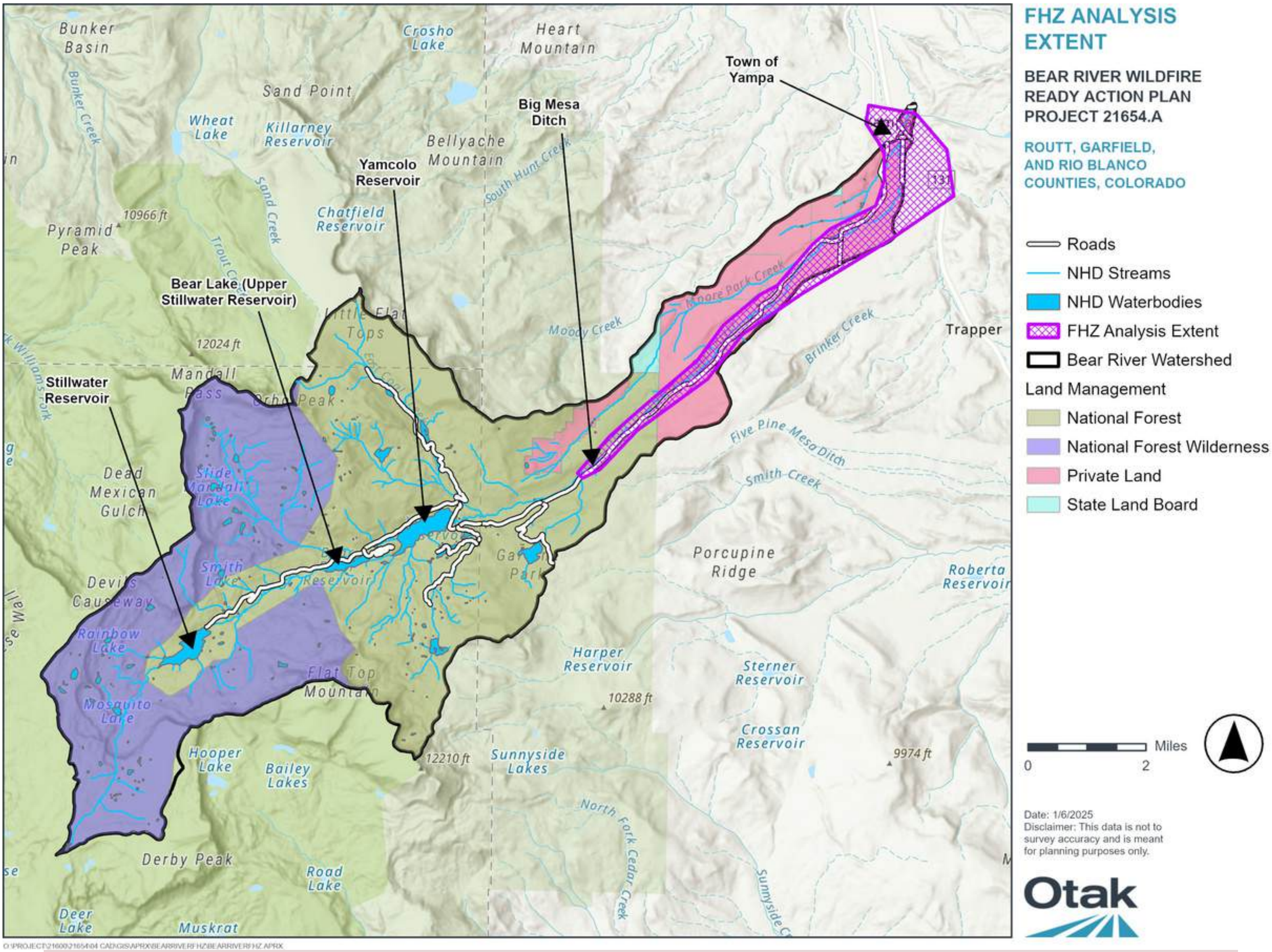
In coordination with JW Associates and the Upper Yampa Water Conservancy District, the project team determined that efforts for this analysis should focus on the lower portion of the watershed. Specifically, the approximately 10-mile stretch between the Town of Yampa and 1,500 feet upstream from the Big Mesa Ditch (FHZ study area; Map 15).

The delineation of the FHZ includes the mapping of an Active Stream Corridor (ASC) and a Fluvial Hazard Buffer (FHB). The ASC is defined as “land adjacent to a stream that has been or could be shaped by stream erosion and deposition under the prevailing flow and sediment regimes” and the FHB represents areas outside of the ASC, including “hillslopes and terraces, that may be susceptible to geotechnical slope failure as a result of toe erosion caused by fluvial scour” (Blazewicz et al., 2020). FHZ mapping also includes two auxiliary hazards: avulsion hazard zones and fans. Avulsion hazard zones are areas where a stream may find a new course across a floodplain or terrace. Fans are areas composed of alluvial sediments or debris flow materials typically deposited at the intersection of a tributary valley with a larger valley.

For details on this methodology, reference the Fluvial Hazard Zone Technical Memorandum, in the *Task 3 - Post-Fire Hazard Analysis* Deliverables.. The key results for the FHZ analysis across the WRAP project area follow.

FHZ ANALYSIS EXTENT

The approximately 10-mile-long FHZ study area on the mainstem Bear River is illustrated in Map 15. Changes in confinement ratio generally increase gradually from upstream to downstream, which is important, as rapid changes in confinement can lead to enhanced erosion/deposition. Towards the upstream extent of the FHZ study area, Bear River is confined (confinement ratio [alluvial valley width divided by the stream width] less than or equal to 5) to partially-confined (confinement ratio between 5 and 12), while lower portions are unconfined (confinement ratio greater than or equal to 12). The reach average slope of Bear River within the FHZ study area is 2.2%.



Map 15. Fluvial Hazard Zone Mapping Extent

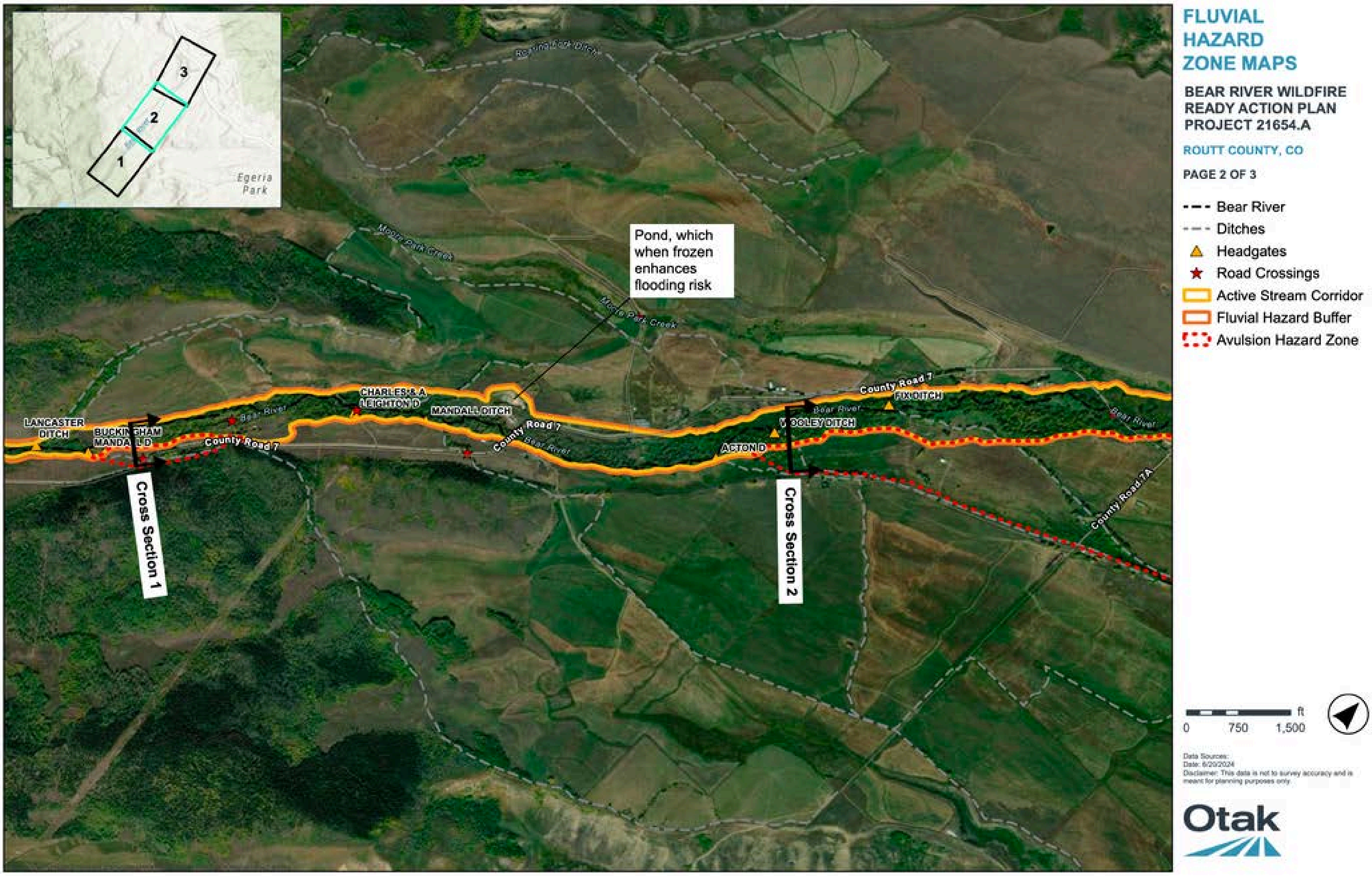
KEY RESULTS - UPPER SUB-REACH

Generally, there is a decrease in confinement and a decrease in slope from upstream to downstream. Map 16 shows a stream that is confined to partially confined and limited to a narrow ASC. Within this section, the stream has high stream power that is likely able to transport large quantities of sediment and debris downstream.

Map 16. Fluvial Hazard Zone Mapping for the Upper Sub-Reach of Bear River

KEY RESULTS - MIDDLE SUB-REACH

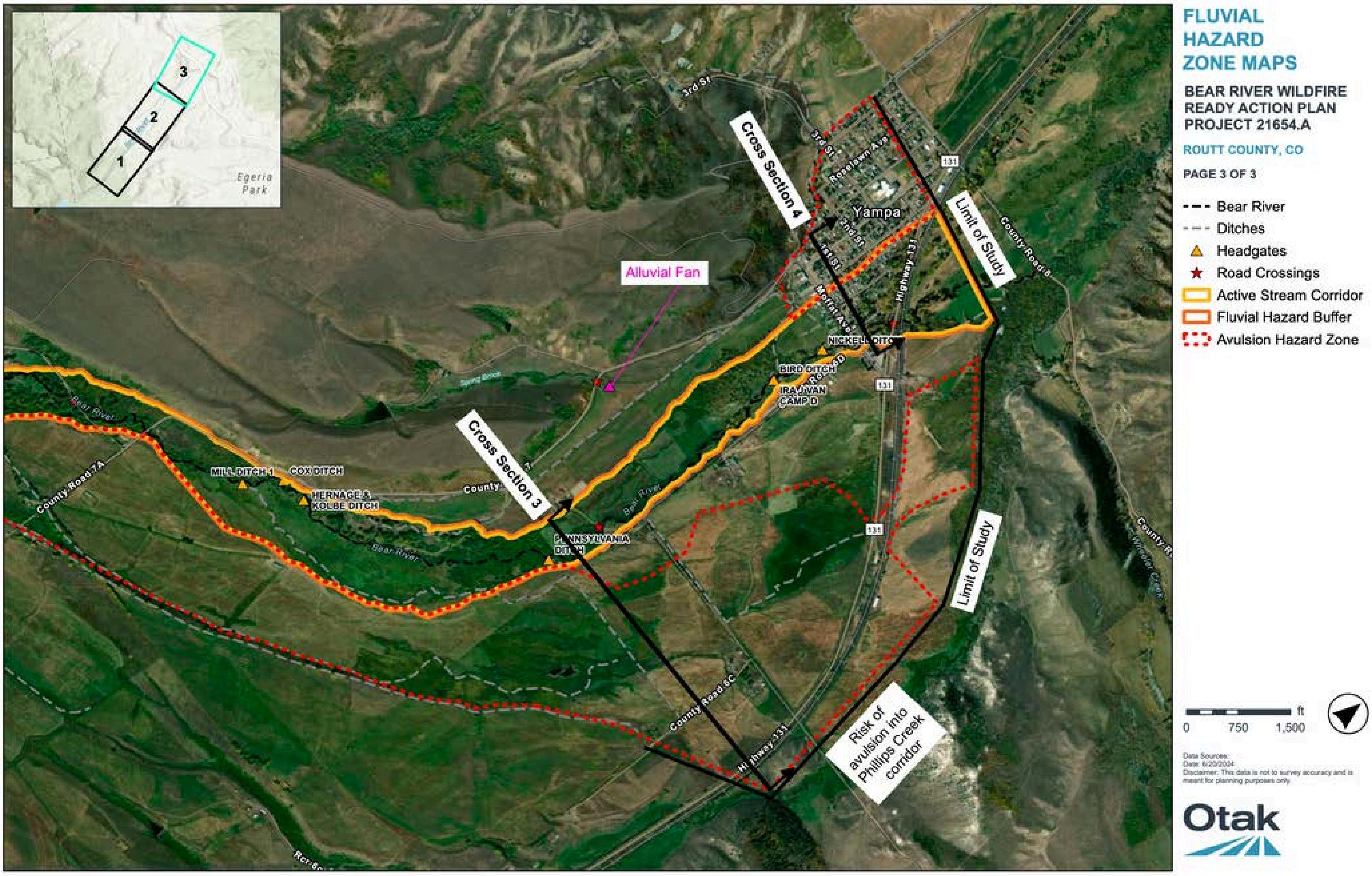
Map 17 shows the stream transitioning to a partially confined state to unconfined. Within this reach there is a heightened risk of deposition and lateral stream adjustments, based on the transition from confined to unconfined and the associated drop in stream power. There are two avulsion hazard zones where the stream may jump out of the ASC during extreme flow events, as evidenced by lower elevation areas located outside of the current channel and ASC (Figures 3 and 4 in FHZ Technical Memorandum). The presence of ditches in the floodplain and/or terraces may also enhance avulsion potential by providing an established flow path away from the main channel. Additionally, a pond located near Mandall Ditch, when frozen, has led to flooding in the low lying area beyond the ASC.



Map 17. Fluvial Hazard Zone Mapping for the Middle Sub-Reach of Bear River

KEY RESULTS - LOWER SUB-REACH

Map 18 features the only mapped alluvial fan in the FHZ study area, where Spring Brook spills into the Bear River corridor. It does not appear to be actively influencing the Bear River corridor. Much of the southern side of the ASC is mapped as an avulsion hazard area (continuing from reaches on Map 17). Where the stream turns north, the valley slopes down towards Phillips Creek and away from Bear River (Figure 5 in FHZ Technical Memorandum). This configuration raises the possibility that a large-scale avulsion may cause the creek to change course towards Phillips Creek, abandoning the current Bear Creek alignment through the Town of Yampa. An additional avulsion hazard zone is located within the Town of Yampa, where the valley widens and the floodplain terrace slopes away from the creek (Figure 6 in FHZ Technical Memorandum). If either of these avulsions were to occur, the results would be catastrophic for the Town of Yampa and Bear River water users.

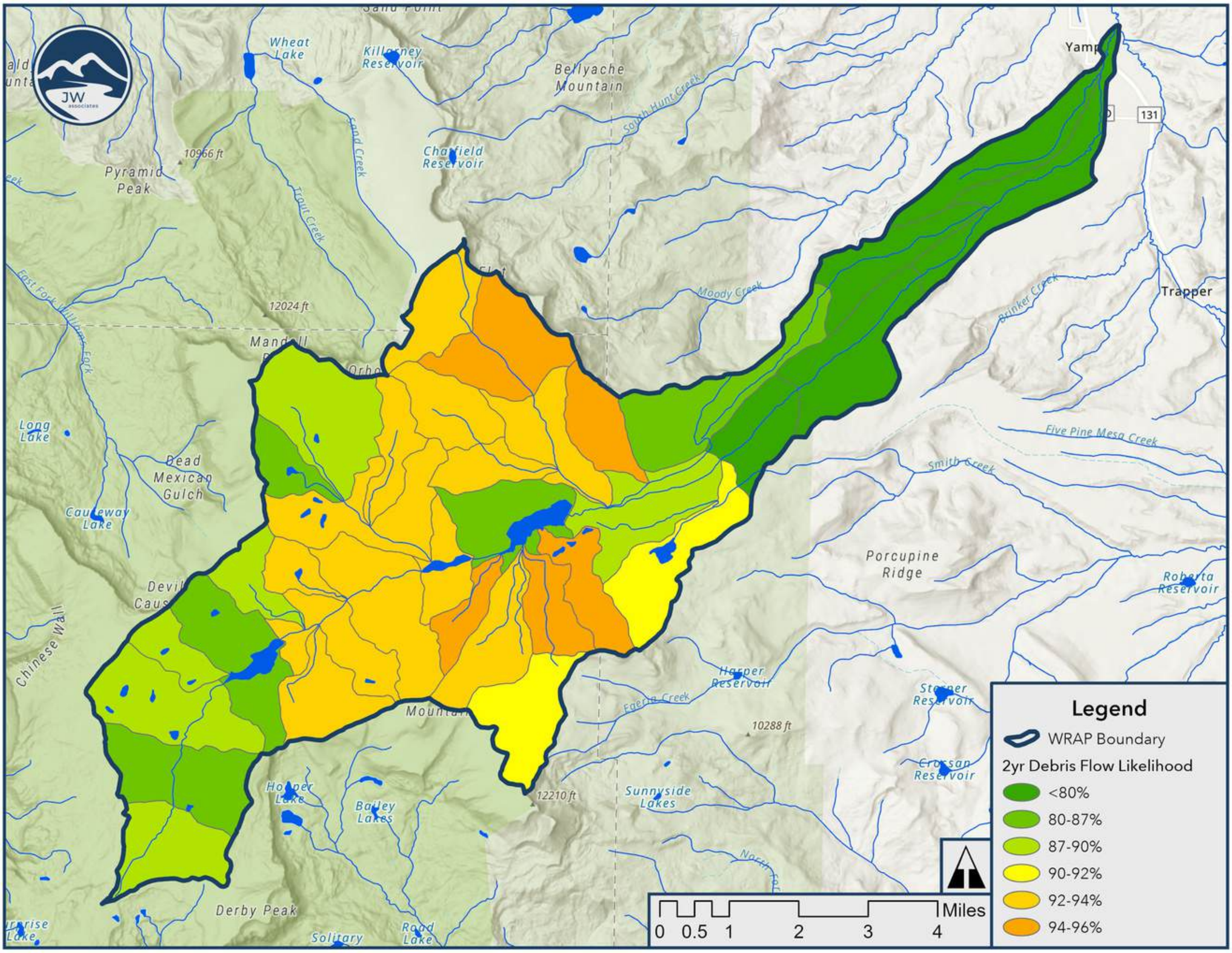


Map 18. Fluvial Hazard Zone Mapping for the Lower Sub-Reach of Bear River

4 H. Post-Fire Debris Flow Modeling & Analysis

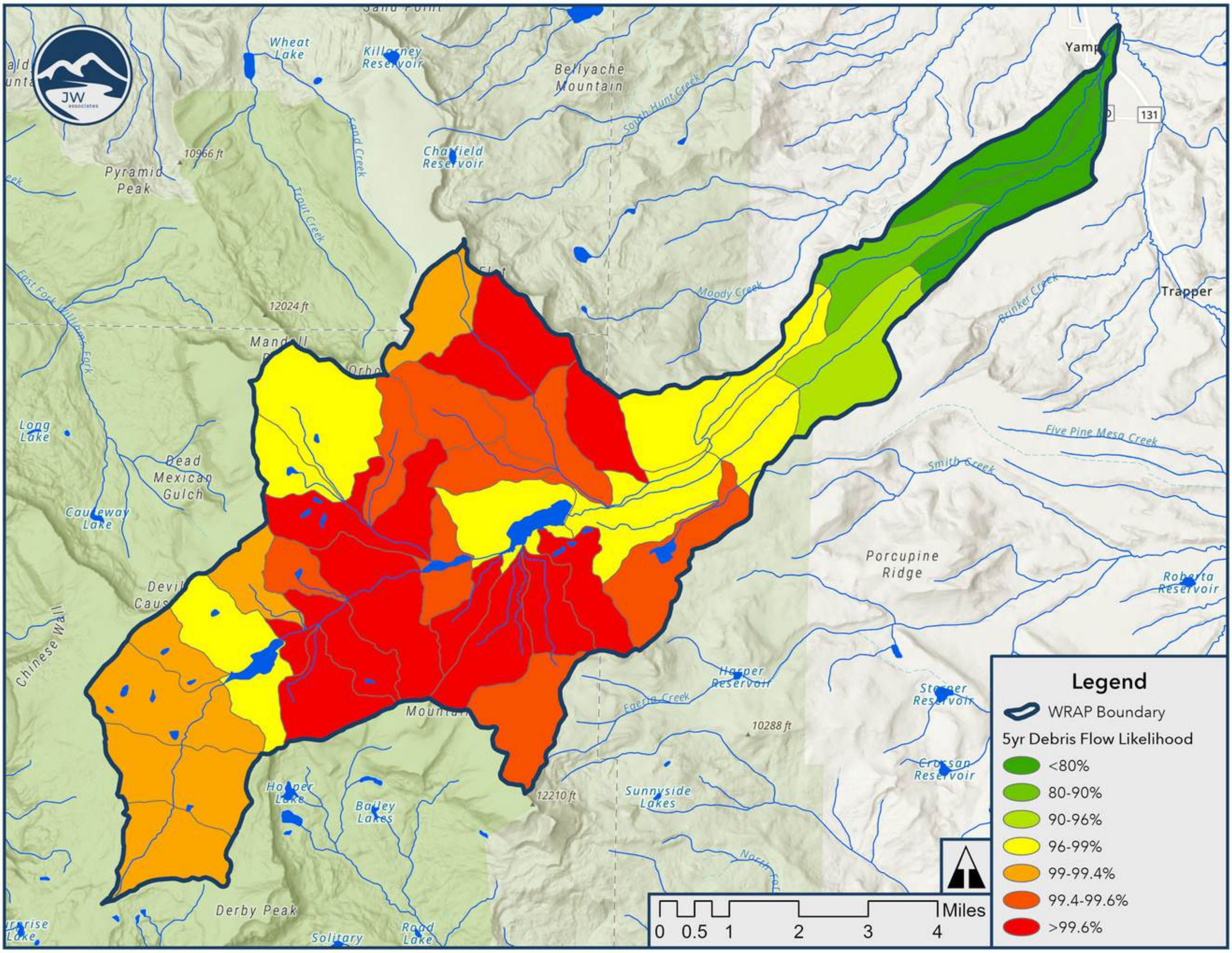
The United States Geological Survey (USGS) created a method for estimating the post-fire debris flow hazards for watersheds before wildfire occurs (Staley et. al., 2018). This is a prediction technique that combines wildfire modeling with other debris-flow indicators including slope and soil erodibility in order to predict the post-fire debris flow hazards in response to a triggering rainfall event. For details on this methodology, reference the Debris Flow Technical Memorandum, in the *Task 3 - Post-Fire Hazard Analysis* Deliverables. The key results for the debris flow analysis across the WRAP project area follow.

KEY RESULTS



Map 19. 2-year Storm Debris Flow Analysis

Map 20. 5-year Storm Debris Flow Analysis

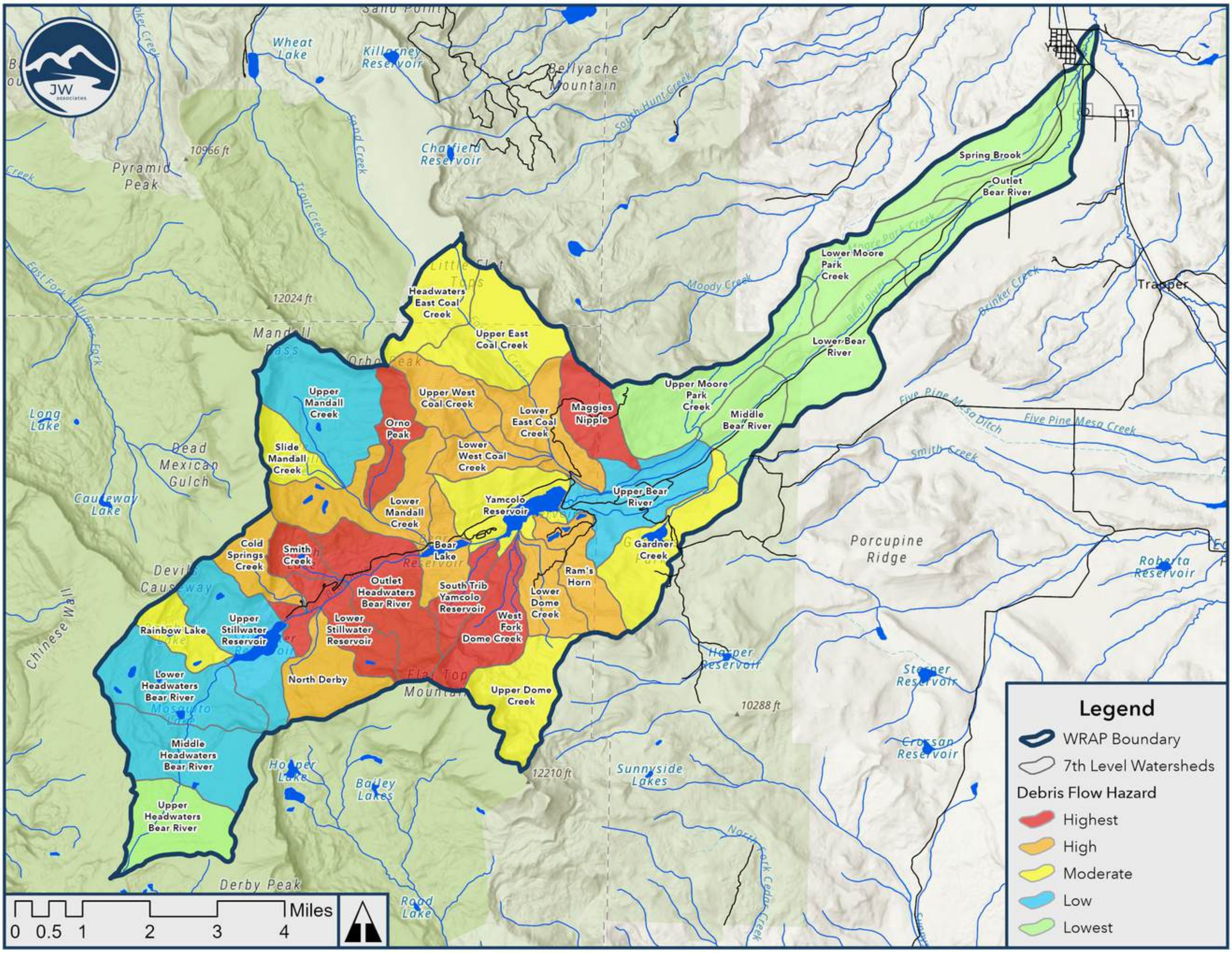


As part of the Watershed Hazard Assessment, a Debris Flow Hazard ranking analysis was completed. This analysis combines the post-wildfire debris flow potential with watershed ruggedness, which amplifies debris flow hazard. Watershed ruggedness is an indicator of the relative sensitivity to debris flows following wildfires and is determined by watershed steepness relative to total area. The Melton ruggedness factor was used to create a slope index, calculated for each 7th level watershed.

4 H. Post-Fire Debris Flow Modeling & Analysis

This analysis uses the USGS debris flow probability prediction model (described above) for the triggering rainfall intensity from a 2-year storm. The probability of this storm causing a debris flow was calculated for each 7th level watershed.

Watersheds were ranked for their relative debris flow potential and ruggedness. The final Debris Flow Hazard combined these rankings and then grouped the 7th level watersheds into five roughly equal categories from lowest to highest Debris Flow Hazard. Map 21 shows the comparative Debris Flow Hazard across the WRAP project area. Further details on this methodology can be found in the Watershed Hazard Assessment, in the *Task 3 - Post-Fire Hazard Analysis* Deliverables..

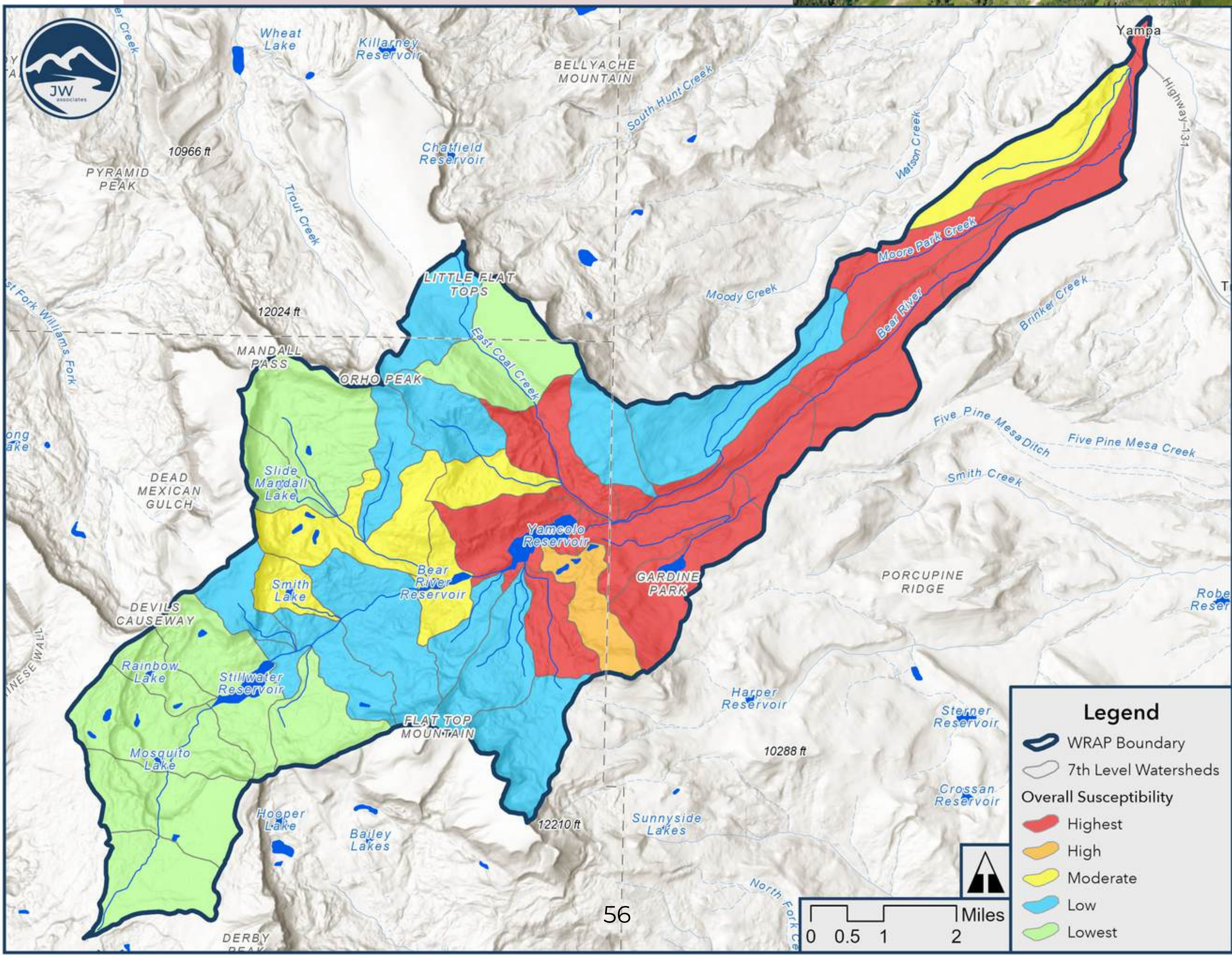


Map 21. Debris Flow Hazard Ranking for 7th Level Watersheds

4 I. Post-Fire Susceptibility Analysis

The project area susceptibility analysis involves the intersection of five post-fire hazards with 8 types of Values at Risk (VAR). The VARs were grouped into two categories: Water Infrastructure, and Life & Property. The 7th level watershed Overall Susceptibility comparison is presented on Map 22. Maps 23 and 24 present the Water Infrastructure and Life & Property Susceptibility comparative analyses. For more detailed information on the Post-fire Susceptibility Analysis for the WRAP project area, see the Susceptibility Mapping and Analysis Report, in the *Task 4 - Susceptibility Analysis* Deliverables.

Map 22. Overall Susceptibility for 7th Level Watersheds



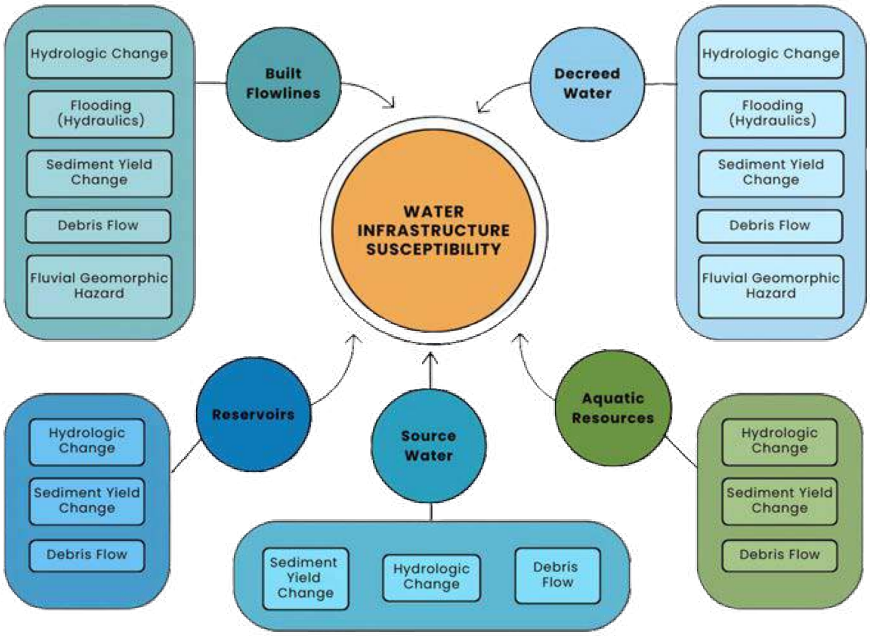
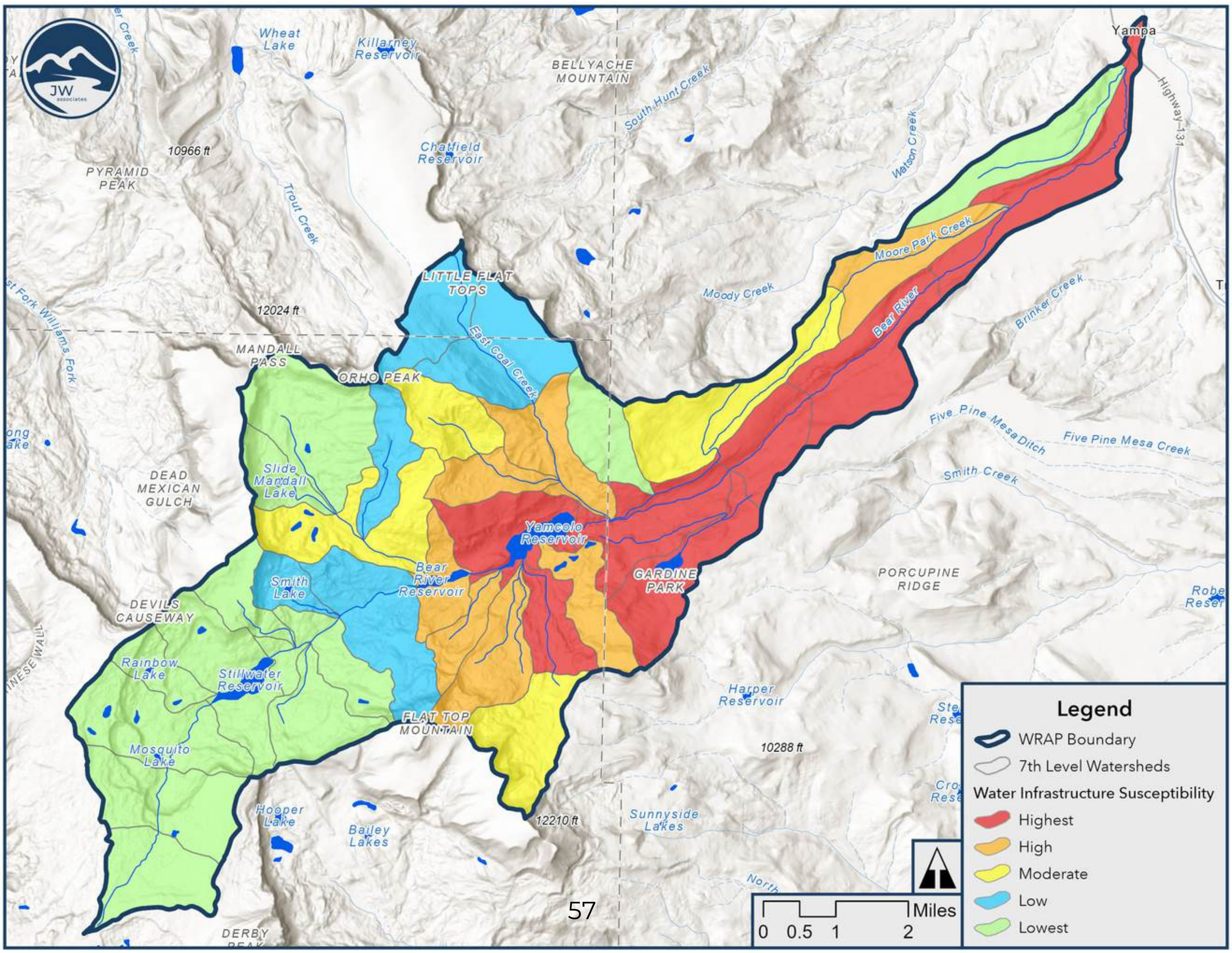


Figure 5. Water Infrastructure Susceptibility Analysis Component Intersections

Map 23. Water Infrastructure Susceptibility for 7th Level Watersheds



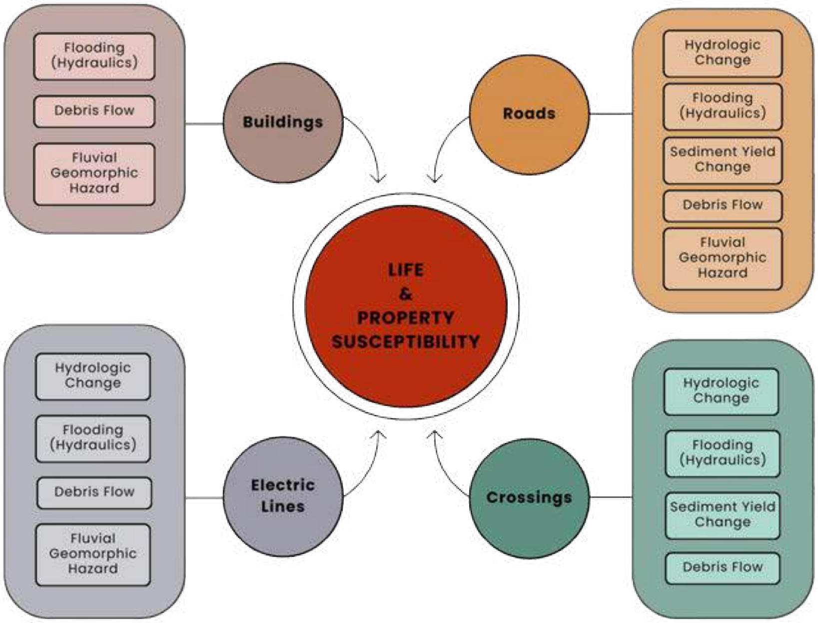
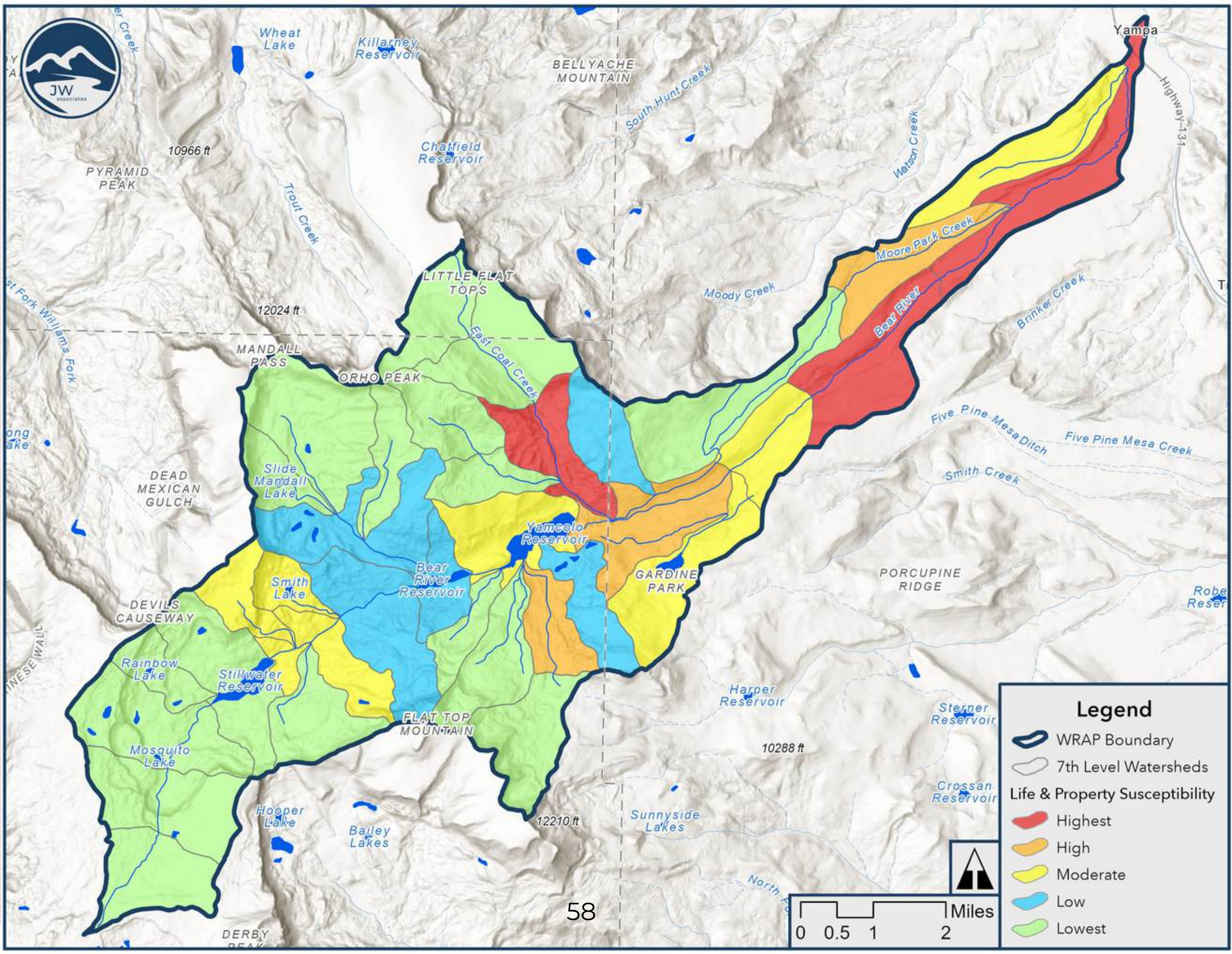


Figure 6. Life & Property Susceptibility Analysis Component Intersections



Map 24. Life & Property Susceptibility for 7th Level Watersheds

5 PRE-FIRE PLANNING & MITIGATION ACTIVITIES

5 A. Creating a Watershed That Burns in a Positive Manner

Wildfire Severity Reduction
Although there are other strategies that can be pursued, the reduction of wildfire severity is the goal for minimizing adverse hydrologic responses following intense wildfires. Wildfire severity is the effect that the fire has on the ground. Vegetative forest treatments can be effective in reducing the threat of crown fire. The following types of treatments accomplish this pre-fire goal.

- **Forest Canopy Treatments** - Reducing forest canopy density and changing the composition of forested stands can reduce the extent of crown fire, decrease severity, and enhance fire-suppression effectiveness and safety. In forested stands that have developed without natural disturbance, forest management (thinning, created openings, and enhancing forest diversity) combined with prescribed fire are the most effective techniques for altering the fuels matrix. Surface fuels created during these actions need to be removed or piled and burned as soon as practical.

- **Fuel Breaks** - Fuel breaks in strategic locations, especially along ridgelines between watersheds with high wildfire hazards. The locations for fuel breaks are determined by examining potential wildfire behavior, wind direction, other fuels treatments, and other values at risk. The effectiveness of fuel breaks should be increased by locating them in combination with existing openings, created openings, fuels treatments, and roads.
  - Maintain fuel breaks to keep them effective: a maintenance plan should be created as part of the initial planning for creating the fuel breaks.
  - Work with existing partners and communicate the value and function of fuel breaks to the partners. Fuel breaks usually cross ownership boundaries and therefore planning and permitting can be complex.
  - Communicate to fire suppression authorities the locations of created fuel breaks that can be used for aerial retardant drops, and potential control lines and safe zones for fire fighters.

- **Address Beetle Mortality** - Reduce areas of insect activity or tree mortality, or areas at risk for future insect mortality, that could be thinned to reduce ecosystem sensitivity hazards and fire regime departure.

Fuels reduction treatments are useful in areas of dense forest to protect reservoirs below from post-wildfire impacts. Photo: JW Associates

Active floodplain below a burned hillslope captures sediment and recovers quickly in East Troublesome Fire, 2022. Photo: JW Associates

Intact Floodplains, Riparian Areas, and Wetlands

Natural processes within healthy, functional river systems including floodplains, riparian areas, and wetlands can help moderate post-fire effects of increased peak flows and sediment yields.

- **Reconnect Floodplains** - Frequent floodplain connectivity helps streams maintain function of riparian and wetland areas during post-fire runoff and can lead to flood attenuation and sediment storage benefits during high flows. Floodplain inundation helps replenish riparian areas to suppress conifer growth and encourage more appropriate riparian vegetation such as willows that provide erosion resistance. Floodplains can be reconnected by removing human impoundments such as berms, strategically grading flow paths into floodplain areas, or installing small in-stream structures such as beaver dam analogs to help raise water into floodplains and re-establish beaver meadows.

Roads

Roads can present hazards both pre- and post-fire. However, post-fire runoff produces significantly higher peakflows and contains more sediment and debris. The situations that are most hazardous are road-stream crossings and roads that run along streams.

- **Ensure road-stream crossings are properly sized** - Improvements can be made to road/stream crossings before a fire, in order to create a crossing that is sized appropriately to pass the increased post-fire peakflows, as well as possible sediment and debris. In key locations that are important for access, life & safety, or that would cause harm if blown out, use the post-fire hydrology and debris flow analyses from the WRAP in order to determine the necessary capacity for current culverts or bridges at the road-stream crossings. During field work for the WRAP, the current culverts and bridges were measured and the current capacity for each was calculated. Investigate the differences between current capacities and likely post-fire peakflows or debris flow likelihoods to prepare the infrastructure to receive post-fire peakflows, and increased sediment and debris. Doing this work before a fire will allow the crossings to withstand post-fire events, without compromising its integrity and maintaining safe access.

- **Determine which roads or crossings may be compromised post-fire** - If the economic cost outweighs the utility of upgrading a road crossing, sometimes it is not feasible to improve or upgrade it before a disaster occurs. However, it is important to note which crossings are likely undersized and therefore may be lost in a post-fire event. This way, following a large wildfire, it will be possible to efficiently re-visit all the vulnerable road-stream crossings and determine what can be done about them at that point in time. In addition, it will be possible to warn the public to stay away from these vulnerable locations, knowing where they exist ahead of time.

Forest road within a burned landscape channelized flow and eroded following the Cameron Peak Fire, 2022. Photo: JW Associates

Vegetation and Canopy Closure Diversity

Historically, the patterns of vegetation across the landscape were shaped by disturbances that maintained the landscape in a condition that was not static but which could withstand events such as fire, insects and disease, or drought. Openings across the landscape that are 20-40 acres in size protect the forested areas from extensive fires because there are large distances between tree crowns from the openings. This mosaic pattern would have been maintained, as the patch-like variations of age classes, densities, and openings, caused fires to skip around rather than kill the majority of trees over large areas in a single fire event. A mosaic of canopy density also allows for more diversity in ground cover species.

- **Create Canopy Openings** - Some vegetation types naturally grown in high density stands, such as Lodgepole pine and Spruce fir. Forest treatments can still be effective in these vegetation types if they utilize patch cuts with variable openings.
- **Reduce Canopy Density** - When the overstory is densely packed, it reduces the amount of sunlight that can reach the forest floor. In this situation, the understory species are limited to shade tolerant plants and often the area is completely barren. Following a wildfire, there is little seed bank that can take advantage of the disturbance to rebound quickly. When the canopy is less dense, more light reaches the forest floor, offering opportunity for a diverse array of understory plants and wildflowers to thrive. These diverse species will also return quickly following wildfire.

Quick recovery and revegetation where there was a gap in the forest canopy before the fire. Big Thompson Watershed, Cameron Peak Fire, 2022. Photo: JW Associates

- **Encourage Forest Diversity** - Increasing diversity helps reduce both insect and disease populations and resulting mortality, as well as reducing wildfire severity. Enhancing aspen by thinning or removing encroaching conifers is an effective strategy for increasing diversity and reducing wildfire severity.

Stakeholder Communications and Agreements for Pre-Fire Actions

- **National Environmental Policy Act (NEPA)** - The UYWCD is currently working with the USFS to complete NEPA approval for forestry projects around Stillwater Ditch and south of Yamcolo Reservoir. Additional pre-fire projects may need NEPA if they are located on NFS lands. Understand which projects on NFS Lands and in Colorado Roadless Areas (Maps 1, 25, & 28) would require NEPA and at which level of assessment. Get the NEPA process started as soon as possible for the highest priority projects.
- **Agreements with USFS** - Signed agreements will likely be needed to do floodplain restoration including Simulated Beaver Structures (SBS). A Good Neighbor Authority (GNA) stewardship agreement allows for partners to accomplish work on National Forest System (NFS) Lands, generally managed by the Colorado State Forest Service.
- **Involve stakeholders** - Stakeholders should be included in the decision process when deciding on next priorities. UYWCD will also support stakeholders that decide to take projects from this WRAP effort and move them toward implementation.

Pre-Fire Stakeholder Communications and Agreements for Post-Fire Actions

- **Document expected actions** - Identify and work with federal and state agencies on planned watershed protection measures. Document expected actions with those agencies so that the planning and approval process can be completed quickly following an emergency. In advance of a fire, intergovernmental agreements (IGAs) or memorandums of understanding (MOUs) between key stakeholders who will support, fund, and implement recovery projects should be developed and executed. Important information to document in these agreements may include, but is not limited to:
    - Roles and Responsibilities: Develop internal guidance for responding to post-fire recovery. Determine roles and responsibilities within the organization and stakeholder group.
    - Financial Needs: Keep an updated budget available that can immediately be used as a justification for emergency funding requests. This should include support for personnel during an emergency and funds to kick off data collection, data analysis, and initial long-term planning. While it will be difficult to estimate exact values, getting order of magnitude estimates correct can accelerate funding immediately post-disaster and avert problems as months and years pass.

- **Pre-fire Conditions Based NEPA** - Pursue pre-fire National Environmental Policy Act (NEPA) compliance for post-fire actions. This could be a conditions-based assessment, which would include a list of post-fire actions that can be implemented based on the ground, forest, and stream conditions following the wildfire. This should document actions such as aerial wood mulching and the ability to utilize burned trees for a wood mulch source, mastication on accessible hillslopes, directional tree felling in gulleys, removing undersized road crossings with temporary low-water crossings, post-fire sediment basins, and other actions that can be specified pre-fire. In addition, the conditions-based NEPA would execute the necessary surveys and should indicate the length of time they remain in effect and clarify the process needed in order to move forward on implementation in post-fire conditions.

Other Pre-Fire Planning Efforts

- **Re-run the watershed hazard analysis** - This should be re-done periodically, as projects are completed. Plan to update the watershed hazard analysis with new data or when significant work has been accomplished in order to re-assess the wildfire modeling and post-fire hazards. This will allow stakeholders to track improvements, as well as re-prioritize future work.

5 C. Pre-Fire Project Recommendations & Mitigation Actions

Multi-Faceted Projects Lead to Multiple Positive Outcomes

Watersheds function best when the uplands, streams, and floodplains are in resilient condition and when whatever development exists is designed to minimally impact the natural hydrologic conditions and function of the system as a whole. Therefore, when implementing projects, it is much more effective to consider the watershed as a system and address multiple hazards and values within a single watershed, before moving on to a new watershed to consider projects. A single project might address a specific hazard, but multiple projects in the same watershed addressing different aspects of the hazards will have a synergistic effect to create as resilient a watershed as possible.

Recommendations - Project Type

- Road Crossing
- Conifer Removal
- Floodplain Improvement
- Wildfire Severity Reduction
- Infrastructure Upgrades/Protection
- Erosion Reduction

The types of recommended projects are illustrated in the legend (left). These icons are used throughout this chapter to identify the types of projects that are recommended within each watershed and region, in order to address the hazards and values at risk that exist there. This is a method of quickly identifying these projects visually, but further description of the projects is provided where appropriate.

5 C. Pre-Fire Project Recommendations & Mitigation Actions

Often, in the recommendations that follow, multiple icons will be located within the same general area. This indicates that there is an opportunity to combine a number of different project types to achieve multiple benefits in that location. These opportunities are highly valuable and should be seen as top priorities for implementation.

In order to summarise project recommendations, the WRAP project area will be discussed in terms of the two 6th level watersheds. Table 5 illustrates a summary of the types of recommendations within each region of the WRAP. The following sections describe each region in further detail. More information and detail about recommendations are listed in the accompanying Excel spreadsheet, Bear River WRAP Pre- and Post-Fire Project List. The specific locations for each recommendation are available in the accompanying GIS data. Both can be found in the *Task 5 - Pre- and Post-fire Planning and Mitigation Activities* Deliverables.

Table 5. Pre-fire project recommendations for each 6th level watershed within the WRAP Project Area

Watershed	Road Crossing	Floodplain Improvement	Wildfire Severity Reduction	Infrastructure Upgrades
Yamcolo Reservoir - Bear River				
Headwaters Bear River				

How do we prioritize or find the next project?

Often the next project will be the one that is closest to the previous project implemented, in order to address the entire watershed in a certain location. The most vital values-at-risk should be considered when identifying where on the landscape to begin with project implementation. From there, it will be important to address all aspects of the watershed to create a system that will be resilient to wildfire and better able to protect the values-at-risk in the area. Understanding the need for permitting and approvals on certain land ownerships, often times it will be important to start planning for future projects early in order to proceed with implementation when the time or funding comes along. Finally, the availability of funding for certain types of projects might dictate which projects can be implemented at a certain time.

How do we know when we are done?

Resource management work is cyclical in nature and the natural world continues to grow and change. It is important to go back to forest mitigation treatments 10-20 years after they are completed, in order to assess the hazards again that may have grown back in that timeframe. Similarly, projects aiming to enhance beaver meadows using simulated beaver structures will need maintenance unless and until beaver move in to help with that work. These types of projects may not be considered "done" for many years, while we work with the system itself to help it achieve the uplift we are striving for.

For the time being, this checklist will help understand whether you have completed as many projects as you can in a single watershed, in order to call it "done" and move on to the next watershed. The caveat exists that some of the completed projects might still require periodic maintenance.

- ✓ Do the uplands demonstrate species diversity where possible?
- ✓ Do fuel breaks and openings exist where possible and is the forest vegetation type aligned with historic resilient conditions?
- ✓ Is high severity wildfire in the uplands relatively small and isolated from other high severity areas?
- ✓ Is the presence and spread of non-native and invasive plant species controlled?
- ✓ Are the floodplains connected to the stream, indicated by healthy riparian vegetation?
- ✓ Will the stream and floodplain be able to work with the natural fluvial geomorphology, rather than against it?
- ✓ Are road/stream crossings sized to withstand post-fire peakflow events? If not, do the benefits of the current crossing outweigh the consequences?
- ✓ Are there aquatic organism passages in place where appropriate?

5 C. Pre-Fire Project Recommendations
Yamcolo Reservoir - Bear River

The majority of the values at risk for the WRAP planning area are in the Yamcolo Reservoir - Bear River region. Yamcolo Reservoir and the Stillwater Ditch are the main components of water infrastructure in this watershed. In addition, there are numerous ditches and headgates along the mainstem of Bear River. The county road, and main access road for the properties and upper watershed, also runs along the Bear River mainstem.

The western watersheds of the Coal Creek tributary are Upper Tier Roadless and both the South Tributary to Yamcolo Reservoir and portions of West Fork Dome Creek are Colorado Roadless Areas. These management designations are noted in Table 6 below, as well as in Map 25.

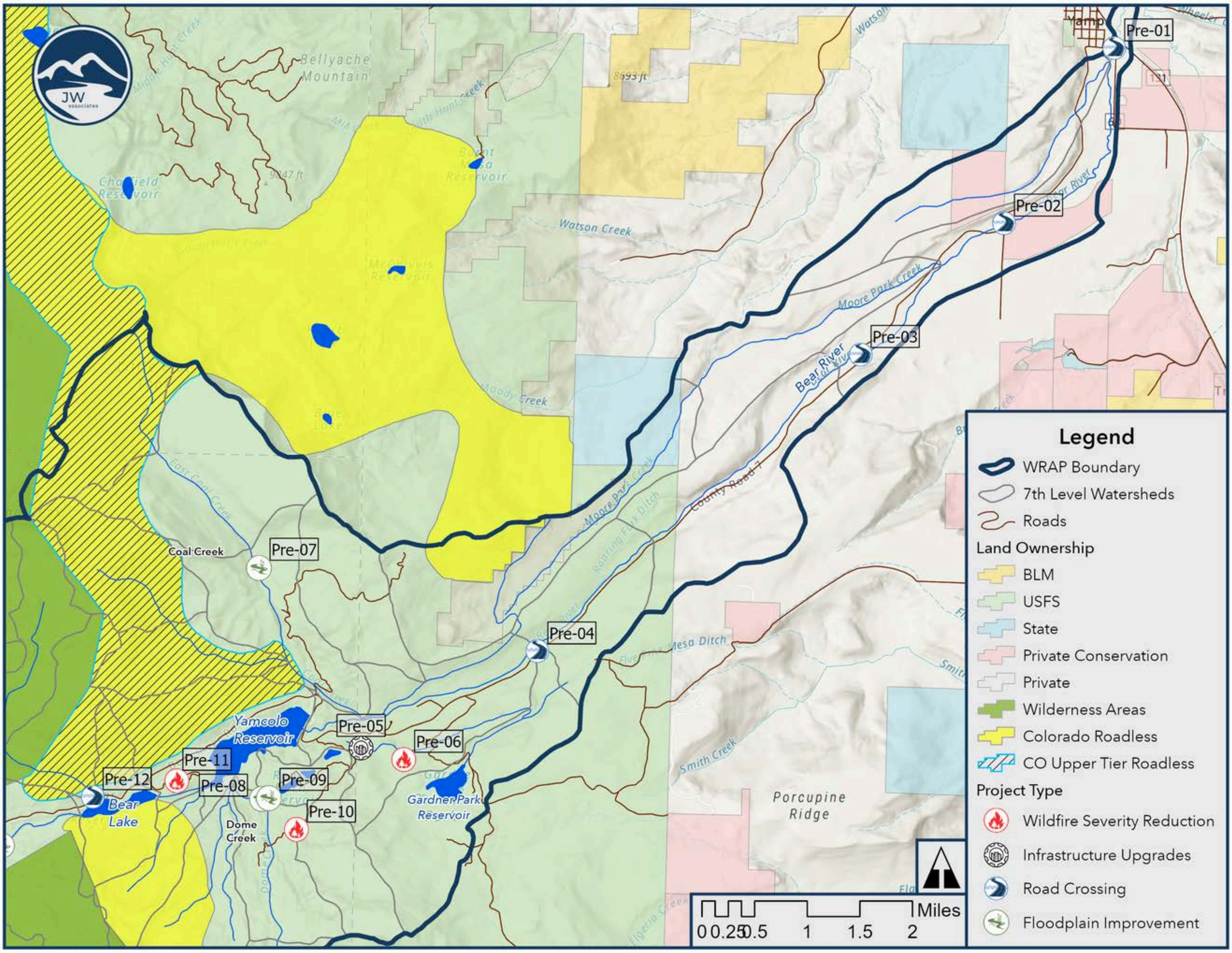
The most significant hazard in the lower Bear River mainstem portion of the watershed is roads. The upper section of the watershed includes Coal Creek to the north, Yamcolo Reservoir, and Dome Creek, Rams Horn, and Gardner Park to the south. The most significant hazards in these watersheds are Wildfire and Debris Flow. Hillslope Erosion is also a hazard in this region, and is exacerbated post-fire when there is no longer vegetative cover keeping the soil in place. For this reason, it is even more imperative to reduce the wildfire severity of this region. UYWCD is already in progress on NEPA for fuels reduction projects on the south side of Yamcolo from Dome Creek east to the Stillwater Ditch. Road crossing projects are recommended where road hazards are Highest and where the current culvert or bridge capacities do not meet the modeled post-fire peakflows.

When wildfire does occur, debris flows and hillslope erosion become a significant threat, especially from the watersheds on the south side of Yamcolo Reservoir and Coal Creek. Therefore, improving floodplains in numerous tributaries above the main channel of the Bear River will help to slow down the flowing water, dissipate some of the stream power, and reduce sediment loading in the streams. This will help to protect the reservoir and other water infrastructure on the Bear River mainstem. Therefore, a number of riparian projects are also recommended (Table 6).

Table 6. Pre-fire project recommendations summary for the Yamcolo Reservoir-Bear River region within the WRAP project area.

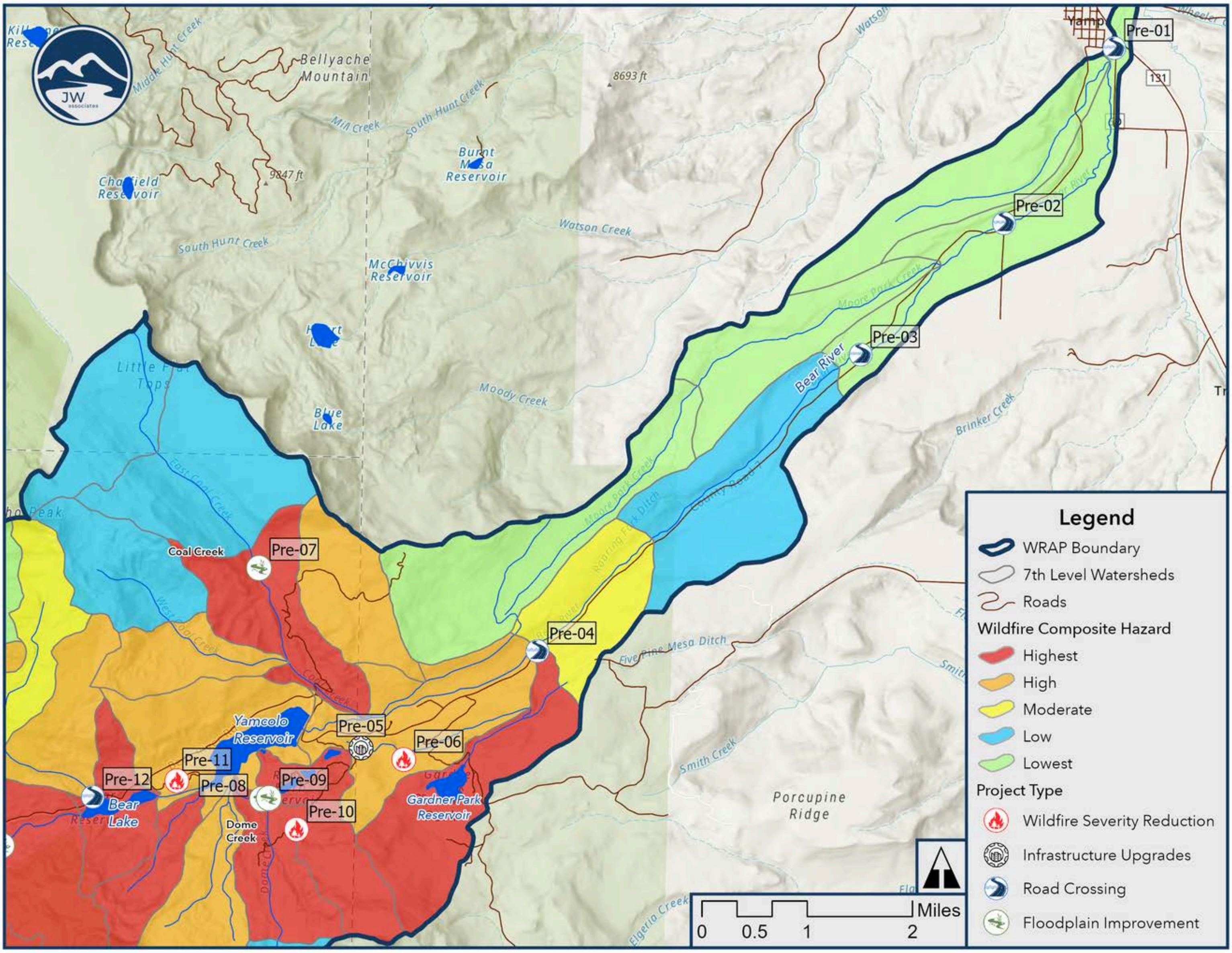
7th Level Watershed Name	WILDFIRE HAZARD	ROADS HAZARD	DEBRIS FLOW HAZARD	HILLSLOPE EROSION	WILDFIRE COMPOSITE HAZARD	LAND MANAGEMENT RESTRICTIONS	RECOMMENDED TREATMENTS
South Trib Yamcolo Reservoir	Highest	Lowest	Highest	High	Highest	Roadless	
Upper Dome Creek	Moderate	Lowest	Moderate	Moderate	Low		
West Fork Dome Creek	Highest	Lowest	Highest	Moderate	High	Roadless	
Lower Dome Creek	Highest	High	High	Moderate	Highest		
Ram's Horn	Highest	Low	High	Moderate	Highest		
Yamcolo Reservoir	Moderate	Moderate	Moderate	Highest	High	Upper Tier Roadless	
Headwaters East Coal Creek	Lowest	Lowest	Moderate	Highest	Low	Upper Tier Roadless	
Upper East Coal Creek	Low	Lowest	Moderate	High	Low	Upper Tier Roadless	
Upper West Coal Creek	Low	Lowest	High	High	Low	Upper Tier Roadless	
Lower West Coal Creek	Highest	Lowest	High	High	High	Upper Tier Roadless	
Lower East Coal Creek	Moderate	Highest	High	High	Highest		
Maggies Nipple	Highest	Low	Highest	Low	High		
Upper Bear River	High	Highest	Low	High	High		
Gardner Creek	Highest	High	Moderate	High	Highest		
Middle Bear River	Low	Highest	Lowest	High	Moderate		
Lower Bear River	Low	Highest	Lowest	Moderate	Low		
Upper Moore Park Creek	Low	Lowest	Lowest	Moderate	Lowest		
Lower Moore Park Creek	Lowest	Highest	Lowest	Lowest	Lowest		
Spring Brook	Lowest	High	Lowest	Lowest	Lowest		
Outlet Bear River	Lowest	Highest	Lowest	Lowest	Lowest		

LAND MANAGEMENT WITH PROJECT RECOMMENDATIONS



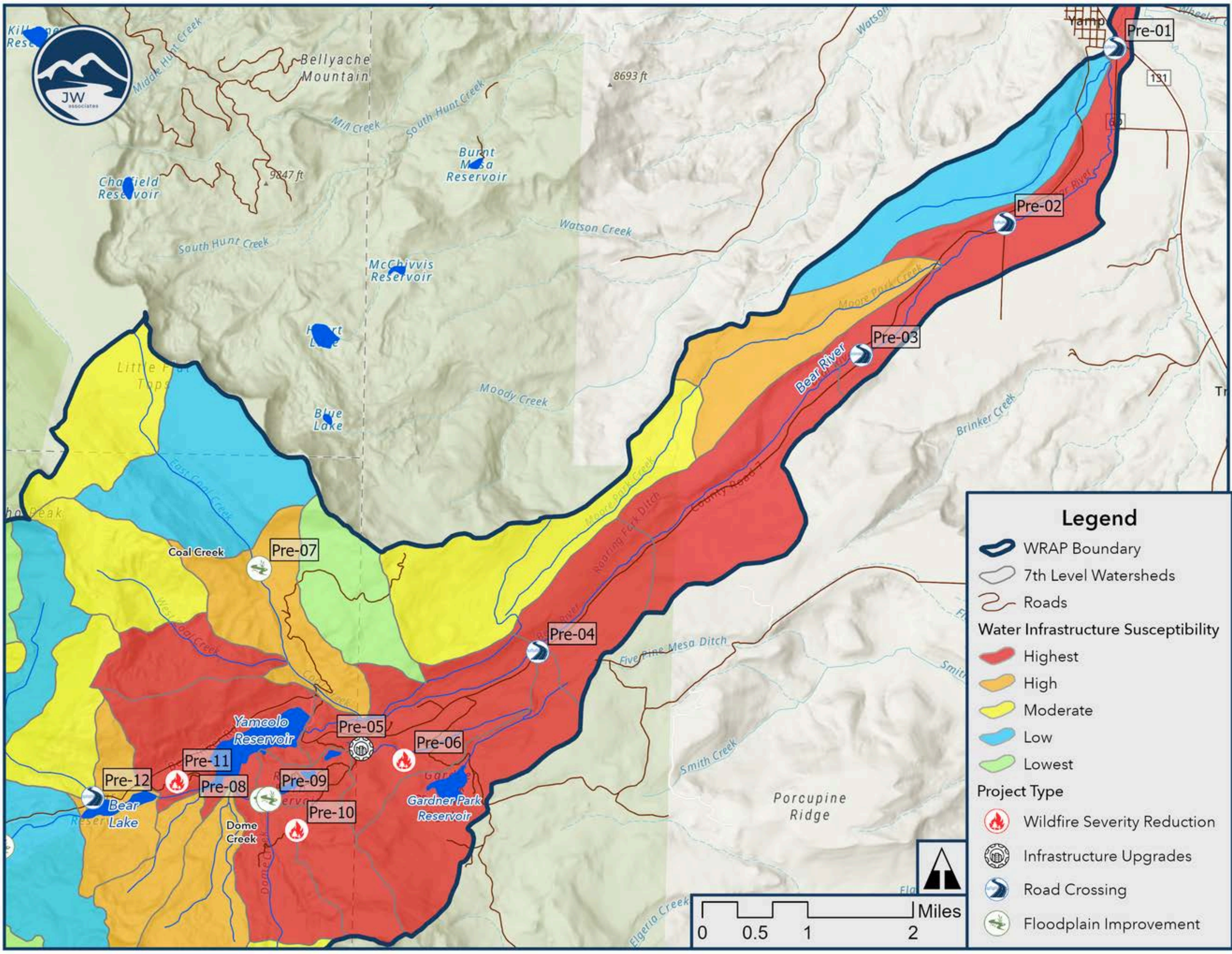
Map 25. Yamcolo Reservoir - Bear River Region Pre-fire Project Recommendations overlaid on Land Ownership

HAZARD ANALYSIS WITH PROJECT RECOMMENDATIONS



Map 26. Yamcolo Reservoir - Bear River Region Pre-fire Project Recommendations overlaid on Wildfire Composite Hazard Analysis Ranks

SUSCEPTIBILITY ANALYSIS WITH PROJECT RECOMMENDATIONS



Map 27. Yamcolo Reservoir - Bear River Region Pre-fire Project Recommendations overlaid on Water Infrastructure Susceptibility Ranks

5 C. Pre-Fire Project Recommendations
Headwaters Bear River

The main value at risk in the Headwaters Bear River watershed is the access road, as well as Stillwater Reservoir and Bear Lake. The main hazards in the region are Wildfire and Debris Flow. Hillslope Erosion is also a hazard in this region, especially from Cold Springs Creek, Mandall Creek and immediately surrounding Bear Lake. The worst issues with debris flow and hillslope erosion stem from post-fire environments when there is no longer vegetative cover keeping the soil in place.

However, most of the wildfire hazard is within Wilderness or Roadless boundaries, making it near impossible to manage the forests to reduce wildfire severity. The Wilderness area extends through most of the watersheds in this region of the WRAP, with a non-wilderness buffer around the reservoirs and road. There is also Colorado Roadless Area and Upper Tier Roadless on either side of Bear Lake. These management designations are noted in Table 7 below, as well as in Map 28.

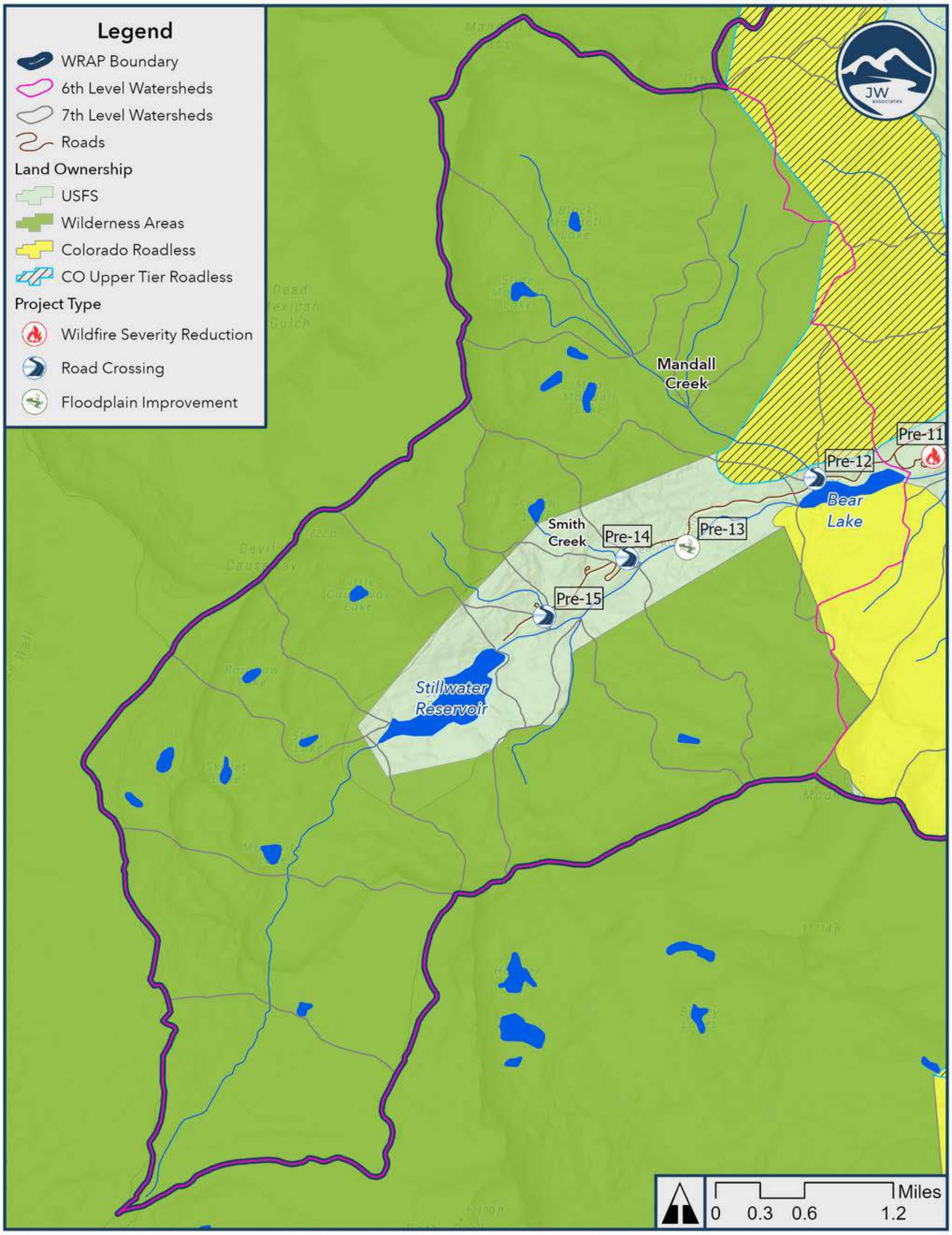
Therefore, all the project recommendations for this region are within the mainstem Bear River corridor and along the road. These locations will be especially vulnerable post-fire, but creating more resilient road crossings and floodplains before a fire occurs will alleviate the need to act immediately to protect some of the most vulnerable locations in the aftermath of a wildfire.

When wildfire does occur, hillslope erosion and debris flows could be destructive to the mainstem Bear River between Stillwater Reservoir and Bear Lake due to the steep, narrow shape of the watersheds and the soil and geologic characteristics of the area. Therefore, improving floodplains, especially above the Bear Lake, to slow down the flowing water, drop sediment onto the floodplain areas and dissipate some of the stream power will help tremendously to protect the reservoir and keep sediment and debris from reaching it. Therefore, a riparian project is also recommended (Table 7).

Table 7. Pre-fire project recommendations summary for the Headwaters Bear River region within the WRAP project area

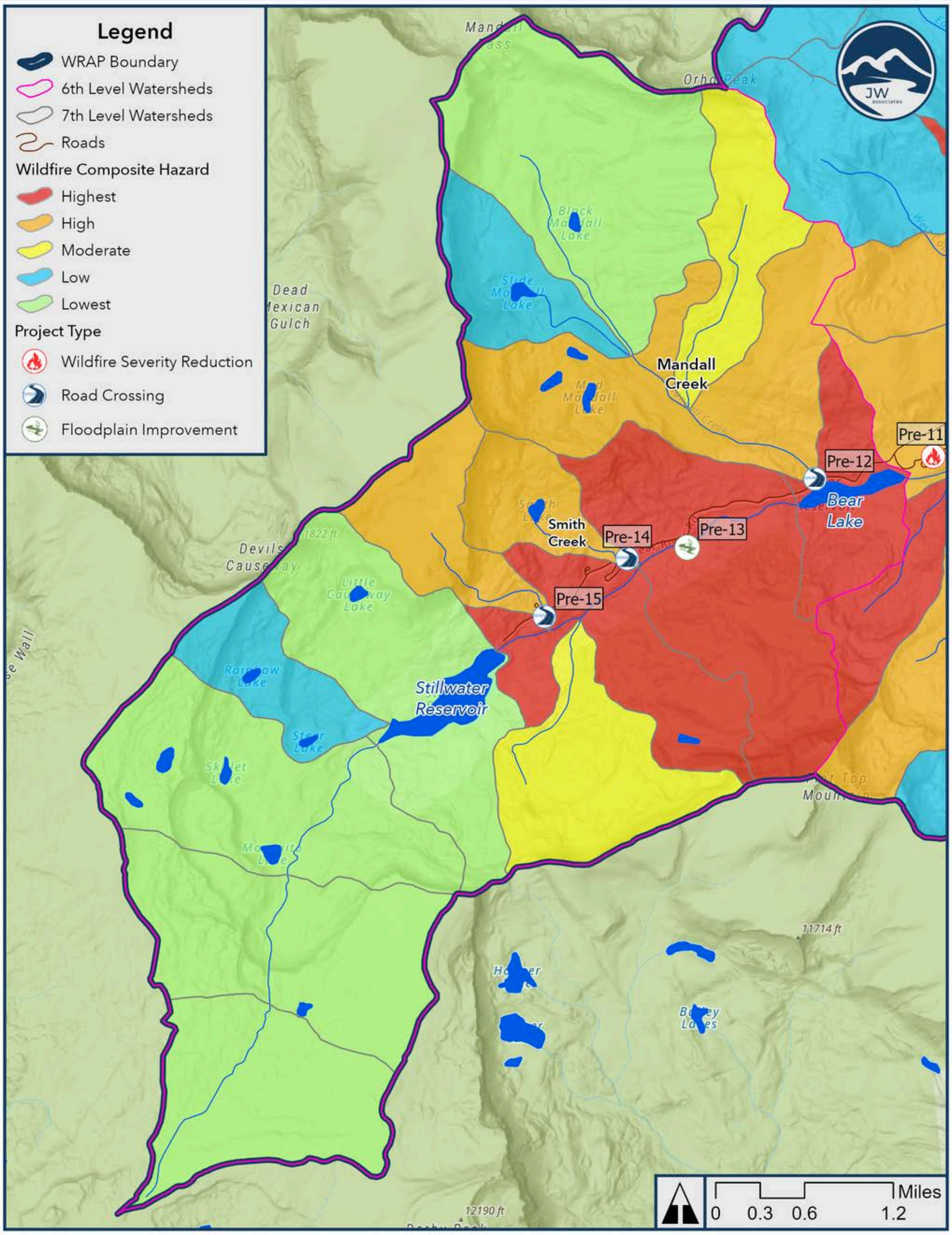
7th Level Watershed Name	WILDFIRE HAZARD	ROADS HAZARD	DEBRIS FLOW HAZARD	HILLSLOPE EROSION	WILDFIRE COMPOSITE HAZARD	LAND MANAGEMENT RESTRICTIONS	RECOMMENDED TREATMENTS
Upper Headwaters Bear River	Lowest	Lowest	Lowest	Highest	Lowest	Wilderness	
Middle Headwaters Bear River	Lowest	Lowest	Low	High	Lowest	Wilderness	
Lower Headwaters Bear River	Moderate	Lowest	Low	Low	Lowest	Wilderness	
Rainbow Lake	Moderate	Lowest	Moderate	Low	Low	Wilderness	
Cold Springs Creek	Low	High	High	Highest	High	Wilderness	
Upper Stillwater Reservoir	High	Lowest	Low	Low	Lowest	Wilderness	
North Derby	Highest	Lowest	High	Moderate	Moderate	Wilderness	
Smith Creek	High	High	Highest	Low	High	Wilderness	
Lower Stillwater Reservoir	Highest	Low	Highest	Moderate	Highest	Wilderness	
Outlet Headwaters Bear River	Highest	Low	Highest	High	Highest	Wilderness	
Upper Mandall Creek	Low	Lowest	Low	Low	Lowest	Wilderness	
Slide Mandall Creek	Low	Lowest	Moderate	Moderate	Low	Wilderness	
Orno Peak	Low	Lowest	Highest	Highest	Moderate	Wilderness	
Lower Mandall Creek	High	Low	High	High	High	Wilderness	
Bear Lake	Highest	Low	High	Highest	Highest	Upper Tier Roadless	

LAND MANAGEMENT WITH PROJECT RECOMMENDATIONS



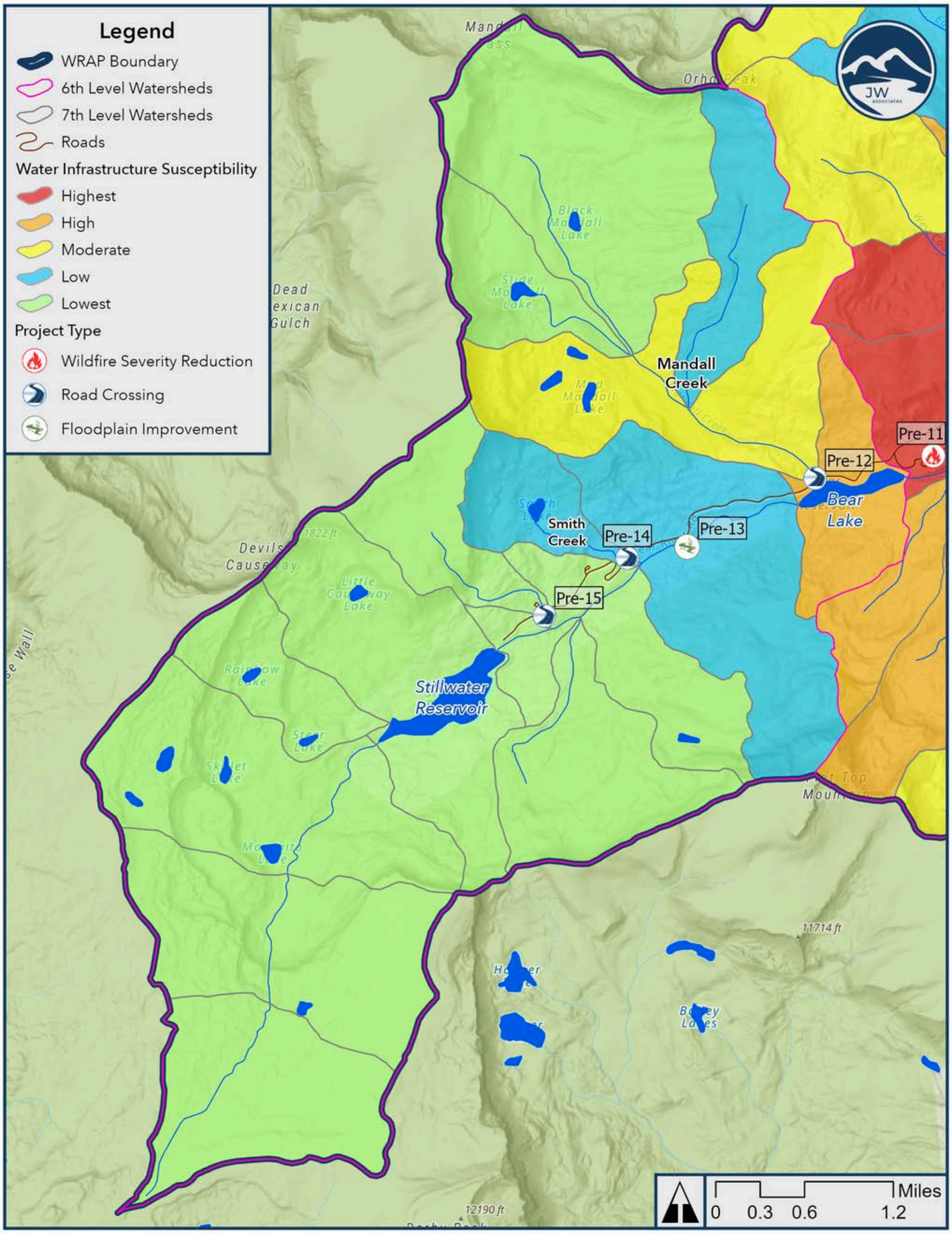
Map 28. Headwaters Bear River Region Pre-fire Project Recommendations overlaid on Land Ownership

HAZARD ANALYSIS WITH PROJECT RECOMMENDATIONS



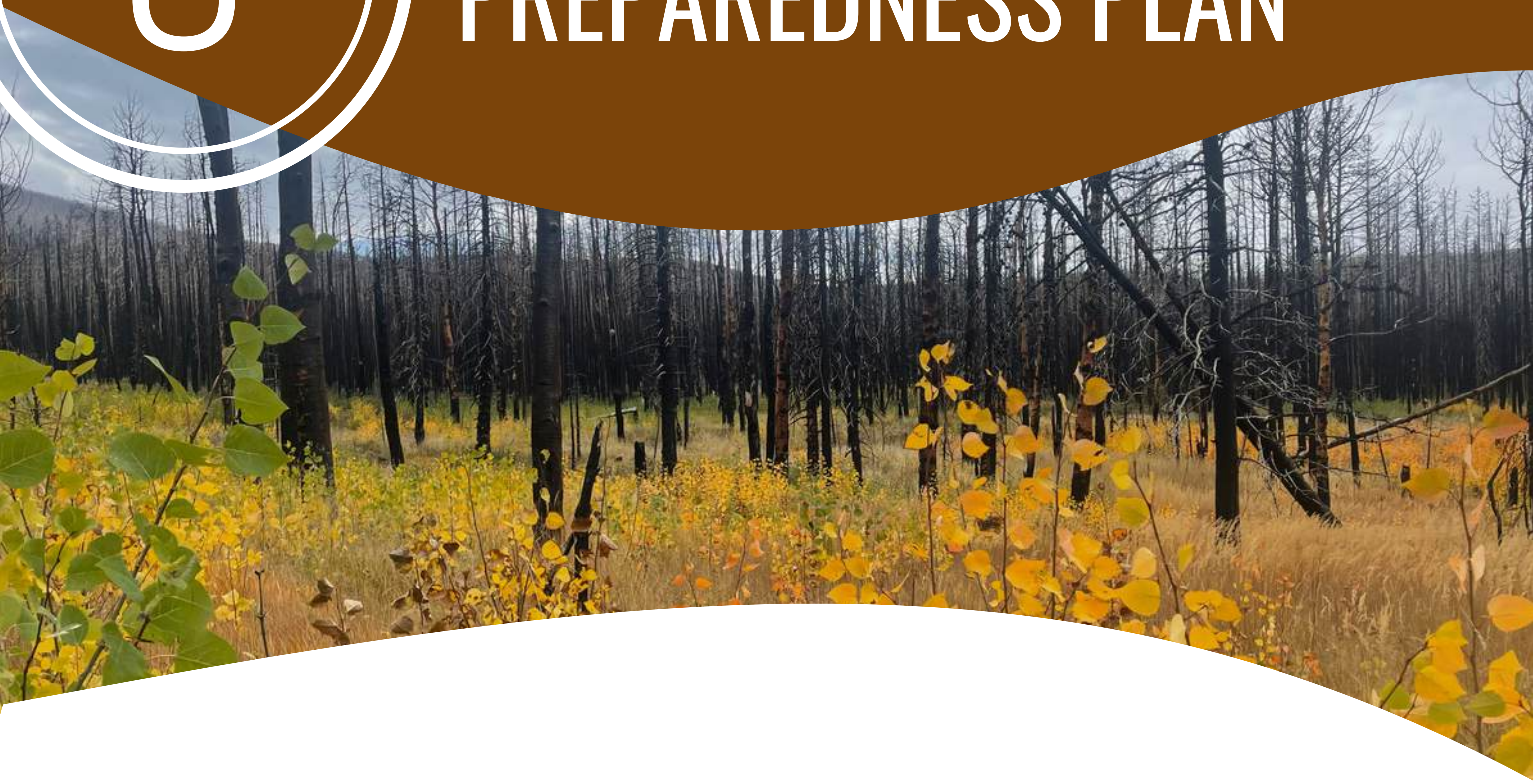
Map 29. Headwaters Bear River Region Pre-fire Project Recommendations overlaid on Wildfire Composite Hazard Analysis Ranks

SUSCEPTIBILITY ANALYSIS WITH PROJECT RECOMMENDATIONS



Map 30. Headwaters Bear River Region Pre-fire Project Recommendations overlaid on Water Infrastructure Susceptibility Ranks

6 POST-FIRE PREPAREDNESS PLAN



Wildfires are emergencies and some of the adverse post-fire effects will occur soon after the fire is contained and some will take a longer time to develop. The location, intensity, duration and extent of rainfall events on burned areas will likely determine the timing and intensity of post-fire effects. Therefore, the urgency of post-fire mitigation measures depends on exposure of the burned area to rainfall events during monsoon season for example. But there are a number of items to begin even before the fire is contained.

Use Small Watershed Analysis for Priorities. During a wildfire, review the small-scale analysis completed pre-fire for this WRAP, to determine if the fire is burning or will likely burn intensely in high hazard areas. Use that assessment to guide suppression efforts to either let that area burn under current conditions or encourage maximum suppression efforts in high hazard areas.

6 A. During Suppression

The Incident Command (IC) is in control of suppression efforts during the fire. They are focused on their very important work. However, there are some situations when communication with the IC would be valuable.

Some of these situations are:

- The IC makes a decision to use full suppression because they know that a reservoir/water supply could be impacted. However, the area that the fire is burning in would benefit from a natural "treatment" and there are other factors that minimize the potential for impacts to water supply lower in the watershed. Communicating those perspectives to the IC might change their decisions about suppression. This situation happened in 2013 with the Big Meadows Fire in Rocky Mountain National Park.
- There are treatments along roads and ridgeline fuel breaks that could be used as control lines or help to slow the fire down. A map of these features within and around the burn perimeter should be prepared and delivered to the IC as soon as possible. The IC could use those features on the landscape for retardant drops or safe zones, etc. This situation happened in 2018 with the Buffalo Fire above Silverthorne.
- There are some critical watersheds identified in this plan that would be especially problematic post-fire. If the IC knows about the locations and conditions of those watersheds, they might be able to use that information to make better decisions in those areas.

Buffalo Fire, 2018

6 B. First Steps Post-fire

There are some resources that provide excellent direction and first steps for being prepared after a fire. The Colorado Post-fire Playbook is a good place to start.

- Contact all the critical contacts from local, state, and federal entities. There may be some new people so this may take more time. Use the Colorado Post-fire Playbook template to identify critical contacts.
- Establish a Local Recovery Group (LRG).
- Identify a post-fire liaison for your entity. Expect this person to be full-time on post-fire for several years. There are sources of funding available, which are described in further detail below.
- Contact the appropriate agencies and request to be involved with the Burned Area Emergency Rehabilitation (BAER) Team. Review the post-fire hazard assessments and bring that information to the BAER Team meetings. Advocate for watershed protection measures during the determination of mitigation measures by the BAER Team.
- Request the Burned Area Reflectance Classification (BARC) map from the BAER Team. The post-fire hazard analysis for this WRAP is based partly on estimates of burn severity. The BARC map can be used as an estimate of actual soil burn severity. Updating the post-fire hazard analysis with the actual soil burn severity will provide valuable information on expected locations and types of post-fire effects. That analysis can be used to prioritize post-fire watershed protection measures.
- Contact the National Weather Service (NWS) about plans for early warning systems. Provide your knowledge and WRAP analysis to the NWS to help develop a robust early warning system. Locations that are Moderate to Highest Hazard in the Susceptibility Analysis would be important places to consider the use of early warning systems.

6 C. Planning and Implementing Post-fire Treatments

The line between post-fire and pre-fire mitigation is blurry and cyclical in nature. Pre-fire actions are vital for preparing watersheds to bounce back more quickly from future fire, and post-fire mitigation actions can be completed to help watersheds recover more quickly. There are four categories of post-fire actions which are described in detail in this section.

1. ***Collaborative Planning & Communication***
2. ***Identifying & Prioritizing Treatments***
3. ***Securing Funding from Various Sources***
4. ***Implementing Post-Fire Treatments***

COLLABORATIVE PLANNING AND COMMUNICATION

Utilizing Steps 1-3 from the First Steps Post-Fire section, gather the appropriate personnel and liaisons to form a committee that maintains regular communication (weekly, monthly, etc.) for post-fire response and watershed mitigation planning. The post-fire liaison from your entity should work with the LRG to gather the necessary local, state, and federal entities to be a part of this committee. This collaboration may seem tedious at a time when quick action is needed, but it can be an invaluable resource for understanding what different entities are doing, what the funding sources are, and how your entity can plug in to help where you are needed and accomplish your specific goals.

The LRG will be valuable for communication between partners and for allocating responsibilities and entities that report back through their organizations. Communication to the public from the LRG can also be useful before, during, and after the emergency. Demonstrating to the public that various agencies and groups are working together and have plans for post-fire response, will alleviate at least some public concerns and provide a consistent public message. Communication to the public is often overlooked in the emergency situations following wildfires but has tremendous value. The LRG should have a designated representative that is responsible for regular public communication.

The LRG should establish a regular schedule for meetings. Initial meeting(s) should be in-person but subsequent meetings can be virtual. The meetings should focus on updates that are important to the group and work that involves several partners. These meetings should be as brief as possible to maintain and encourage participation.

IDENTIFYING AND PRIORITIZING TREATMENTS

For most wildfires, and especially large fires, there will be a gap between the initial estimates of the cost of treatments and the available funding. Therefore, identifying priorities is essential in applying limited funding to the watersheds and treatments that are most effective and have important values at risk.

Mitigation measures will need to be determined on a site-specific basis. However, it is recommended that mitigation measures focus on effectiveness of treatment rather than cost per acre. Mitigation that targets fewer acres but with a higher effectiveness will likely be more successful. For example, wood shred mulch is much more effective on steep, high burn severity slopes than agricultural straw, but costs more. Targeting specific high hazard areas to be treated allows these more effective, but possibly more expensive, treatments to provide higher levels of watershed protection, sometimes at the same overall cost.

Utilize the Pre-fire Projects List, in the *Task 5 - Pre- and Post-fire Planning and Mitigation Activities* Deliverables. to identify the action items that were not accomplished pre-fire. Often, these can be done post-fire to protect infrastructure and other values-at-risk. There is often more funding available and fewer permitting hurdles in a post-fire situation, than there would be pre-fire. Infrastructure upgrades and improvements, removal or replacement of existing infrastructure, creation of redundant intakes or development of water supply alternatives generally would not occur pre-fire due to limited financial resources, permitting requirements, property owner permissions, or other factors.

Use the Watershed Hazard Assessment, in the *Task 3 - Post-Fire Hazard Analysis* Deliverables, for priorities. During a wildfire, review this small-scale analysis, which was completed pre-fire, to determine if the fire is burning or will likely burn intensely in high hazard areas. The analysis completed for this WRAP utilized modeled burn severity mapping. Upon receiving the updated burn severity BARC map from the BAER team, plug the actual burn severity data into the same small-scale watershed analysis to determine the post-fire hazards specific to the burn area. This process should be efficient and can use much of the GIS data already collected as part of the WRAP planning process.

Consider the geomorphology and connectivity of headwaters to the mainstem. Watersheds connected to perennial streams in areas of high valley confinement should be given higher treatment priority than those with low valley confinement due to lack of alluvial fans and a wide floodplain for sediment to settle out before the water enters a river (Rathburn from Miller et al., 2017). Research following the High Park Fire suggests that across a large burn area, remote sensing and "connectivity indices" based on the degree of valley confinement can be used to evaluate the network of smaller catchments feeding into the mainstem to prioritize treatment after a burn (Miller et al., 2017).

CONNECTED TREATMENTS

As with pre-fire actions, accomplishing multiple treatment types within priority watersheds and on locations that have important values-at-risk to protect, will be more successful than distributing the post-fire projects throughout a larger area, but with fewer projects in each location.

Upper Hillslopes and Connections to Streams

High-severity fires can dramatically change runoff and erosion processes on hillslopes in watersheds, particularly if followed by high-intensity rainfall events. Sediment yields from hillslopes burned at a moderate to high severity tend to be an order of magnitude higher than those burned at low severity (Johansen et al. 2001, Gannon et al. 2017). High-severity fires increase erosion susceptibility by exposing soils as more of the forest floor is consumed, which increases both sediment and water yields (Wells et al. 1979, Robichaud and Waldrop 1994, Soto et al. 1994, Neary et al. 2005, and Moody et al. 2008). High-severity fires also can cause the development of hydrophobic layers, a formation consisting of a waxy, water repellent layer, created by fire-induced volatilization of organics. These hydrophobic layers reduce infiltration rates which exacerbates runoff (Hungerford et al. 1991).

The delivery of hillslope sediments to streams has numerous ramifications for water supply infrastructure, including both the physical effects of sediment deposition in surface waters as well as chemical changes to water quality. Increased nutrients in the sediments can promote growth of algae, affecting water taste and odor. Increased concentrations of dissolved organic carbons can form potentially carcinogenic by-products during disinfection and increased metals can increase treatment costs (Writer and Murphy 2012).

Table 8. Frequently used post-fire treatments by category

CATEGORY	TREATMENT	DESCRIPTION
ROAD	Armouring	Covering road, hillslope surface or ditch with aggregates and rocks to protect the surface
	Culvert modifications	Upsizing existing culverts; armouring inlet and outlet areas; attaching metal end sections
	Culvert removal	Removing cross-drain culverts that are too small (≤60 cm (24 in)) for expected increased flows
	Culvert risers	Vertical extension of upstream culvert to sieve debris and to allow passage of water
	Debris racks or deflectors	Barrier (trash rack) across stream channel to hold debris and keep culverts open
	Low-water crossing	Temporary fords and low-water overflows when culverts cannot handle increased flows
	Out-sloping	Shaping a road surface to divert water off the surface to the road fill
	Overflow structures	Structures to control runoff across across the road surface and to protect the road fill
	Road closure	Closing roads with gates, jersey barriers, barricades, signs and closure enforcement
	Rolling dips or water bars	Road grade reversal to direct surface flow across the road
	Storm patrol	Checking and cleaning drainage structure flow across the road
HILLSLOPE	Silt fences	Geotextile fabric installed to form an upright fence to trap sediment
	Mulching	Materials spread over burned soil using aerial or ground application technologies
	Agricultural straw mulch	Wheat, barley and rice straw are most frequently used, should be certified weed free
	Hydromulch	Fibrous material (wood, paper, etc.), tackifiers and optional materials mixed with water into slurry for application; hydromulch adheres to the soil surface after it dries
	Wood shreds	Green or burned trees shredded by a horizontal grinder to produce a coarse mulch
	Wood strands	Narrow slats of wood of various lengths manufactured from scrap veneers
	Seeding	Plant seeds spread over burned area; usually applied aerially
	Slash spreading	Trees and brush scattered over burned area
	Soil scarification or drilling	Tilling burned soils with a rake or disc to break up water-repellent soil layer
CHANNEL	Channel-debris clearing	Removal of woody debris from channels when there are vulnerable values-at-risk downstream
	Channel deflectors	Structures that direct stream flow away from unstable banks or values-at-risk
	Check dams	Small structures placed perpendicular to the flow that store sediment on the upstream side; made of logs, straw bales, rocks, etc.
	Debris basins	Constructed basin to trap and hold sediment and debris
	Grade stabilisers	Structures installed at channel grade to decrease incision; made of rocks, logs and wood
	In-channel tree felling	Felled trees placed at a diagonal angle along channel reaches to slow flow and trap sediment
	Stream bank armouring	Rock reinforcement of the stream bank

Adapted from Robichaud *et al.* (2014)

Applying treatments to the burned hillslopes, addresses the source of runoff and soil erosion. Treatments at the top of the watershed will minimize the power of runoff that can pick up more sediment and cause more erosion and head cutting as it gains energy making its way down the hillslope. These hillslope treatments could include grade control structures high in watersheds to minimize gully head-cutting, felling of dead trees into small channels to provide roughness, and application of wood shred or wood straw mulch.

Treating Hillslopes with Wood Mulch

Mulching is one of the most effective post-fire landscape level treatments (Robichaud et al. 2010) and has been proven to reduce rainfall splash and surface runoff, increase soil moisture and, consequently, improve revegetation. Wood mulch has been increasingly used as a post-fire treatment in Colorado, including after the High Park Fire (2012), Cameron Peak Fire (2020), and East Troublesome Fire (2020). One key benefit of aerial mulching is that the permitting requirements are minimal because it is not a ground disturbing activity. Often, mulching is the only treatment that happens within the first year post-fire, due to the needs for permitting in-stream treatments on National Forest Lands.

Unlike agricultural straw mulch, which can bring invasive weeds and during dry weather can be moved off site by wind, wood mulch can be made from trees burned in the fire, thereby minimizing the risk of introducing any noxious plants or foreign materials. It is also less prone to being blown off-site during windy periods. The wood mulch used following the High Park Fire survived the 2013 Flood, which dumped 12 inches of rain in two days on the burned area. A recent meta-analysis of 222 post-fire soil erosion mitigation treatments showed that 81% of treated areas

Photo: John Hammond

had reduced erosion compared to the untreated controls (Girona-Garcia et al., 2021). This study shows both wood mulch and straw mulch having a significant effect on post-fire erosion rates, which increase with increasing application rates, up to a point, above which higher application rates have a limited impact on the overall erosion reduction. Girona-Garcia et al. (2021) also indicate that the treatment effectiveness has a tendency to decrease with time-since-fire but only for the first three post-fire years. The treatments' effectiveness also becomes increasingly variable with more years post-fire. This illustrates the need to get treatments on the ground as soon as possible following the fire, in order to have the greatest impact on runoff and erosion mitigation.

Aerial wood mulch application following the Cameron Peak Fire. Photo: JW Associates

Aerial application of wood mulch can be expensive, usually costing between $1,500-2,500 per acre, depending mostly on the flight distance and the location of the mulch source. One option for reducing this cost is to utilize on-site or nearby burned trees, for example the hazard trees along USFS roads, as a mulch source. Another way to reduce the cost would be to utilize in-situ mastication rather than aerial application of wood mulch in areas that have sufficient access for the mastication equipment. Using hazard trees on NFS Lands would likely be easier if an agreement is in place before the fire occurs with the USFS.

New technology such as Ponsee Equipment can perform mastication on slopes up to 60% with little to no soil compaction or disturbance. Doing either of these on USFS lands requires approval of and coordination with the Forest Service. Planning for this ahead of the fire could significantly reduce the amount of time it would take to accomplish this in order to execute the treatments quickly following the fire. It was also advised following debrief of the mulch operations on Cameron Peak Fire (2020) that the helicopter mulching contract should be compensated by tons of mulch applied or hours of work, rather than by area mulched. This would allow on the ground inspectors to determine when the area has been mulched adequately.

Mulching may be effective for keeping sediment in place on hillslopes, but has not been shown to have a larger scale effect on in-channel processes at the watershed scale. Research on the watershed scale impacts of aerial wood mulch treatments by Colorado State University following the East Troublesome Fire identified some key lessons learned that can be implemented to improve the efficacy of the wood mulch treatments.

IMPROVE THE EFFICACY OF WOOD MULCH TREATMENTS BY:

1. Target lower and middle elevations which may be more susceptible to erosion due to their topographic characteristics.
2. Apply mulch as quickly as possible after the fire and before summer thunderstorms can initiate erosional pathways.
3. Mulch greater fractions of high-priority watersheds at higher application rates.
4. Use high-resolution topography to identify potential flowpaths so that mulch placement may disrupt connectivity to larger stream channels.

Source: Nelson et al., 2024

Mulching can also reduce the rapid overland flow on moderate and high burn severity soils, thereby reducing post-fire peak flows from rainfall events. Mulch, used in combination with other treatments in channels or further downstream, can increase the effectiveness of the combined treatments. In general, mulch is recommended to be used when there is a large percentage of a watershed that contains moderate or high burn severity and there is a value at risk downstream.

The following graphic from *Science You Can Use* in 2017 summarizes research conclusions from the mulching operations on the High Park Fire (2012).

MANAGEMENT IMPLICATIONS

What can we say about mulching and seeding after the High Park Fire?

- Mulching reduces soil movement on hillslopes, depending on the application and whether or not the mulch stays in place. Over time the mulch moves off the site and the areas become vegetated. Straw mulch did not work as well when applied to exposed areas (where it could easily blow away); these areas are good candidates for wood mulch. Straw mulch only worked well to control erosion when applied in a smooth rather than clumped fashion.
- At the larger watershed scale, the effects of mulching on water quality are difficult to quantify because of variable rainfall across the burn area and challenges of quantifying how much of the sediment eroded from hillslopes reaches the outlets of watersheds.
- Mulching does not negatively affect lodgepole pine regeneration and may enhance it, although other factors such as seed sources and elevation may be more important.
- Seeding helped to control weeds and created a high level of perennial grass cover. However, over 3 years the trend was that the seeded mixture dominated the site, which suppressed weeds but also slightly reduced overall plant diversity.

Source: Miller at al. 2017. Learn from the burn: The High Park Fire 5 years later.

The following graphic from the Executive Summary of a CWCB funded Mulch Monitoring Study summarizes conclusions from the mulching operations on the Cameron Peak Fire (2020).

Lessons Learned for Future Aerial Wood Mulch Operations:

Aerial mulch is the quickest treatment to be permitted on National Forest Lands.

- Mulching is expensive but treating as much as possible in hazardous watersheds increases effectiveness.
- Adjust mulch treatment areas for slope to correctly apply the amount of mulch needed for good coverage.
- Areas that contain higher rock content can still benefit from mulching.

Contractor management

- Plan for enough time for adequate inspection to ensure the best treatment on the ground.
- Consider modifying the compensation structure. Paying the contractor by tons of mulch applied or hours of work, rather than by area mulched could improve results.

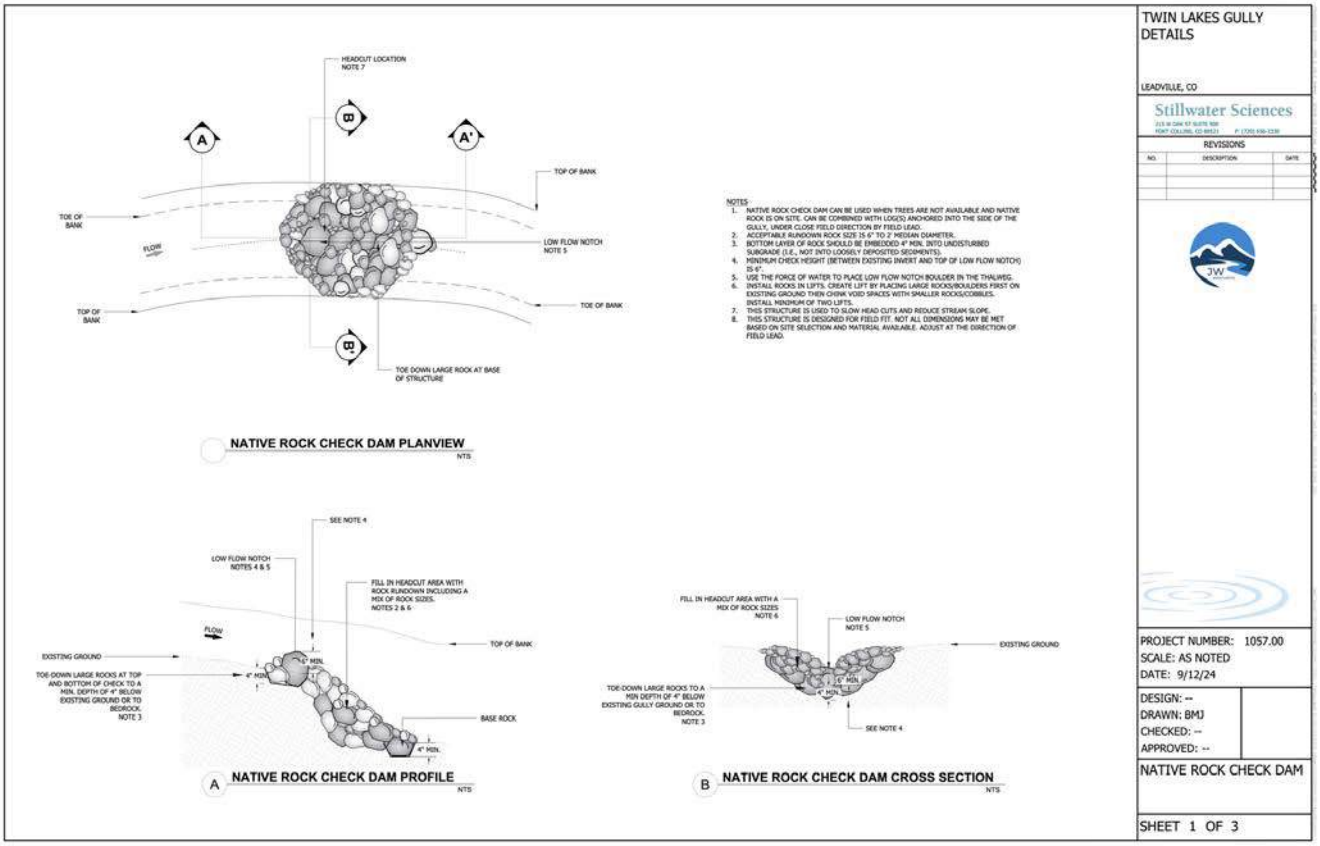
Grade Control and Gulley Treatments

Grade control structures are used in very small headwater channels that are in danger of downcutting. They are typically made from large rocks and/or trees that are found close to the site. They are usually installed in a series of 10 or more. Areas that are identified for the use of these structures would be burned areas where there is no riparian vegetation and the burned areas surround the channel.

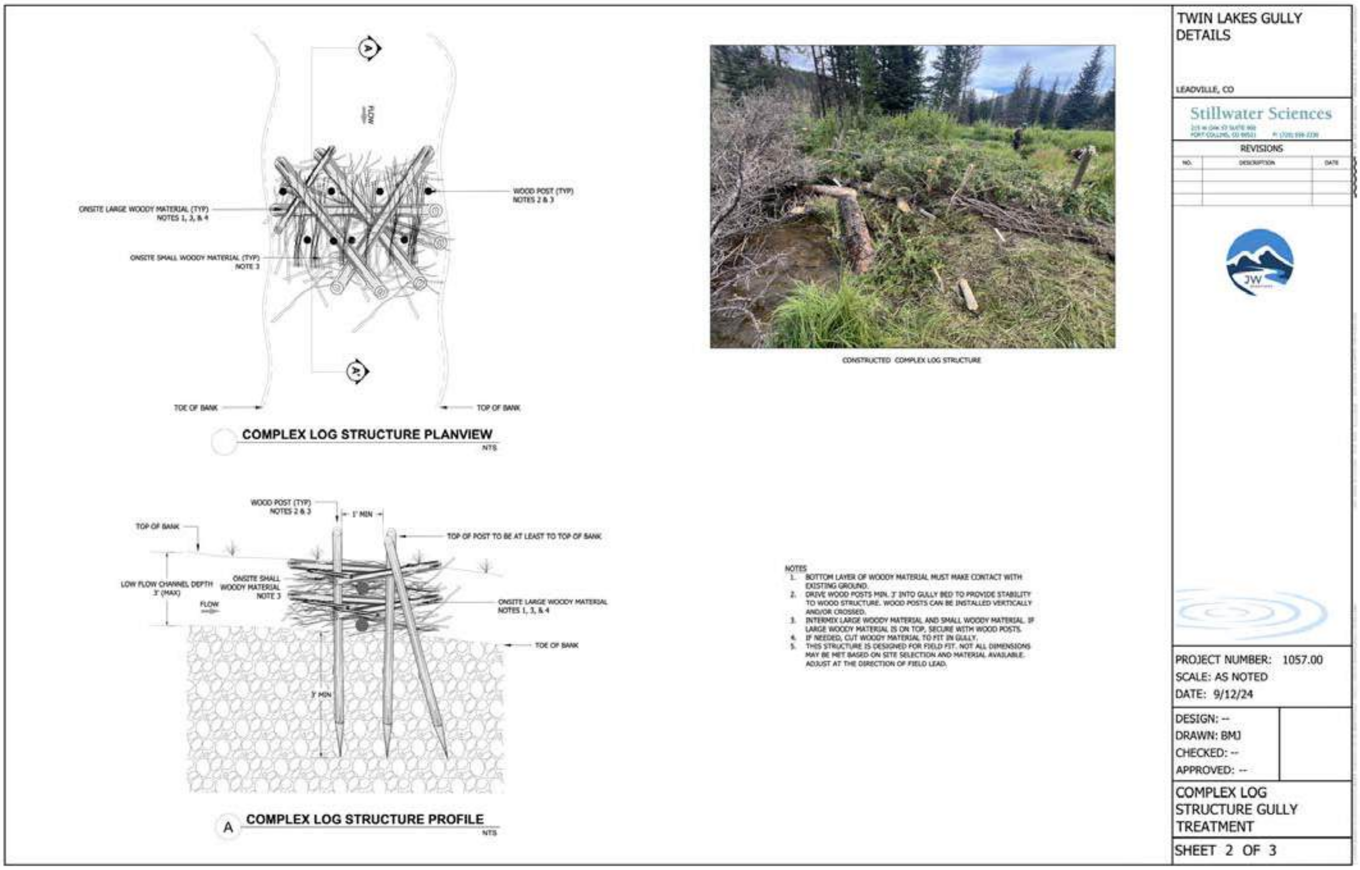
Locations for grade control structures would need to be identified in the field, although some analysis tools could be used to provide initial estimates. Targeting structures to within mulch polygons would help with efficiency of field verification, as well as possible cost reduction for implementation. It is also likely that both treatments would be targeted at the highest priority watersheds. Because the locations are usually on steeper ground and not necessarily close to roads, they would be installed by hand crews. The materials costs would be minimal but crews of 2-3 people would need a day to install ~10 structures. They would likely not be installed in Wilderness Areas.

GULLEY TREATMENT DESIGNS

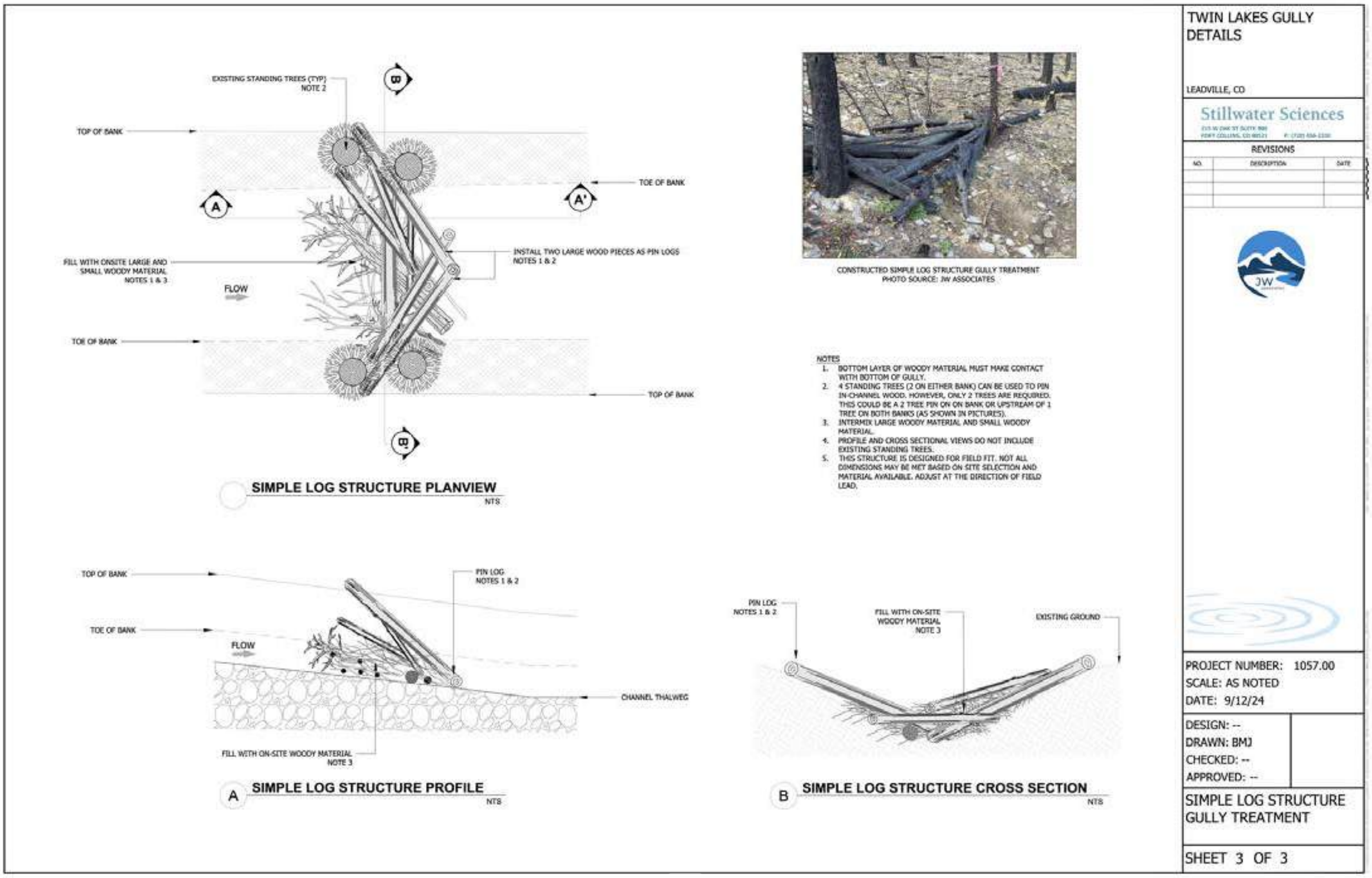
Treatment 1: Native Rock Check Dam



Treatment 2: Complex Log Structure



Treatment 3: Simple Log Structure



In-stream Treatments

In-stream treatments below burned areas should be installed where they either protect Values-at-Risk (see below) or enhance natural stream functions. Natural stream functions that can be beneficial post-fire are sediment depositional areas that settle out some of the increased sediment yield from post-fire runoff, and functional connections between the stream and the floodplain. Connected floodplains can function as sediment depositional areas and can ameliorate post-fire peakflows. Low Tech Processes Based Restoration (LTPBR) such as beaver dam analogs (BDAs) are popular because they are relatively low cost and mimic natural processes. LTPBR can be used as in-stream treatments post-fire but care should be taken in their application due to the flashy nature and dramatic volumes of post-fire stream flows. All in-stream treatments below burned areas should be designed to enhance natural stream function, which will increase their effectiveness. In-stream treatments should also be monitored, especially after rainfall events, to determine if modifications are needed to increase or maintain their function. Upper hillslope and gulley treatments above the in-stream treatments will make the in-stream treatments more effective and lower the risk of them being destroyed during runoff events.

Hazards above Denver Creek road crossing – East Troublesome Fire. Photo: JW Associates

Beaver Dam Analogs installed along Fish Creek in Estes Park, have trapped sediment and reconnected the floodplain. Photo: Stillwater Sciences

Fancy Creek Crossing replaced pre-fire. Photo: JW Associates

Protecting Downstream Values-at-Risk

Roads

Use the pre-fire roads analysis to target road crossings and roads by streams for treatments. If you were able to upgrade road crossings pre-fire, those should be lower priority for post-fire treatments, as they should already be more resilient to post-fire conditions. The crossings identified as hazardous that have yet to be upgraded should be the first priority for post-fire treatment. One of the most effective treatments on low volume forest roads is to replace culverts at stream crossings with low water crossings. These can be installed quickly and at low cost. They allow sediment and debris to move across the road. Road crossing failures are common post-fire and can initiate debris flows downstream and/or stream channel instability. It is also possible that high post-fire peak flows will blow out a road that is vital for access to important water supply structures and/or life and safety. The low water crossings can then be replaced with more appropriate crossings if needed 5+ years post-fire.

Structure Protection

Use the pre-fire hydrology, sediment, and debris flow analyses to identify locations, often at the base of high hazard watersheds, that are in danger of increased peak flows, flooding, or debris flows. Identify structures using the GIS data included in the WRAP and determine the best methods for protecting those structures based on site-specific characteristics and hazard modeling.

Black Hollow Debris Flow - Cameron Peak Fire

Sediment Control

Review plans for sediment control structures and determine if they should be taken through the final stages of permitting and installation. Although these structures are expensive, the effects from fire may be even more expensive. Several water agencies with recent experience in Colorado have estimated that it is 10-20 times more expensive to remove sediment from a reservoir than the cost of these temporary structures.

Concrete (permanent) sediment basin at the mouth of a tributary to West Monument Creek, installed following the Waldo Canyon Fire (2018). Photo: Stillwater Sciences

Recent wildfires in Colorado have resulted in significant impacts to watersheds from increased sediment yield and debris flows following post-fire rainstorms. A number of the large fires (e.g. Hayman Fire 2004, High Park Fire 2012 and Waldo Canyon Fire 2012) resulted in impacts to water quality and water supply infrastructure. Post-fire hillslope and upper watershed channel treatments and mitigation measures were in many cases inadequate to reduce the impacts to water supply infrastructure. Post-fire sediment basins of various designs have been used with some success in reducing the impacts from wildfires during runoff events following wildfires.

Sediment basins near the bottom of the highest hazard watersheds should be considered. These would be recommended only where there is a combination of lack of ability to complete upper watershed treatments and location of values at risk just downstream of the watershed. A number of different types of sediment basins have been used in post-fire environments in Colorado. The type of structure depends on the expected sediment volume, suitability of the site, access to the location, and downstream values or structures. Sediment basins usually require cleaning out following significant storms and removal after they are no longer needed.

Sediment Basin in Soldier Canyon after High Park Fire (2012). This Gabion wall was quite efficient at settling out sediments while allowing water to move through. Following removal, the sediment collected was used to improve the conditions on local roads. Photo: JW Associates

It is ideal to use temporary structures that can be removed from the area once the watershed has recovered or revegetated. Temporary structures include earthen levees, temporary and quickly deployable structures such as a Muscle Wall, water filled barriers such as an AquaDam, or rock-filled wire baskets called Gabion walls. Sediment basins can be used in small drainages post-fire to retain flood flows, sediment, and debris to help protect critical infrastructure downstream, but are ideally only used when absolutely necessary in emergency scenarios. A sediment basin is a large berm feature, often installed at the mouth of the basin, that spans the valley bottom to catch sediment and debris. Sediment basins are expensive to construct and require long-term maintenance to remove the accumulated sediment and debris over time and have risk of inadvertently causing additional impacts if the berm feature fails during a large event.

When possible, sediment basins should be constructed with earthen berms rather than concrete to allow for cheaper and less intrusive removal of the structure once fire-impacts within the drainage have subsided.

Although sediment basins can help reduce impacts to downstream infrastructure post-fire, they also disrupt natural sediment continuity processes, which can lead to undesirable channel response downstream such as channel incision and/or widening. Therefore, when considering the use of sediment basins, it is important to understand the potential geomorphic response in downstream reaches to a reduced sediment supply. Installing sediment basins on larger, perennial tributaries that naturally contribute more sediment will be more impactful, while smaller, ephemeral tributaries that naturally contribute minimal sediment except episodically (such as post-wildfire) will generally be less impactful.

SECURING FUNDING FROM VARIOUS SOURCES

Post-fire projects can be expensive but there are a number of programs that provide funding/grants at both the state and federal level. The United States Department of Agriculture (USDA) and Federal Emergency Management Agency (FEMA) both have post-wildfire programs (Tables 9 and 10). In Colorado, the Colorado Water Conservation Board (CWCB) has provided funding for post-fire projects. There are many different requirements and limitations on the use of funding and a myriad of requirements to obtaining the funding, permitting its use, and reporting back to the agency during and after the projects are completed. Table 11 shows some of the key sources of funding in Colorado (this table is presented in the Colorado Post-fire Playbook). Make sure to check any updates to the Colorado Post-fire Playbook.

These various funding requirements and limitations are changing and therefore an in-depth description of the requirements and limitations would not be helpful in this plan. The best post-fire strategy is to contact the agencies and other funding organizations and have them describe the best application for their available funding. It is also recommended to start early communication with local, state, and federal officials and legislators. Provide information to these officials and legislators on the need for post-fire funding and the values at risk.

Table 9. Partial list of USDA post-wildfire programs.

PROGRAM/ POLICY	JURISDICTIONAL FOCUS	TIMEFRAME	ROLE IN POST-FIRE RESPONSE AND RECOVERY PROCESS
USFS Burned Area Emergency Response (BAER)	National Forest System lands and Tribal trust lands	Within one year of incident containment	Emergency stabilization and treatments on federal lands to protect and prevent further degradation of natural and cultural resources threatened by post-fire conditions, assess post-burn soil, plant, habitat, and hydrologic conditions, and prepare integrated plans to respond to threats.
USFS Burned Area Rehabilitation (BAR)	National Forest System lands and Tribal trust lands	Within three years of incident containment	Recovery of burned landscapes unlikely to recover without human intervention, including mitigation of invasive species threats, soil disturbance, reseeding/seedling planting, contouring for runoff control, or minor infrastructure/resource repairs.
NRCS Emergency Watershed Protection (EWP)	Private land and property	Projects must be completed within 220 days of EWP funding allocation for non-life-threatening disasters	Conduct emergency measures to safeguard life and property and remove/reduce hazards caused by natural disasters, including streambank stabilization, channel sediment and debris removal, infrastructure repair, and slope stabilization.
FSA Emergency Forest Restoration (EFRP)	Non-industrial privately owned forest land	Within two years of project approval	Provides up to 75 percent of cost-share funding for debris/downed tree removal for establishing new stands, replanting costs, reconstruction of forest roads, fire lanes, fuel breaks and erosion control structures, fencing, and wildlife habitat enhancement.

Table 10. Partial list of FEMA post-wildfire programs.

PROGRAM/POLICY	JURISDICTIONAL FOCUS	TIMEFRAME	ROLE IN POST-FIRE RESPONSE AND RECOVERY PROCESS
Public Assistance (PA) program (Section 402)	National Forest System lands and Tribal trust lands	Within one year of incident containment	Emergency stabilization and treatments on federal lands to protect and prevent further degradation of natural and cultural resources threatened by post-fire conditions, assess post-burn soil, plant, habitat, and hydrologic conditions, and prepare integrated plans to respond to threats.
Hazard Mitigation Grant Program (HMGP) - Program available in the Fire Management Assistance Grants (FMAG)	Public land (state, county, or municipality)	Within six months of the end of the fiscal year in which FMAG funding was awarded.	Actions to prevent long-term damage to life and property from natural hazards, e.g., soil stabilization, flood diversion, and reforestation.
The Robert T. Stafford Disaster Relief Act (Stafford Act)	All non-federal lands	N/A	Governing policy for every FEMA program.

Table 11. Key Sources of Post-fire Funding in Colorado

FUNDING MECHANISM	FUNDING SOURCE	DEADLINE	AVAILABLE FUNDS	MATCH
Emergency Watershed Protection Funding	USDA-NRCS	Within 60 days of the fire	Project Specific	Sponsor pays 100% up front costs; reimbursed up to 75%
Colorado Watershed Restoration Grant Program	CWCB	November	$4 million statewide	>50% in-kind or cash
Colorado Water Supply Reserve Fund Grants	CWCB (with approval from a Basin Roundtable)	Rolling	Variable - $1m-$12m per basin	> 25% in-kind or cash (possible waiver)
Colorado Severance Tax Operational Fund Grants	CWCB	January	Not specified	Not specified
Colorado Healthy Rivers Fund (partner with a local watershed organization)	Colorado Watershed Assembly	November	$20k maximum	> 20% in-kind or cash (cash match only for project application)
Post-fire - Fire Management Assistance Grant	FEMA	When a state or tribal disaster is declared	Variable depending on Hazard Mitigation Plan status. About $500k	Not specified
FEMA Public Assistance Program	FEMA	When a state or tribal disaster is declared	Not specified	The federal share of assistance is not <75% of the eligible cost
Community Development Block Grant - Disaster Recovery	DOLA-HUD	Following presidential disaster declaration	Not specified	Not specified
Emergency Community Water Assistance Grants (for rural communities and tribes)	USDA - Rural Development Office	Year round	Up to $500k	None required

IMPLEMENTING POST-FIRE TREATMENTS

CONTRACTING

Possibility for post-disaster contracting and agreement development. This may include:

- Creating and procuring active on-call or as-needed contracts with technical assistance teams so that when a disaster occurs, teams can be deployed quickly. These on-call contracts should plan for the fact that there will be many logistical needs if deployed.
- Maintaining on-call contracts with contractors who can implement fire recovery actions such as mulching, stream work, or infrastructure protection.
- Have a strategy for permitting in place ahead of time. Consider development of model ordinances for disaster recovery, i.e., streamlined permitting processes for emergency recovery actions. Within these, have clear language as to what type, size, and scale of event triggers the use of the disaster response permitting process.

6 D. Post-Fire Project Recommendations & Mitigation Actions

In order to summarise project recommendations, the WRAP project area will be discussed in terms of the two 6th level watersheds. Table 12 illustrates a summary of the types of recommendations within each region of the WRAP. The following sections describe each region in further detail. More information and detail about recommendations can be found in the accompanying Excel spreadsheet, Bear River WRAP Pre- and Post-Fire Project List. The specific locations for each recommendation are available in the accompanying GIS data. Both can be found in the *Task 5 - Pre- and Post-fire Planning and Mitigation Activities* Deliverables.

Table 12. Post-Fire project recommendations for each 6th level watershed within the WRAP Project Area

Watershed	Road Crossing	Floodplain Improvement	Erosion Reduction	Infrastructure Upgrades
Yamcolo Reservoir - Bear River				
Headwaters Bear River				

6 D. Post-Fire Project Recommendations
Yamcolo Reservoir - Bear River

The majority of the values at risk for the WRAP planning area are in the Yamcolo Reservoir - Bear River region. Yamcolo Reservoir and the Stillwater Ditch are the main components of water infrastructure in this watershed. In addition, there are numerous ditches and headgates along the mainstem of Bear River. The county road and main access road for the properties and upper watershed also runs along the Bear River mainstem.

The most significant hazard in the lower Bear River mainstem portion of the watershed is roads. If the pre-fire road crossings recommendations have not yet been completed, it will be important to look at those locations for post-fire infrastructure protection. Some of these crossings have post-fire recommendations that are different from the pre-fire recommendations. More information and detail about recommendations are listed in the accompanying Excel spreadsheet, Bear River WRAP Pre- and Post-Fire Project List. The specific locations for each recommendation are available in the accompanying GIS data. Both can be found in the *Task 5 - Pre- and Post-fire Planning and Mitigation Activities* Deliverables.

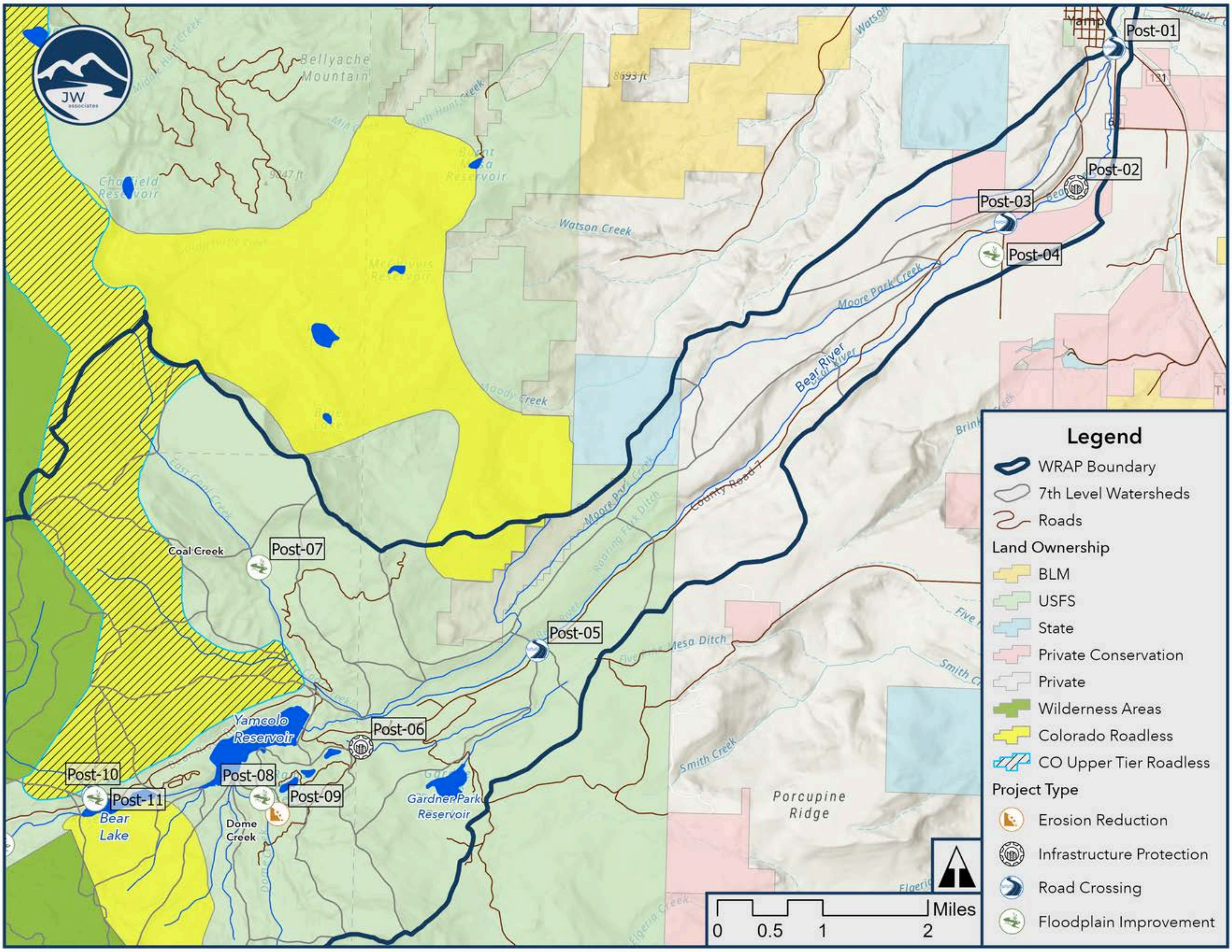
The upper section of the watershed includes Coal Creek to the north, Yamcolo Reservoir, and Dome Creek, Rams Horn, and Gardner Park to the south. The most significant post-fire hazard in these watersheds is Debris Flow. Hillslope Erosion is also a hazard in this region, and is exacerbated post-fire when there is no longer vegetative cover keeping the soil in place. Lower Dome Creek and Lower East Coal Creek both have large meadow areas that can be utilized to store post-fire sediments and slow water down before it reaches the values-at-risk below. Inspect the conditions of these locations post-fire to determine if adding structures or wood to the system will help with sediment retention. Adding mulch or gulley treatments to the hillslopes above these meadows will also create additional sediment retention higher up in the watershed.

Roads and infrastructure protection projects are also recommended in some watersheds. The necessity to implement these projects will depend on the size and severity of the burn, which will affect the impact that post-fire peakflow events may have downstream.

Table 13. Post-fire project recommendations summary for the Yamcolo Reservoir-Bear River region within the WRAP project area.

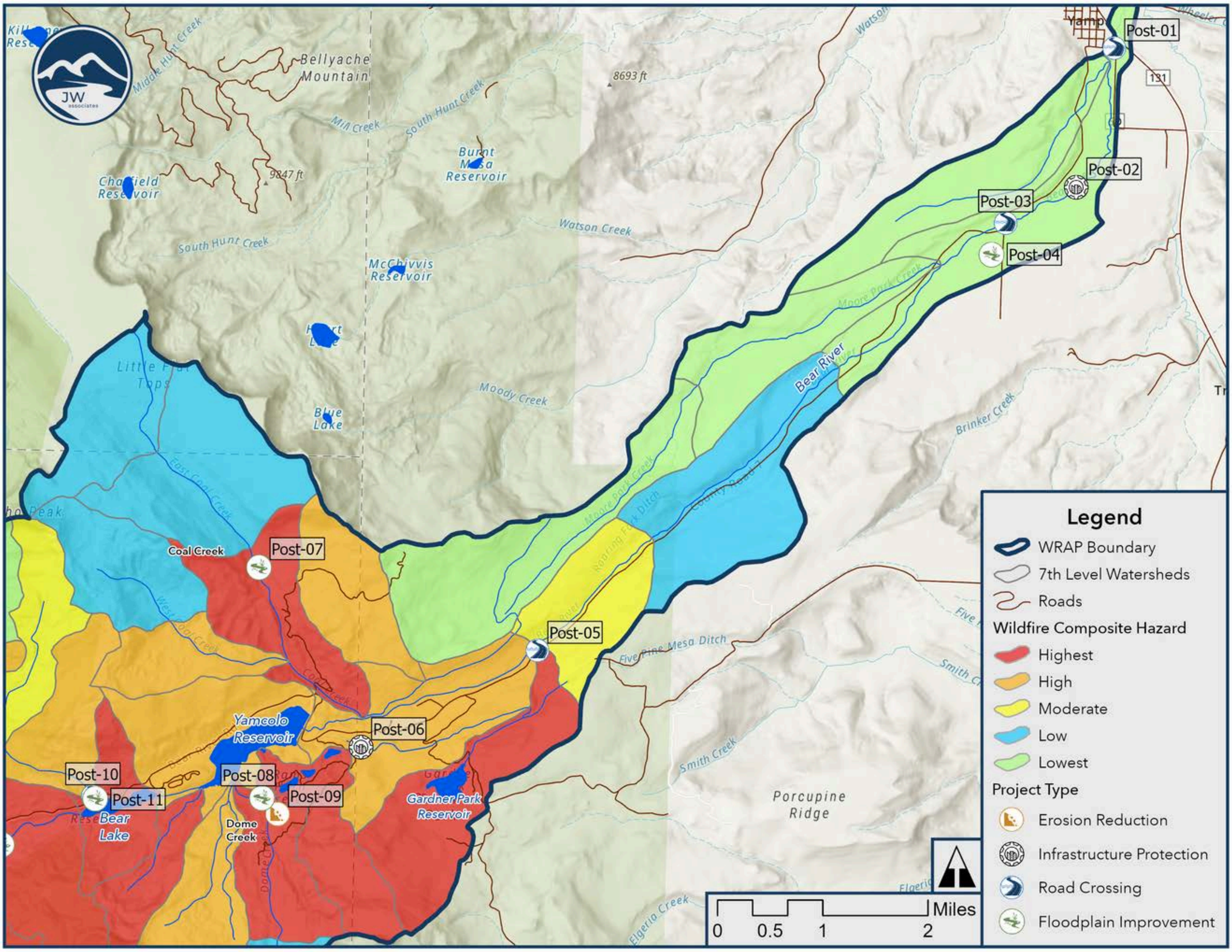
7th Level Watershed Name	WILDFIRE HAZARD	ROADS HAZARD	DEBRIS FLOW HAZARD	HILLSLOPE EROSION	WILDFIRE COMPOSITE HAZARD	LAND MANAGEMENT RESTRICTIONS	RECOMMENDED TREATMENTS
South Trib Yamcolo Reservoir	Highest	Lowest	Highest	High	Highest	Roadless	
Upper Dome Creek	Moderate	Lowest	Moderate	Moderate	Low		
West Fork Dome Creek	Highest	Lowest	Highest	Moderate	High	Roadless	
Lower Dome Creek	Highest	High	High	Moderate	Highest		 
Ram's Horn	Highest	Low	High	Moderate	Highest		
Yamcolo Reservoir	Moderate	Moderate	Moderate	Highest	High	Upper Tier Roadless	
Headwaters East Coal Creek	Lowest	Lowest	Moderate	Highest	Low	Upper Tier Roadless	
Upper East Coal Creek	Low	Lowest	Moderate	High	Low	Upper Tier Roadless	
Upper West Coal Creek	Low	Lowest	High	High	Low	Upper Tier Roadless	
Lower West Coal Creek	Highest	Lowest	High	High	High	Upper Tier Roadless	
Lower East Coal Creek	Moderate	Highest	High	High	Highest		
Maggies Nipple	Highest	Low	Highest	Low	High		
Upper Bear River	High	Highest	Low	High	High		
Gardner Creek	Highest	High	Moderate	High	Highest		
Middle Bear River	Low	Highest	Lowest	High	Moderate		
Lower Bear River	Low	Highest	Lowest	Moderate	Low		
Upper Moore Park Creek	Low	Lowest	Lowest	Moderate	Lowest		
Lower Moore Park Creek	Lowest	Highest	Lowest	Lowest	Lowest		
Spring Brook	Lowest	High	Lowest	Lowest	Lowest		
Outlet Bear River	Lowest	Highest	Lowest	Lowest	Lowest		 

LAND MANAGEMENT WITH PROJECT RECOMMENDATIONS



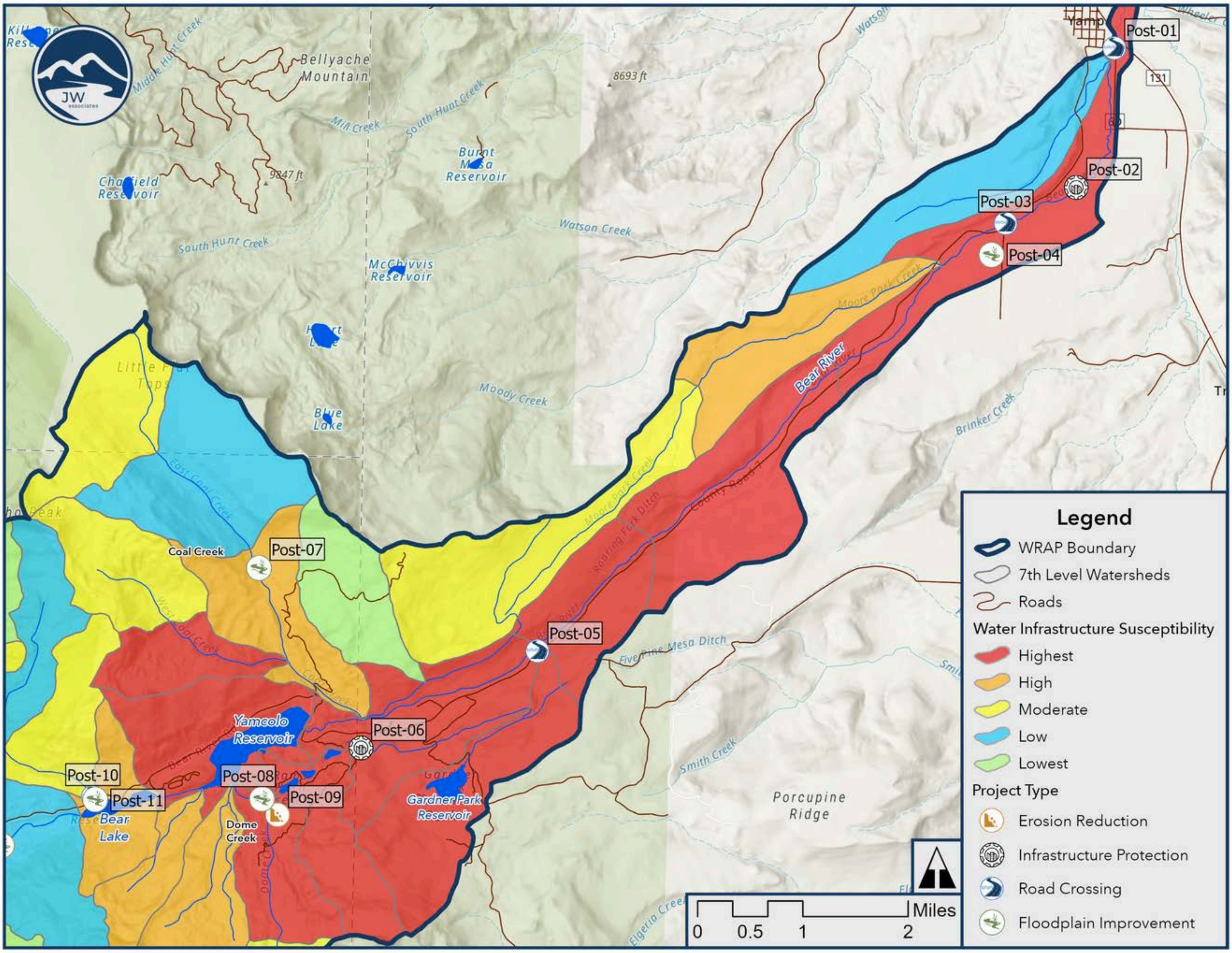
Map 31. Yamcolo Reservoir - Bear River Region Post-fire Project Recommendations overlaid on Land Ownership

HAZARD ANALYSIS WITH PROJECT RECOMMENDATIONS



Map 32. Yamcolo Reservoir - Bear River Region Post-fire Project Recommendations overlaid on Wildfire Composite Hazard Analysis Ranks

SUSCEPTIBILITY ANALYSIS WITH PROJECT RECOMMENDATIONS



Map 33. Headwaters Bear River Region Post-fire Project Recommendations overlaid on Water Infrastructure Susceptibility Ranks

6 D. Post-Fire Project Recommendations
Headwaters Bear River

Due to the significant amount of Wilderness Area in this region of the WRAP project area, the forest conditions are unlikely to be managed by treatments to reduce the wildfire severity hazard. Therefore, when wildfire does occur, it is likely to burn hot and cause significant swaths of moderate and high severity burn in these watersheds. Debris flows and hillslope erosion then become a significant threat, especially from the hillslopes that enter the mainstem Bear River between Stillwater Reservoir and Bear Lake, which are steep and follow a direct path to Bear River.

Fortunately, the post-wildfire hazards (Map 35) and the water infrastructure susceptibility (Map 36) are low in all the watersheds above Stillwater Reservoir. These watersheds do not contain any man-made Values-at-Risk, and maintain natural ecological resilience and watershed function due to their unaltered character within the Flattops Wilderness Area. This should work to protect Stillwater Reservoir from significant post-fire impacts. However, it would be prudent to inspect the conditions of these watersheds and their open meadow areas post-fire to ensure they did not lose significant function as a result of the burn.

Improving floodplain conditions in the mainstem Bear River, between Stillwater Reservoir and Bear Lake, following the burn will help to slow down the flowing water, capture sediment or debris flows entering the mainstem Bear River, and reduce the likelihood that sediment reaches Bear Lake. There are currently well-connected floodplains in this region and there is a pre-fire recommendations to enhance the area even more. Whether or not this is accomplished pre-fire, it will be important to evaluate the condition of the stream and floodplain following the fire to determine if it is necessary to implement post-fire in-stream projects, and if so, the best techniques to utilize to enhance channel and floodplain connectivity.

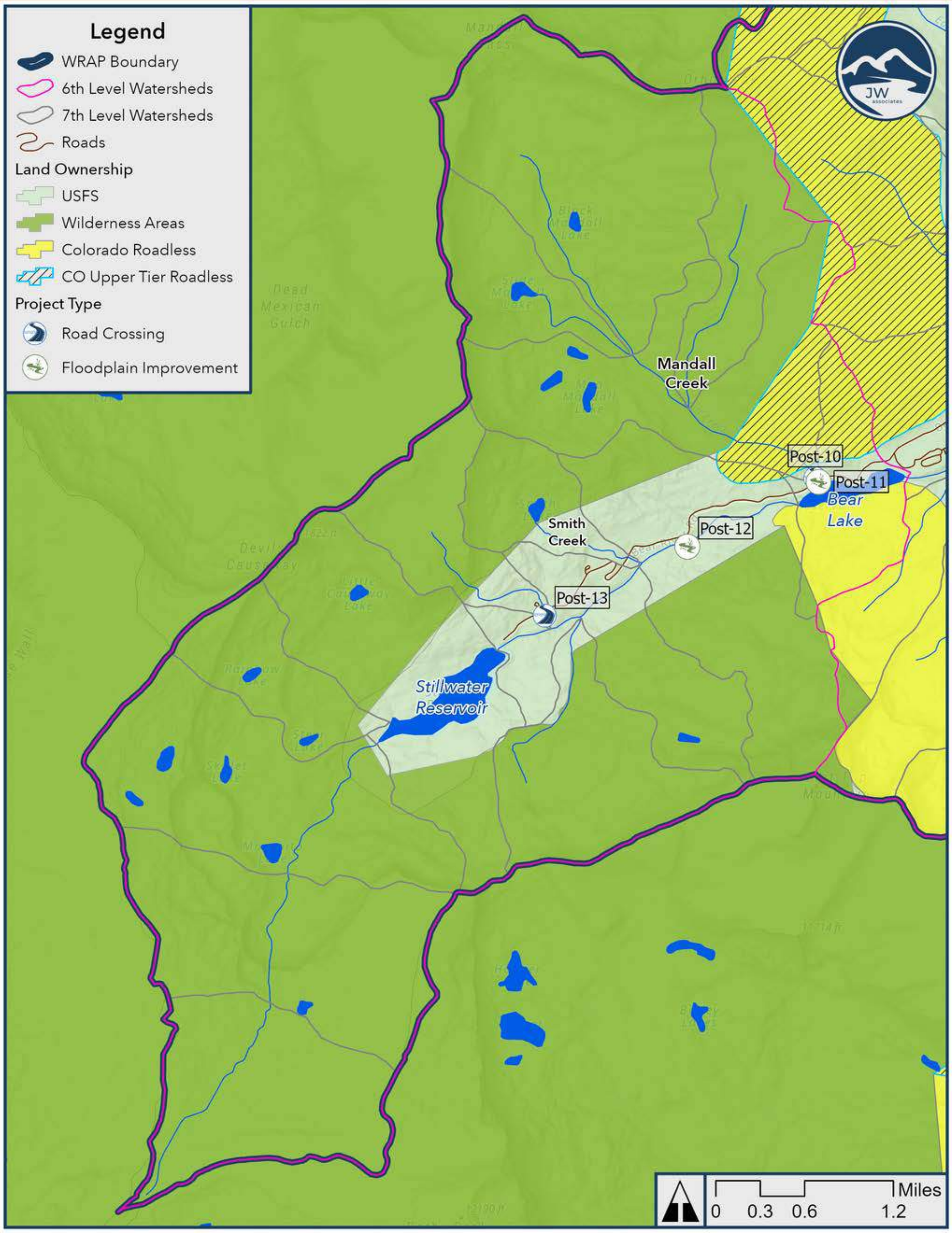
6 D. Post-Fire Project Recommendations
Headwaters Bear River

The road crossing at Cold Springs Creek has a small pond above it that could function as a sediment pond, if needed. The road crossing at Mandall Creek also has an elevated grade on the road, relative to the stream below it, offering space for sediment retention before it reaches Bear Lake. Both road crossings have identified recommendations that are listed in detail in the accompanying Excel spreadsheet, Bear River WRAP Pre- and Post-Fire Project List. The specific locations for each recommendation are available in the accompanying GIS data. Both can be found in the *Task 5 - Pre- and Post-fire Planning and Mitigation Activities* Deliverables.

Table 14. Post-fire project recommendations summary for the Yamcolo Reservoir-Bear River region within the WRAP project area.

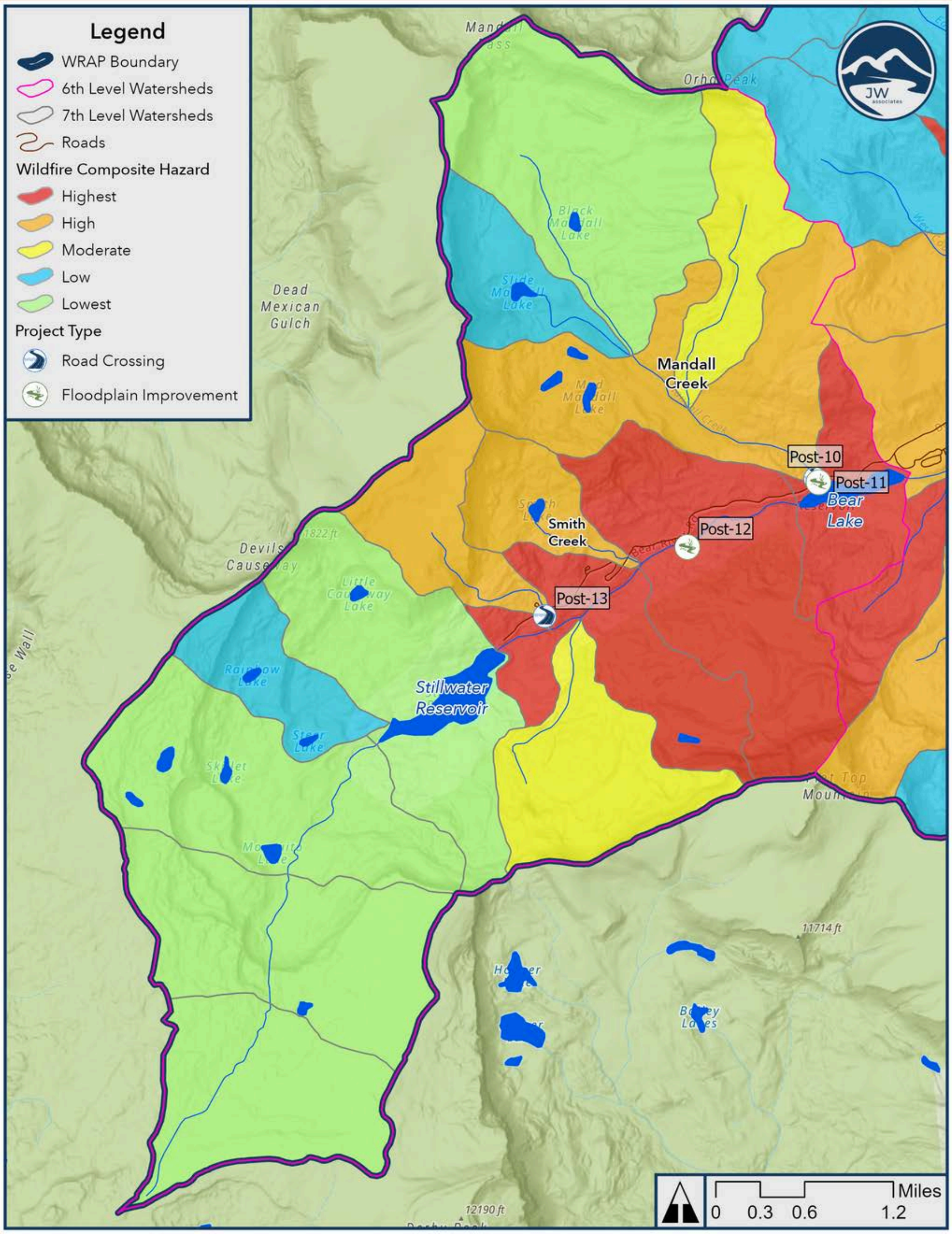
7th Level Watershed Name	WILDFIRE HAZARD	ROADS HAZARD	DEBRIS FLOW HAZARD	HILLSLOPE EROSION	WILDFIRE COMPOSITE HAZARD	LAND MANAGEMENT RESTRICTIONS	RECOMMENDED TREATMENTS
Upper Headwaters Bear River	Lowest	Lowest	Lowest	Highest	Lowest	Wilderness	
Middle Headwaters Bear River	Lowest	Lowest	Low	High	Lowest	Wilderness	
Lower Headwaters Bear River	Moderate	Lowest	Low	Low	Lowest	Wilderness	
Rainbow Lake	Moderate	Lowest	Moderate	Low	Low	Wilderness	
Cold Springs Creek	Low	High	High	Highest	High	Wilderness	
Upper Stillwater Reservoir	High	Lowest	Low	Low	Lowest	Wilderness	
North Derby	Highest	Lowest	High	Moderate	Moderate	Wilderness	
Smith Creek	High	High	Highest	Low	High	Wilderness	
Lower Stillwater Reservoir	Highest	Low	Highest	Moderate	Highest	Wilderness	
Outlet Headwaters Bear River	Highest	Low	Highest	High	Highest	Wilderness	
Upper Mandall Creek	Low	Lowest	Low	Low	Lowest	Wilderness	
Slide Mandall Creek	Low	Lowest	Moderate	Moderate	Low	Wilderness	
Orno Peak	Low	Lowest	Highest	Highest	Moderate	Wilderness	
Lower Mandall Creek	High	Low	High	High	High	Wilderness	 
Bear Lake	Highest	Low	High	Highest	Highest	Upper Tier Roadless	

LAND MANAGEMENT WITH PROJECT RECOMMENDATIONS



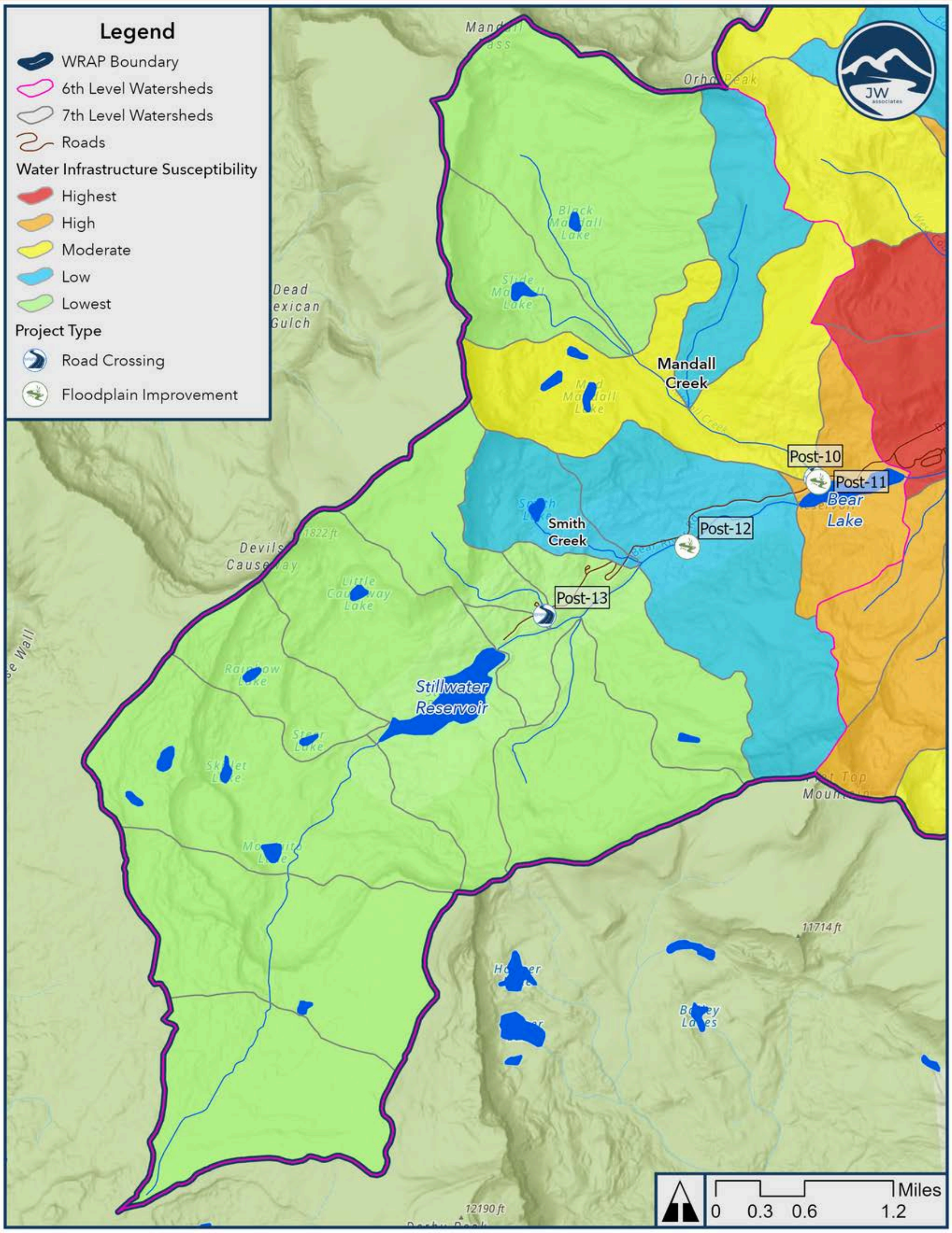
Map 34. Yamcolo Reservoir - Bear River Region Post-fire Project Recommendations overlaid on Land Ownership

HAZARD ANALYSIS WITH PROJECT RECOMMENDATIONS



Map 35. Yamcolo Reservoir - Bear River Region Post-fire Project Recommendations overlaid on Wildfire Composite Hazard Analysis Ranks

SUSCEPTIBILITY ANALYSIS WITH PROJECT RECOMMENDATIONS



Map 36. Headwaters Bear River Region Post-fire Project Recommendations overlaid on Water Infrastructure Susceptibility Ranks

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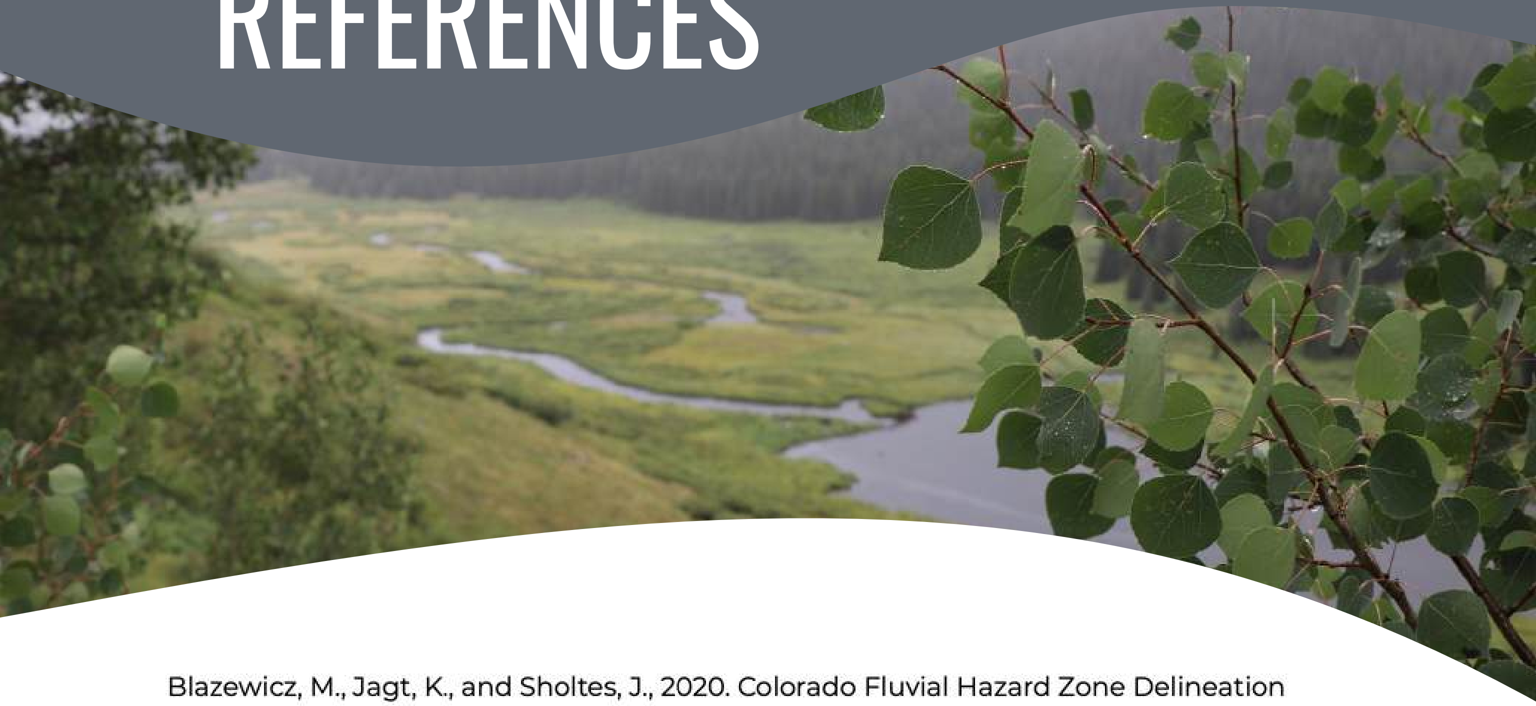

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