THE Ember Alliance

2022

GLACIER VIEW FIRE PROTECTION DISTRICT

LARIMER COUNTY, COLORADO

Community Wildfire Protection Plan

Glacier View Fire Protection District 2022 Community Wildfire Protection Plan

Prepared for Glacier View Fire Protection District

1414 Green Mountain Drive, Livermore, CO 80526

Prepared by The Ember Alliance

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Table of Contents

How to use this CWPP Document

This document is designed for everyone that lives, works, and manages land within and around the Glacier View Fire Protection District. Different sections will be most helpful to different people; please use this guide to direct you to the resources most relevant to you.

I want to learn the basics about wildfires, my local fire districts, and what a CWPP is.

Look for:
- Section 1.a to learn about CWPPs
- Section 1.c to learn about wildfires
- Section 2 to learn about your local fire districts

I'm a resident / homeowner and want to learn about protecting my family, home, and property from wildfires.

Look for:
- Section 3.a to learn about the actions you can take, including detailed recommendations and research-backed guidance for protecting your home and family
- Section 3.c to find detailed hazard ratings and recommendations for your neighborhood

I want to learn about community-lead wildfire mitigation actions for neighborhoods or HOAs.

Look for:
- Sections 3.b, 3.d, 3.e., and 3.f. to learn about the actions communities can take together to better protect everyone, including funding opportunities
- Section 3.c to find detailed hazard ratings and recommendations for your neighborhood

I'm with a government agency or cross-boundary organization and want to learn about landscape-scale wildfire mitigation.

Look for:
- Section 2.d and 2.e to learn about fire history and treatment history in the area
- Section 4.a to learn about fuel treatment objectives
- Section 4.b to learn about stand-level fuel treatment priorities and recommendations
- Section 4.c to learn about roadway treatment priorities and recommendations
- Section 4.d. to learn about slash management options

I want to learn about the science behind these recommendations and how priorities were made.

Look for:
- Appendix A to learn about modelling methodology for fire behavior and evacuations
- Appendix B to learn about prioritization for plan units, stand treatments, and roadway treatments

Acronyms

BDSR	Ben Delatour Scout Ranch
BSA	Boy Scouts of America
CPRW	Coalition for the Poudre River Watershed
CPW	Colorado Parks & Wildlife
CSFS	Colorado State Forest Service
CWPP	Community Wildfire Protection Plan
DFPC	Division of Fire Prevention and Control
FAC	Fire Adapted Community
FEMA	Federal Emergency Management Agency
GVFPD	Glacier View Fire Protection District
HIZ	Home Ignition Zone
HOA	Homeowner's Association
IIBHS	Insurance Institute for Business & Home Safety
IRPG	Incident Response Pocket Guide
ISO	Insurance Services Office
LCCC	Larimer Conservation Corps
LCD	Larimer Conservation District
LCOEM	Larimer County Office of Emergency Management
LCSO	Larimer County Sherriff's Office
LCSO ES	Larimer County Sherriff's Office Emergency Services
NCFC	Northern Colorado Fireshed Collaborative
NFPA	National Fire Protection Association
NWCG	National Wildfire Coordinating Group
RAWS	Remote Automatic Weather Stations
TEA	The Ember Alliance
USFS	U.S. Forest Service

For definitions of the words and phrases used throughout this document, refer to the **Glossary**.

1. Introduction

1.a. Purpose and Need for a Community Wildfire Protection Plan

Community Wildfire Protection Plans (CWPPs) help communities assess local hazards and identify strategic investments to mitigate risk and promote preparedness **(Figure 1.a.1)**. Assessments and discussions during the planning process can assist fire protection districts with fire operations in the event of a wildfire and help residents prioritize mitigation actions. These plans also enable the districts and residents to be better positioned to acquire funding since many grants require an approved CWPP. This represents a significant benefit of completing a CWPP as funding gaps are often present related to implementing fuel mitigation projects.

Figure 1.a.1. Elements of a holistic and actionable CWPP.

The 2022 CWPP for the Glacier View Fire Protection District (GVFPD) is the first district-wide CWPP for GVFPD. It addresses a changing landscape and takes advantage of modern fire science. It includes a wildfire risk analysis, prioritization of mitigation activities, and implementation recommendations. This document is a tool for GVFPD, land managers, residents, communities, and homeowner's associations (HOAs) to begin prioritizing projects that make GVFPD a safer and more resilient community to wildfire. The objectives of this project are to:

- Produce an actionable CWPP based on robust analyses of fuel hazards, burn probability, evacuation routes, and community values across the fire district.
- Provide recommendations, including prioritization, for reducing fire hazards, hardening homes, and increasing evacuation safety.
- Engage community members during the CWPP process to address local needs and concerns.
- Set the stage for planning and implementation within CWPP plan units to mitigate hazards and promote community preparedness.

The Ember Alliance (TEA)—a Colorado non-profit dedicated to fire management and community engagement—worked with GVFPD to conduct fire behavior analyses and prepare the CWPP. TEA and representatives from GVFPD, forming the Core Team, synthesized and interpreted these analyses to develop the CWPP. They incorporated lessons learned from the challenging 2020 wildfire season in Colorado and considered valuable insights shared by community members and other stakeholders.

This CWPP is a call to action. GVFPD shares some risk factors common to past catastrophic wildfires across the country and has experienced the effects of recent wildfires in northern Colorado. The 2022 CWPP provides an assessment of wildfire risk in the GVFPD and includes suggestions for residents, community leaders, and emergency responders to mitigate risk and enhance community safety.

GVFPD Station 1 apparatus—the local fire department that protects the GVFPD. Photo from glacierviewfire.gov.

1.b. Partners and Stakeholder Engagement

Collaboration is an essential part of CWPPs. Community engagement, partner commitment, and follow through are what make a CWPP successful. The Core Team, formed of TEA and GVFPD representatives) engaged stakeholders from across the district and neighboring districts to develop the recommendations set forth in this CWPP. They brought lessons learned from the High Park fire in 2012 and Cameron Peak fire in 2020 and considered community and stakeholder values and input.

TEA and GVFPD would like to thank the following partners for their time and effort in developing this CWPP by providing data and feedback, as well as planning for implementation projects:

- Ben Delatour Scout Ranch
- Coalition for the Poudre River Watershed
- Colorado Forest Restoration Institute
- Colorado Parks and Wildlife
- Colorado State Forest Service
- Crystal Lakes Fire District
- Glacier View Fire Protection District Board
- Larimer County Conservation Corps
- Larimer Conservation District
- Larimer County Office of Emergency Management
- Larimer County Sheriff's Office – Emergency Services
- Northern Colorado Fireshed Collaborative
- Poudre Canyon Fire District
- Red Feather Lakes Fire District
- The Nature Conservancy Colorado Chapter
- United States Forest Service – Arapaho-Roosevelt National Forest
- University of Denver Mountain Campus

TEA is grateful to Larimer County, Colorado Forest Restoration Institute, and the State of Colorado for sharing geospatial data across the GVFPD.

This project was managed by a Core Team comprised of staff from The Ember Alliance, retired Glacier View Chief Warren Jones, Assistant Chief Peter Henderson, a volunteer firefighter, and two members of the Glacier View Fire District Board. This team reviewed analysis content, made decisions about how to move forward with the document and CWPP process, and led community and stakeholder engagement. Core Team members provided local context and guided The Ember Alliance to meet the needs of this community with the planning process.

In September 2021, the Core Team met with community leaders including HOA presidents, GVFPD Board members, and North 40 Alliance members to gain a better understanding of the community's current knowledge of wildfire and to assess their concerns. Feedback from this community meeting informed the development of recommendations and priorities for the 2022 CWPP.

In November 2021, the Core Team hosted a meeting of partner agencies and organizations with a shared interest in mitigation of wildfire hazards across the GVFPD. Partners like Colorado State Forest Service (CSFS), United States Forest Service (USFS), and Colorado Parks and Wildlife (CPW) have valuable assets within and adjacent to the community, and agencies like USFS and CPW manage land surrounding the GVFPD. CWPP analysis was shared and the Core Team gathered feedback on common challenges in this area around wildfire mitigation. This informed the set of recommendations within the body of this CWPP document.

In February 2022, the Core Team met with land managers and other partners to discuss priority treatment locations to mitigate wildfire risk in and around the GVFPD. Attendees represented the Ben Delatour Scout Ranch, Coalition for the Poudre River Watershed, Colorado State Parks and Wildlife, Colorado State Forest Service, Larimer County Office of Emergency Management, Larimer County Sheriff's Office Emergency Services, Larimer Conservation District, Larimer County Conservation Corps, The Nature Conservancy, and United States Forest Service.

Community engagement to share findings from the CWPP began in late March 2022, meeting first with community leaders on March 23rd with a final community meeting held on April 6th, at the University of Denver Mountain Campus. Community leaders saw the CWPP results first at Station 1 to ask questions and provide input about community barriers and opportunities. The final meeting on April 6th focused on implementation at the resident level, with speakers from CSFS, BDSR, CPRW, LCD, LCSO, and the USFS.

1.c. Introduction to Wildfire Behavior and Terminology

Many aspects of wildfires are predictable based on knowledge of the physical processes that drive fire behavior. That knowledge is supported by scientific research and much of the work in this CWPP is based on that research and computer models of wildfire behavior. A basic understanding of fire behavior aids in interpreting the findings and recommendations reported herein. The **Glossary** at the end of this document provides definitions for the key terms used in this CWPP.

Fire Behavior Triangle

Complex interactions among wildland fuels, weather, and topography determine how wildfires behave and spread. These three factors make up the sides of the fire behavior triangle (**Figure 1.c.1**), and they are the variables that wildland firefighters pay attention to when assessing potential wildfire behavior during an incident (NWCG 2019).

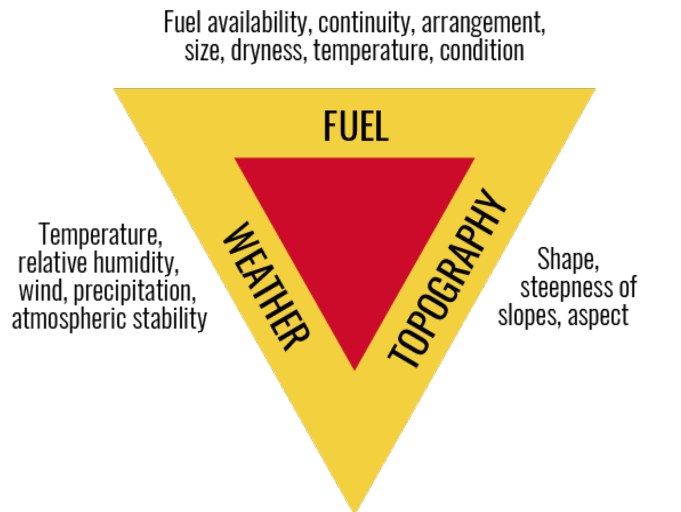

Figure 1.c.1. Interactions between fuels, weather, and topography dictate fire behavior (source: California State University).

Fuels

Fuels include live vegetation such as trees, shrubs, and grasses, dead vegetation like pine needles and cured grass, and materials like houses, sheds, fences, trash piles, and combustible chemicals.

Grasses and pine needles are known as “flashy” fuels because they easily combust and burn the fastest of all fuel types. Flashy fuels dry out faster than other fuel types when relative humidity drops or when exposed to radiant and convective heat[1]. If you think of a campfire, flashy fuels are the kindling that you use to start the fire. Fires in grassy fuel types can spread quickly across large areas, and fire behavior can change rapidly with changes in weather conditions.

Dead branches on the surface dry out slower than flashy fuels, release more radiant heat when they burn, and take longer to completely combust. The rate of spread is fast to moderate through shrublands depending on their moisture content, and long flame lengths can preclude direct attack by firefighters. Shrubs and small trees can also act as ladder fuels that carry fire from the ground up into the tree canopy.

Dead trees (aka, snags) and large downed logs are called “heavy fuels”, and they take the longest to dry out when relative humidity drops and when exposed to radiant and convective heat. Heavy fuels release tremendous radiant heat when they burn, and they take longer to completely combust, just like a log on a campfire. Fire spread through a forest is slower than in a grassland or shrubland, but forest fires release more heat and can be extremely difficult and unsafe for firefighters to suppress. An abundance of dead trees killed by drought, insects, or disease can exacerbate fire behavior, particularly when dead trees still have dry, red needles (Moriarty et al. 2019; Parsons et al. 2014).

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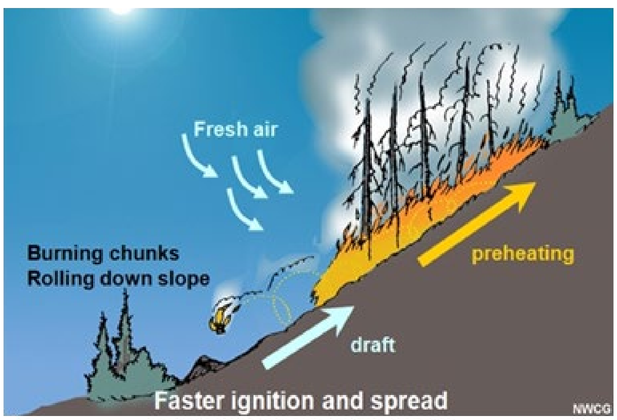
[1]See the **Glossary** at the end of the CWPP for definitions of heat transfer methods.

Topography

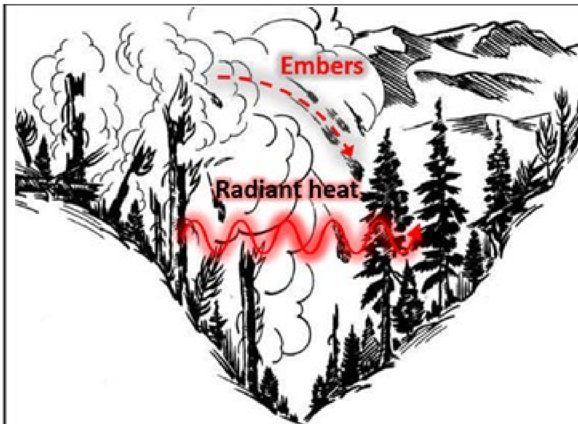
Topography (slope and aspect) influences fire intensity, speed, and spread. In the northern hemisphere, north-facing slopes experience less sun exposure during the day, resulting in higher fuel moistures. Tree density is often higher on north-facing slopes due to higher soil moisture. South-facing slopes experience more sun exposure and higher temperatures and are often covered in grasses and shrubs. The hotter and drier conditions on south-facing slopes mean fuels are drier and more susceptible to combustion, and the prevalence of flashy fuels results in fast rates of fire spread.

Fires burn more quickly up steep slopes due to radiant and convective heating. Fuels are brought into closer proximity with the progressing fire, causing them to dry out, preheat, and become more receptive to ignition, thereby increasing rates of spread. Steep slopes also increase the risk of burning material rolling and igniting unburnt fuels below (**Figure 1.c.2**).

Narrow canyons can experience increased combustion because radiant heat from fire burning on one side of the canyon can heat fuel on the other side of the canyon. Embers can easily travel from one side of a canyon to the other (**Figure 1.c.2**). Topography also influences wind behavior and can make fire spread unpredictable. Wildfires burning through steep and rugged topography are harder to control due to reduced access for firefighters and more unpredictable and extreme fire behavior.



Slope increases fire spread through radiant and convective heating (source: NWCG).



Fires can easily cross narrow canyons (source: U.S. Forest Service).

Figure 1.c.2. Steep slopes and topographic features such as narrow canyons exacerbate fire behavior and fire effects.

Weather

Weather conditions that impact fire behavior include temperature, relative humidity, precipitation, and wind speed and direction. The National Weather Service uses a system called a red flag warning to indicate local weather conditions that can combine to produce increased risk of fire danger and behavior. Red flag warning days indicate increased risk of extreme fire behavior due to a combination of hot temperatures, very low humidity, dry fuels, strong winds, and the presence of thunderstorms (**Table 1.c.1**).

Direct sunlight and hot temperatures impact how ready fuels are to ignite. Warm air preheats fuels and brings them closer to their ignition point. When relative humidity is low, the dry air can absorb moisture from fuels, especially flashy fuels, making them more susceptible to ignition. Long periods of dry weather can dehydrate heavier fuels, including downed logs, increasing the risk of wildfires in areas with heavy fuel loads.

Wind influences fire behavior by drying out fuels (think how quickly your lips dry out in windy weather), increasing the amount of oxygen feeding the fuel, preheating vegetation through convective heat, and carrying embers more than a mile ahead of an active fire. Complex topography, such as chutes, saddles, and draws, can funnel winds in unpredictable directions, increasing wind speeds and resulting in erratic fire behavior.

Table 1.c.1. Red flag days are warnings issued by the National Weather Service using criteria specific to a region.

National Weather Service – Denver/Boulder Forecast Office Red Flag Warning Criteria	
Option 1	**Option 2**
Relative humidity less than or equal to 15%	Widely scattered dry thunderstorms
Wind gusts greater than or equal to 25 mph	Dry fuels
Dry fuels	

Very Large Air tanker drops retardant near the Manhattan Road south of Red Feather Lakes during the 2020 Cameron Peak Fire on August 27, 2020. Photo credit: NWCG InciWeb.

Categories of Fire Behavior

Weather, topography, and fuels influence fire behavior, and fire behavior in turn influences the tactical options available for wildland firefighters and the risks posed to lives and property. There are three general categories of fire behavior described throughout this CWPP: surface fire, passive crown fire, and active crown fire (**Figure 1.c.3**).

- **Surface fire –** Fire that burns fuels on the ground, which include dead branches, leaves, and low vegetation. Surface fires can be addressed with direct attack using handcrews when flame lengths are less than four feet and with equipment when flame lengths are less than eight feet. Surface fires can emit significant radiant heat, which can ignite nearby vegetation and homes.
- **Passive crown fire –** Fire that arises when surface fire ignites the crowns of trees or groups of trees (aka, torching). Torching trees reinforce the rate of spread, but passive crown fires travel along with surface fires. Firefighters can sometimes address passive crown fires with indirect attack, such as dropping water or retardant out of aircraft or digging fireline at a safe distance from the flaming front. The likelihood of passive crown fire increases when trees have low limbs and when smaller trees and shrubs grow below tall trees and act as ladder fuels. Radiant heat and ember production from passive crown fires can threaten homes during wildfires.
- **Active crown fire –** Fire in which a solid flame develops in the crowns of trees and advances from tree crown to tree crown independently of surface fire spread. Crown fires are very difficult to contain, even with the use of aircraft dropping fire retardant, due to long flame lengths and tremendous release of radiant energy. The likelihood of active crown fires increases when trees have interlocking canopies. Radiant heat and ember production from active crown fires can threaten homes during wildfires.

Passive and active crown fires can result in short- and long-range ember production that can create spot fires and ignite homes. Spot fires are particularly concerning because they can form a new flaming front, move in unanticipated directions, trap firefighters between two fires, and require additional firefighting resources to control. Crown fires are generally undesirable in the wildland-urban interface (WUI) because of the risk to lives and property; however, passive and active crown fires are part of the natural fire regime for some forest types and result in habitat for plant and animal species that require recently disturbed conditions (Keane et al. 2008; Pausas and Parr 2018). Passive and active crown fires historically occurred in some lodgepole pine forests and higher-elevation ponderosa pine and mixed-conifer forests on north-facing slopes (Romme 1982; Addington et al. 2018).

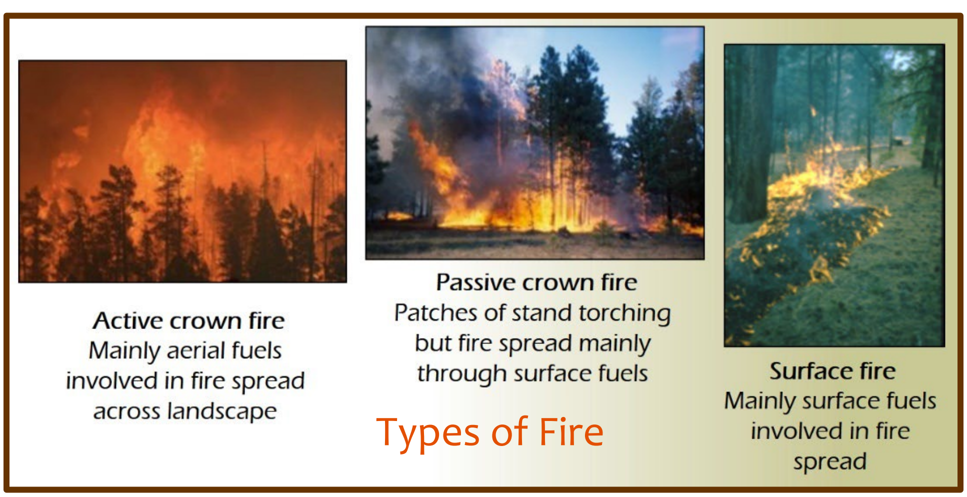


Figure 1.c.3. Active crown fire, passive crown fire, and surface fire are common types of fire behavior.

Wildfire Threats to Homes

Every year, wildfires result in billions of dollars in fire suppression costs and destroy thousands of homes across the United States. Some of the most destructive, deadly, and expensive wildfires in the have occurred in the past several years, partly due to expansion of the wildland-urban interface (WUI) and more severe fire weather perpetuated by climate change (Caton et al. 2016).

The Wildland-Urban Interface is any area where the built environment meets wildfire-prone areas—places where wildland fire can move between natural vegetation and the built environment. and result in negative impacts on the community (Forge 2018). WUI exists along a continuum of wildland to urban densities (**Figure 1.c.4**). Over the past 50 years, immigration to the mountains along the Colorado Front Range has increased the number of occupied structures within this historically forested landscape. This population change increased the density and size of the WUI, and the risk of structure loss from wildfire and the likelihood of fire starts.

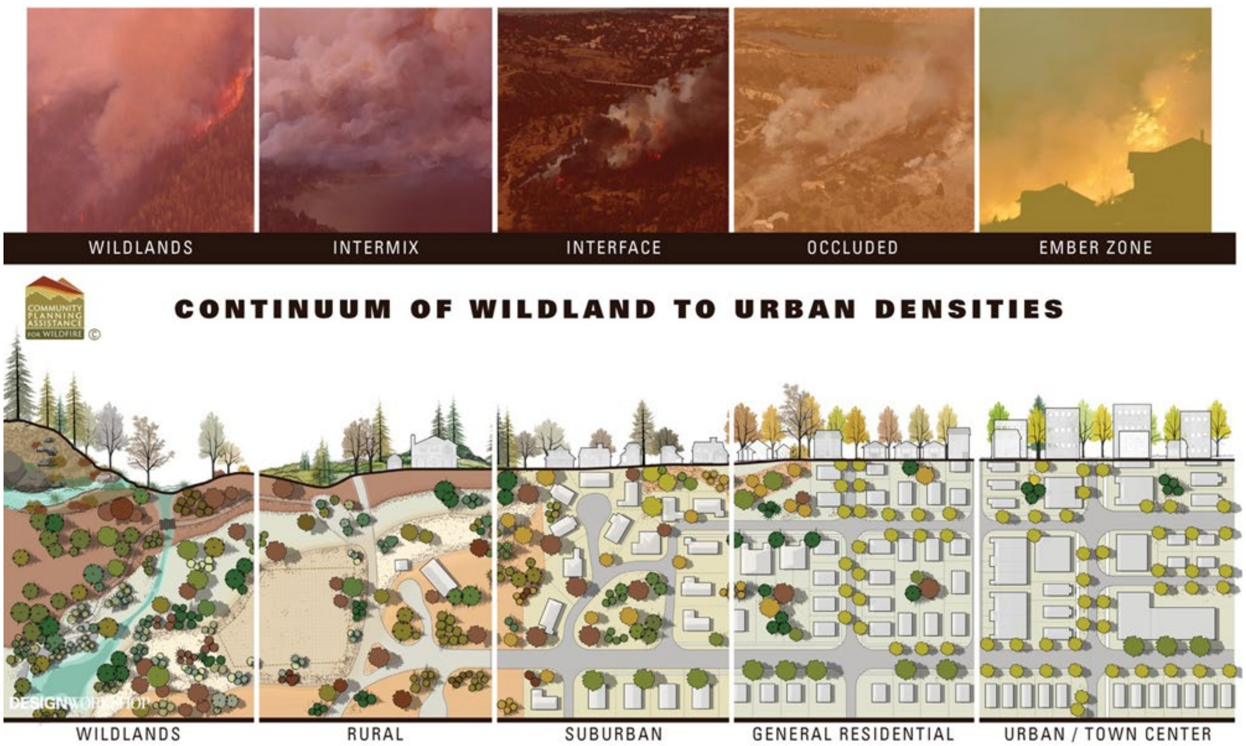


Figure 1.c.4. The wildland-urban interface exists along a continuum of wildland to urban densities. (Source: Community Planning Assistance for Wildfire).

Wildfires can ignite homes through several pathways: radiant heat, convective heat, and direct contact with flames or embers. The ability for radiant heat to ignite a home is based on the properties of the structure (i.e., wood, metal, or brick siding), the temperature of the flame, the ambient air temperature, and distance from the flame (Caton et al. 2016). Ignition from convective heat is more likely for homes built along steep slopes and in ravines and draws. For flames to ignite a structure, they must directly contact the building long enough to cause ignition. Flames from a stack of firewood near a home could cause ignition to the home, but flames that quickly burn through grassy fuels are less likely to ignite the home (although the potential still exists). Fires can also travel between structures along fuel pathways such as a fence or row of shrubs connecting a shed and a home (Maranghides et al., 2022). Some housing materials can burn hotter than the surrounding vegetation, thereby exacerbating wildfire intensity and initiating home-to-home ignition (Mell et al. 2010).

Homes built mid-slope and at the top of steep slopes and within ravines and draws are at greater risk of convective heat from wildfires. A wildfire could rapidly spread up this steep slope and threaten the home above. Photo credit: The Ember Alliance.

Homes can be destroyed during wildfires even if surrounding vegetation has not burned. During many wildland fires, 50 to 90% of homes ignite due to embers rather than radiant heat or direct flame (Babrauskas 2018; Gropp 2019). Embers can ignite structures when they land on roofs, enter homes through exposed eaves, or get under wooden decks. Embers can also ignite nearby vegetation and other combustible fuels, which can subsequently ignite a home via radiant heating or direct flame contact. Burning homes can release embers that land on and ignite nearby structures, causing destructive home-to-home ignitions, as evidenced by the destructive 2021 Marshall Fire in Boulder County. Structural characteristics of a home can increase its exposure to embers and risk of combustion, such as wood shingle roofs and unenclosed eaves and vents (Hakes et al. 2017; Syphard and Keeley 2019). Embers can also penetrate homes if windows are destroyed by radiant or convective heat. See **Section 3.a Individual Recommendations** for recommendations to harden your home against wildfires.

Firefighting in the WUI

One of the standard firefighter orders is to "fight fires aggressively, having provided for safety first" (NWCG 2018a). Firefighters are committed to protecting lives and property, but firefighting is particularly perilous in the WUI. The firefighter community is increasingly committed to safety of wildland firefighters, which can require the difficult decision to cease structure protection when conditions become exceedingly dangerous, particularly around homes with inadequate defensible space, safety zones, and egress routes.

High-intensity, fast-moving wildfires in the WUI can quickly overwhelm firefighting resources when homes begin igniting each other (Caton and others 2016). Firefighters are often forced to perform structure triage to effectively allocate limited resources during an incident, and more importantly, to protect the lives of firefighters. The Incident Response Pocket Guide (IRPG), which is carried by all firefighters certified under the National Wildfire Coordinating Group, explicitly states, "**Do not** commit to stay and protect a structure unless a safety zone for firefighters and equipment has been identified at the structure during sizeup and triage" (NWCG 2018a). The IRPG outlines four categories of structure triage: (1) defensible – prep and hold, (2) defensible – stand alone, (3) non-defensible – prep and leave, and (4) non-defensible – rescue drive-by.

Do not count on firefighters staying to defend your home—your home should be able to survive a wildfire on its own. There are never enough firefighters to stay and defend every single home during large incidents. Section **Mitigate the Home Ignition Zone** of this CWPP provides recommendations for how residents can increase the chance of their homes surviving wildfires and enhance the safety of wildland firefighters.

Resources for More Information on Fire Behavior

- Introduction to Fire Behavior from the National Wildfire Coordinating Group (9:57 minute video)
- The Fire Triangle from the National Wildfire Coordinating Group (7:26 minute video)
- Understanding Fire Behavior in the Wildland/Urban Interface from the National Fire Protection Association (20:51 minute video)
- Understanding Fire from California State University (website)
- S-190 Introduction to Wildland Fire Behavior Course Materials from the NWCG (PowerPoints, handouts, and videos)

2. Glacier View Fire Protection District (GVFPD): Background

2.a. General Description

GVFPD covers the community around County Road 74E (Red Feather Lakes Road), north of Colorado State Highway 14 (CO-14) and seven miles west of U.S. Highway 287 (US 287) in Larimer County, Colorado (**Figure 2.a.1**). It covers 59 square miles and is home to 1,500 year-round residents across 1,215 homes in the foothills of northern Colorado. Subdivisions within the GVFPD include Whispering Pines, Red Feather Highlands, North Rim, Green Mountain Meadows, Glacier View Meadows, Deer Meadows, Hewlett Gulch, Sundance Trail Guest Ranch, and Drake Ranch.

GVFPD neighbors the Poudre Canyon Fire Protection District to the south, Livermore Fire Protection District to the north and east, and Red Feather Lakes Fire Protection District to the west. Landowners in the GVFPD include the USFS, Colorado State Land Board, CPW, Larimer County, and private landowners including Boy Scouts of America (BSA), University of Denver Mountain Campus, and private residences (**Figure 2.a.2**).

Elevations range from 5800 to 8700 feet above sea level. The district lies in the Cache la Poudre Watershed, which feeds into the South Platte River. Most of the land is montane shrubland and ponderosa pine woodland, interspersed with mixed conifer stands and montane grasslands (**Figure 2.a.3**; **Figure 2.a.4**). Black bear, mountain lion, moose, elk, and mule deer are some of the large wildlife found in the GVFPD.

Fuel loads, a way to interpret vegetation as a source for wildfire, vary across the GVFPD, with light to moderate loads on the eastern side of the district and light to very heavy fuel loads found on the western side (**Appendix Figure 9.a.2**). The area burned by the High Park Fire in 2012 has lighter fuel loads. Some areas have widely spaced trees with few ladder fuels; these areas would most likely experience surface fires with occasional passive crown fires. Other areas are densely forested on steep north-facing slopes or canyons and could experience active crown fires that would be difficult if not impossible for firefighters to contain. Grassy areas across the GVFPD could experience fast-moving surface fires. Homes serve as an additional source of fuel that could produce high-intensity flames, emit embers, and initiate home-to-home ignitions.

Non-residential values at risk within GVFPD include one university facility (which also will serve as a national shelter system facility), one fire station, one wastewater treatment plant, one COOP weather station, two water storage areas, two drinking water treatment plants, and an electrical transmission line. The University of Denver Mountain Campus and future national shelter system facility are in the northwest part of the district, at 17900 W County Road 74E. The fire station is in the center of the district, just south of 74E at 1414 Green Mountain Drive. The wastewater treatment plant, water storage areas, and drinking water treatment plants are spread throughout the Glacier View Meadows subdivisions. The power line intersects the northern part of the district and runs east to west (**Figure 2.a.5**).

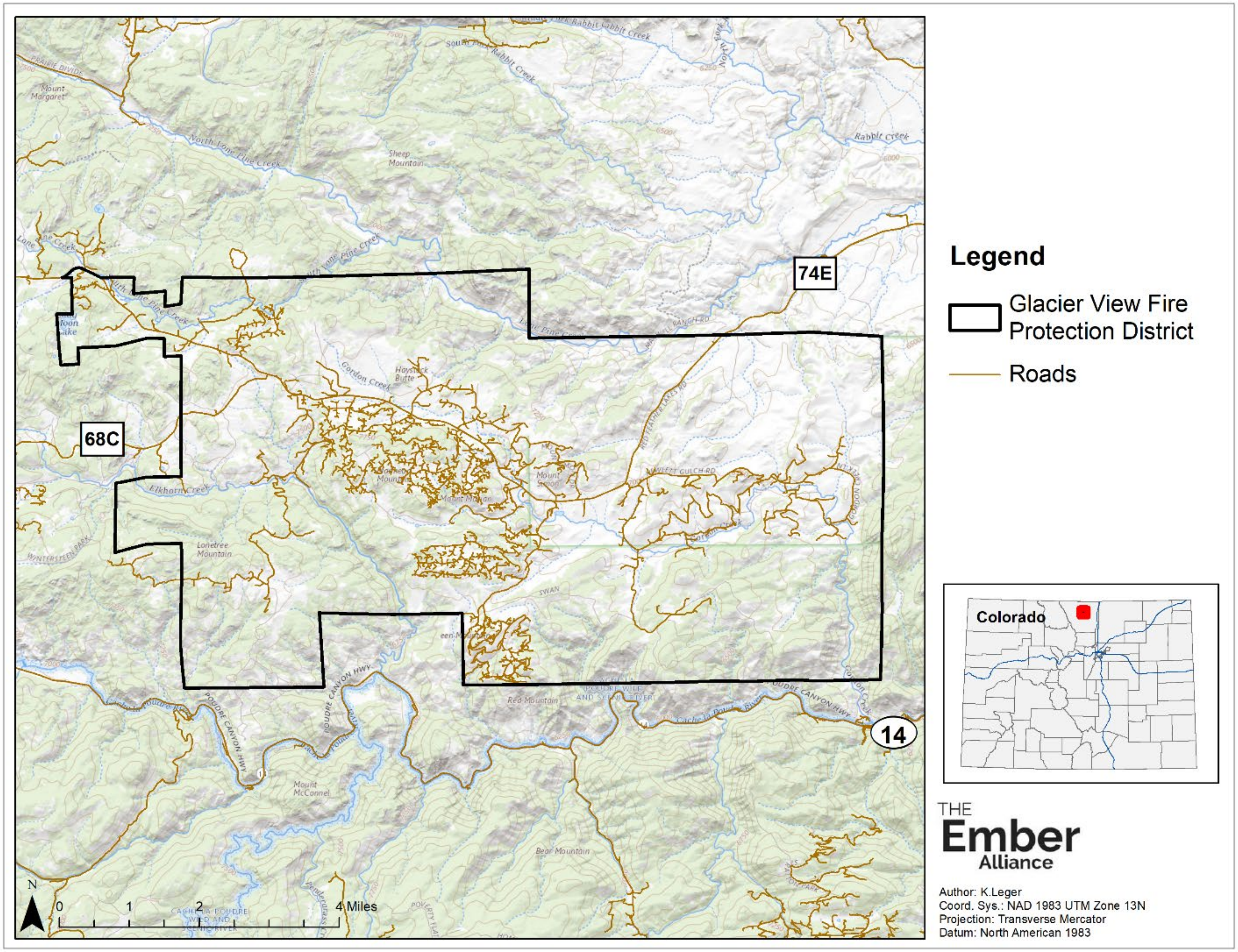


Figure 2.a.1. Boundary of GVFPD that will be used throughout the document. (Source: Colorado Department of Local Affairs and OpenStreetMap).

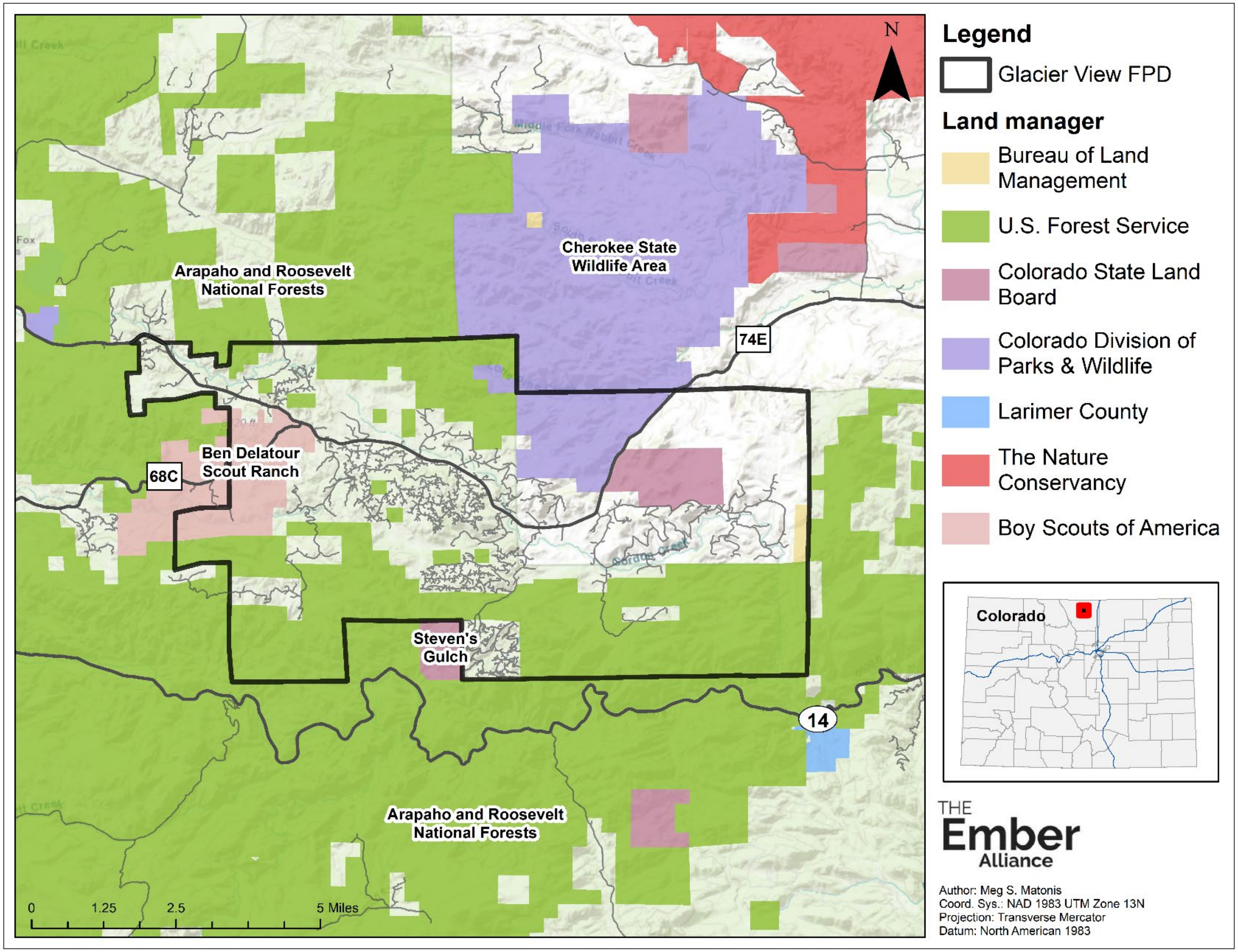


Figure 2.a.2. Publicly owned land across GVFPD, with major units called out. (Source: U.S. Geological Survey, Protected Areas Database of the United States). An interactive map with land ownership is available online at https://experience.arcgis.com/experience/225f72cc029c4e37a2acbdefc60b2140/page/Plan-Units/.

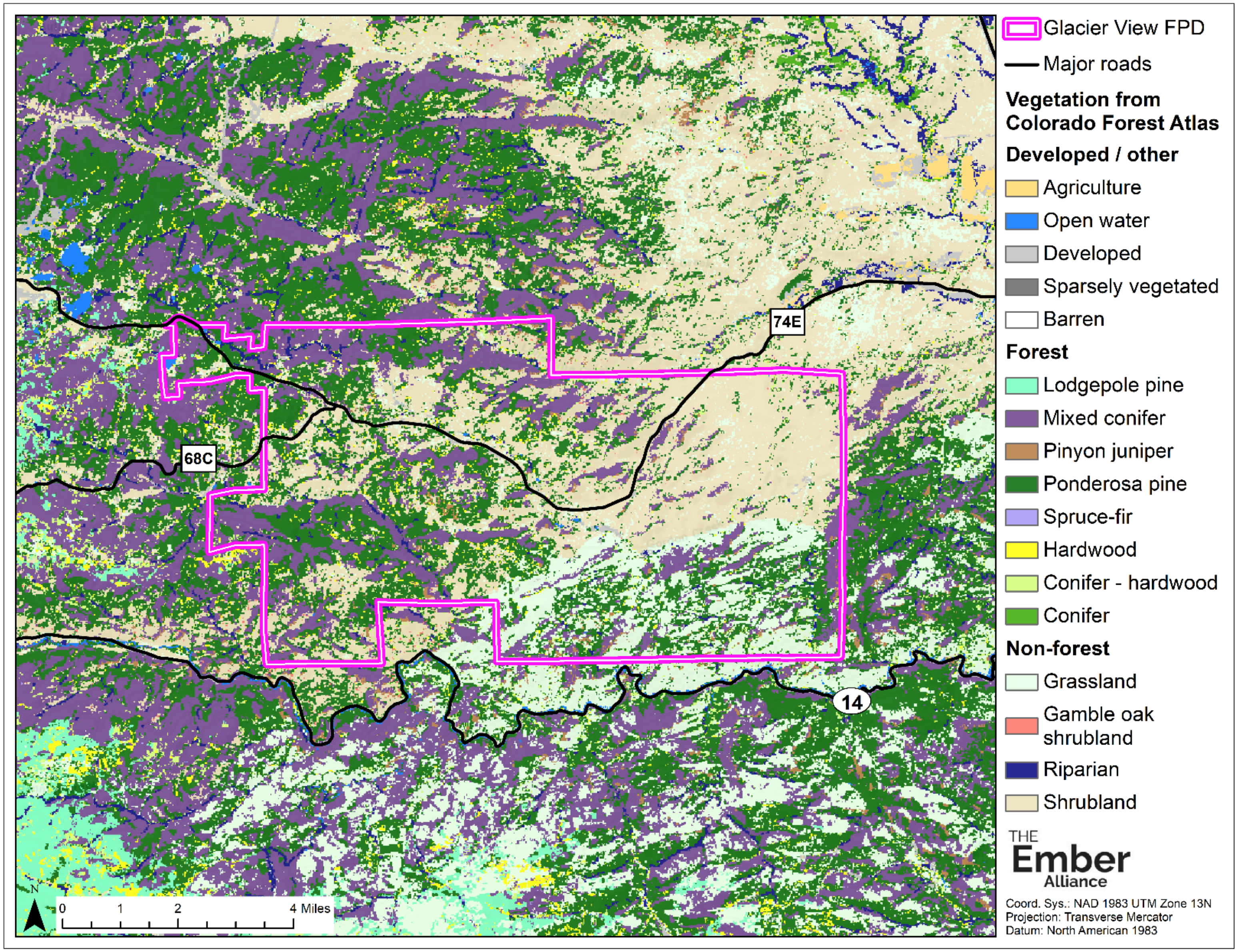


Figure 2.a.3. Map of vegetation across GVFPD. Most of the land is montane shrubland and ponderosa pine woodland, interspersed with mixed conifer stands and montane grasslands. (Source: Colorado State Forest Service, Colorado Forest Atlas).

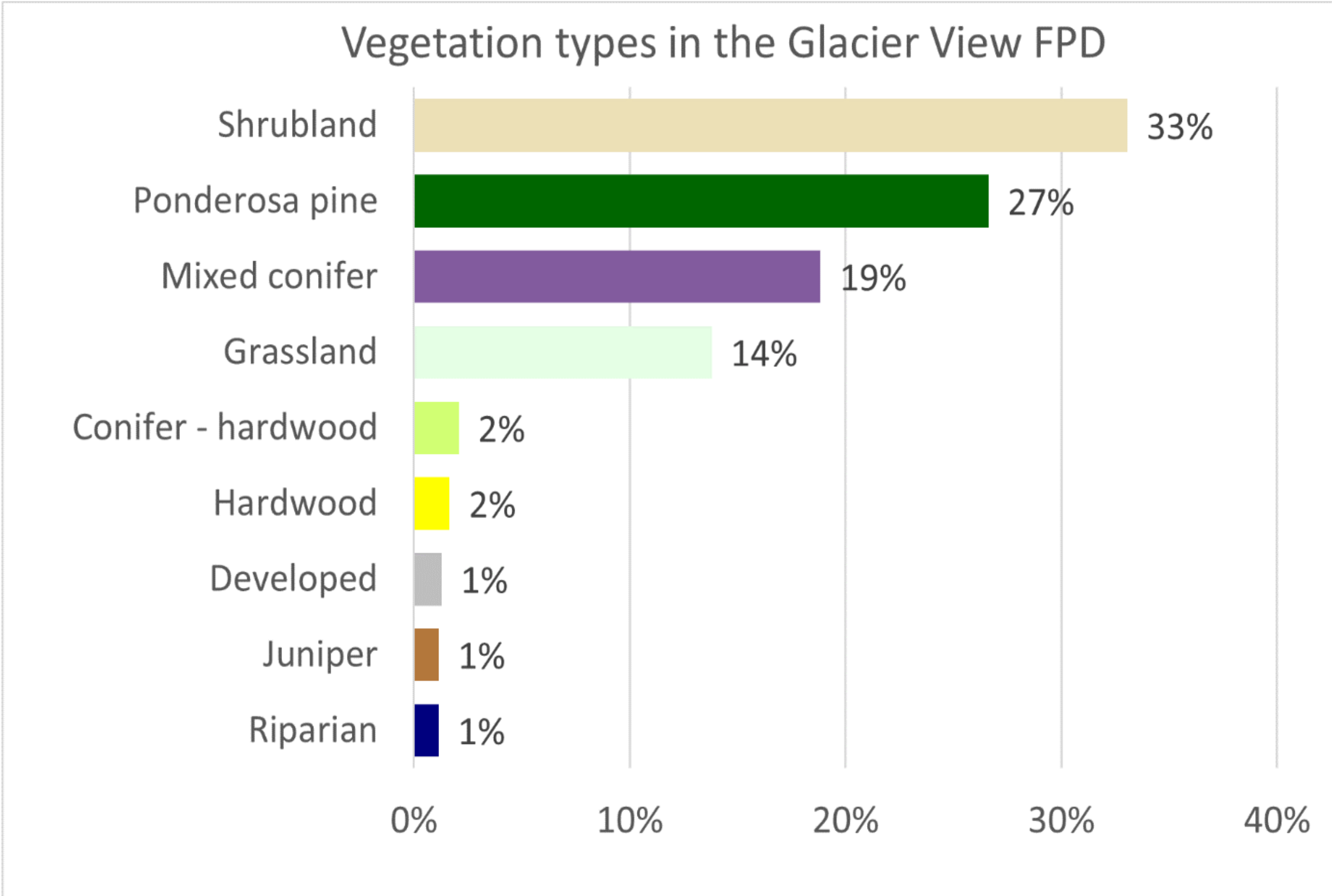


Figure 2.a.4. GVFPD and surrounding area are primarily covered with montane shrublands and ponderosa pine woodland, interspersed with mixed conifer stands and montane grasslands. Mixed conifer stands in this area are comprised of ponderosa pine, Douglas-fir, and Rocky Mountain juniper, with occasional blue spruce. Colors correspond to the symbol legend in **Figure 2.a.3**. (Source: Colorado State Forest Service, Colorado Forest Atlas).

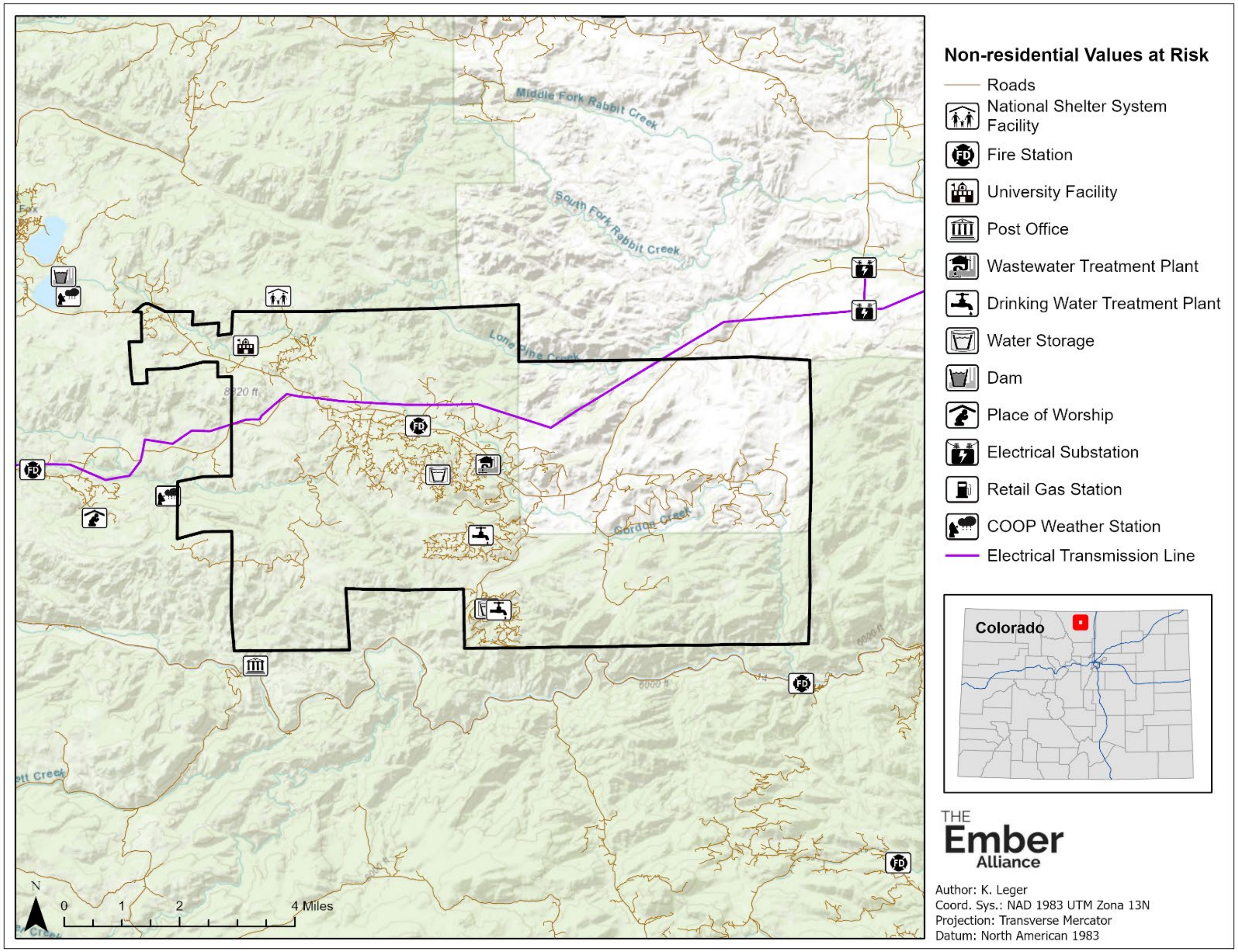


Figure 2.a.5. Non-residential values at risk to wildfire within and around GVFPD. (Sources: CO Department of Public Health and Environment, CO Division of Oil and Public Safety, Homeland Infrastructure Foundation-Level Data, Federal Deposit Insurance Corporation, U.S. Environmental Protection Agency, U.S. Geological Survey, National Oceanic and Atmospheric Administration with revisions based on input from the CWPP Core Team).

2.*b.* Wildland-Urban Interface

The Wildland-Urban Interface (WUI) is any area where the built environment meets wildfire-prone areas—places where wildland fire can move between natural vegetation and the built environment and result in negative impacts on the community (Forge 2018). People that live and work in the WUI must be aware of the effect that ecosystem processes and disturbances, such as wildland fire, have on their lives. WUI exists along a continuum of wildland to urban densities (**Figure 1.c.4**). Wildland-urban intermix refers to areas where housing and wildland vegetation blend and mix, while wildland-urban interface refers to areas where housing is in the vicinity of a large area of dense wildland vegetation (Martinuzzi et al. 2015).

All residents of GVFPD live in the WUI (**Figure 2.b.1**). Over the past 50 years, immigration to the mountains along the Colorado Front Range has increased the number of occupied structures across this landscape. This population change has increased not only the density and size of the WUI, but also increased the risk of structure loss from wildfire and the likelihood of fire starts.

According to the 2020 Wildfire Risk to Communities analysis by the USFS, homes in Glacier View and the surrounding areas have a higher risk of fire than 92% of the communities in the state (**Figure 2.b.2**) (USFS 2021a). High fire risk is common to many WUI communities along the Colorado Front Range (Radeloff et al. 2018). Damages from wildfires in the Colorado's WUI can be extensive, as demonstrated by the 2013 Black Forest Fire that destroyed 511 structures, and the 2020 East Troublesome Fire that destroyed at least 366 structures, and the 2021 Marshall Fire that destroyed over 1,000 structures. The 2012 High Park Fire burned through the southern part of the GVFPD and destroyed 259 homes, 50 of which were in the district

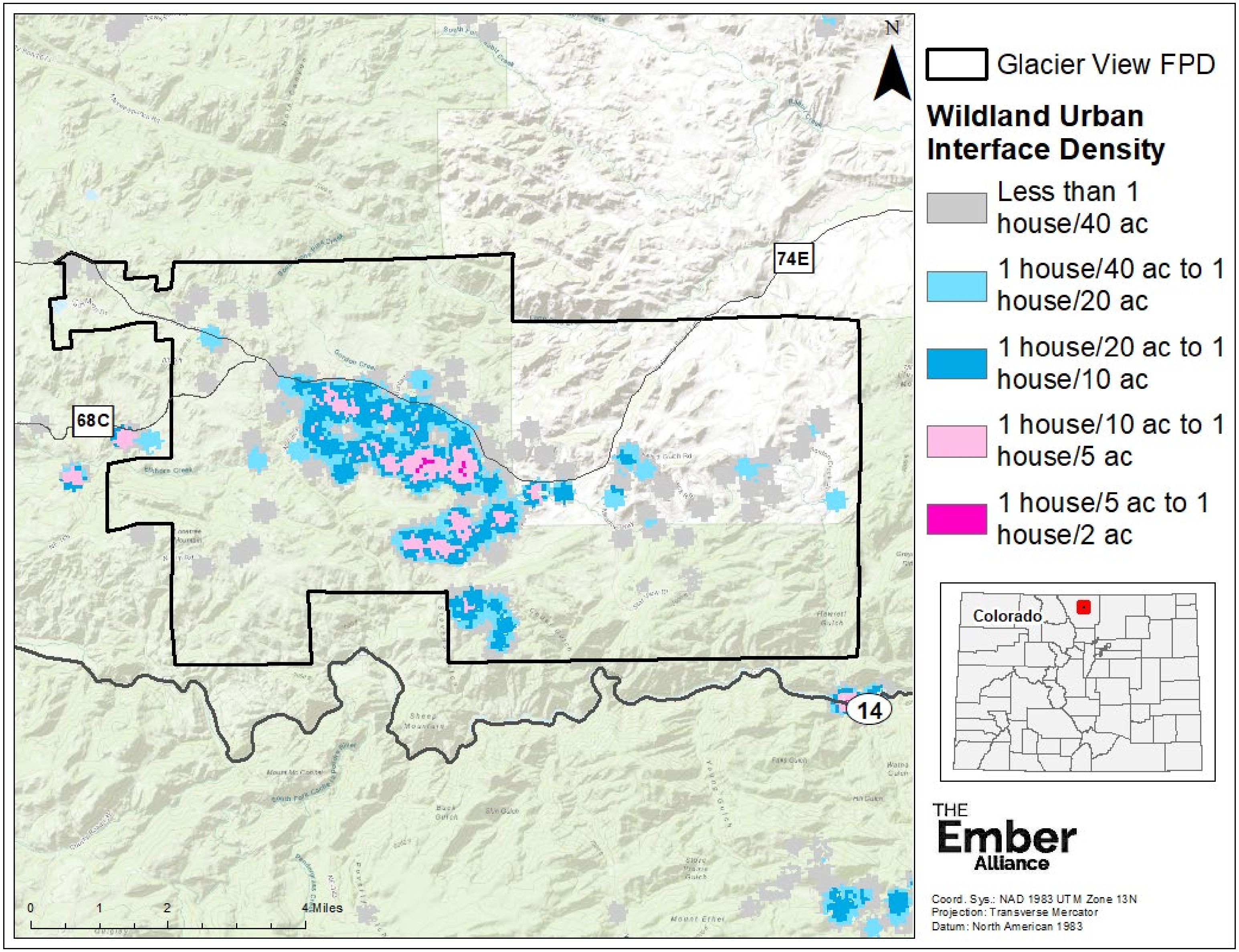


Figure 2.b.1. Wildland-Urban Interface and Intermix in the GVFPD displayed by housing density per acre, from the lowest density of less than 1 house per 40 acres to the highest density of 1 house per 2 acres. (Source: Colorado State Forest Service, Colorado Forest Atlas).

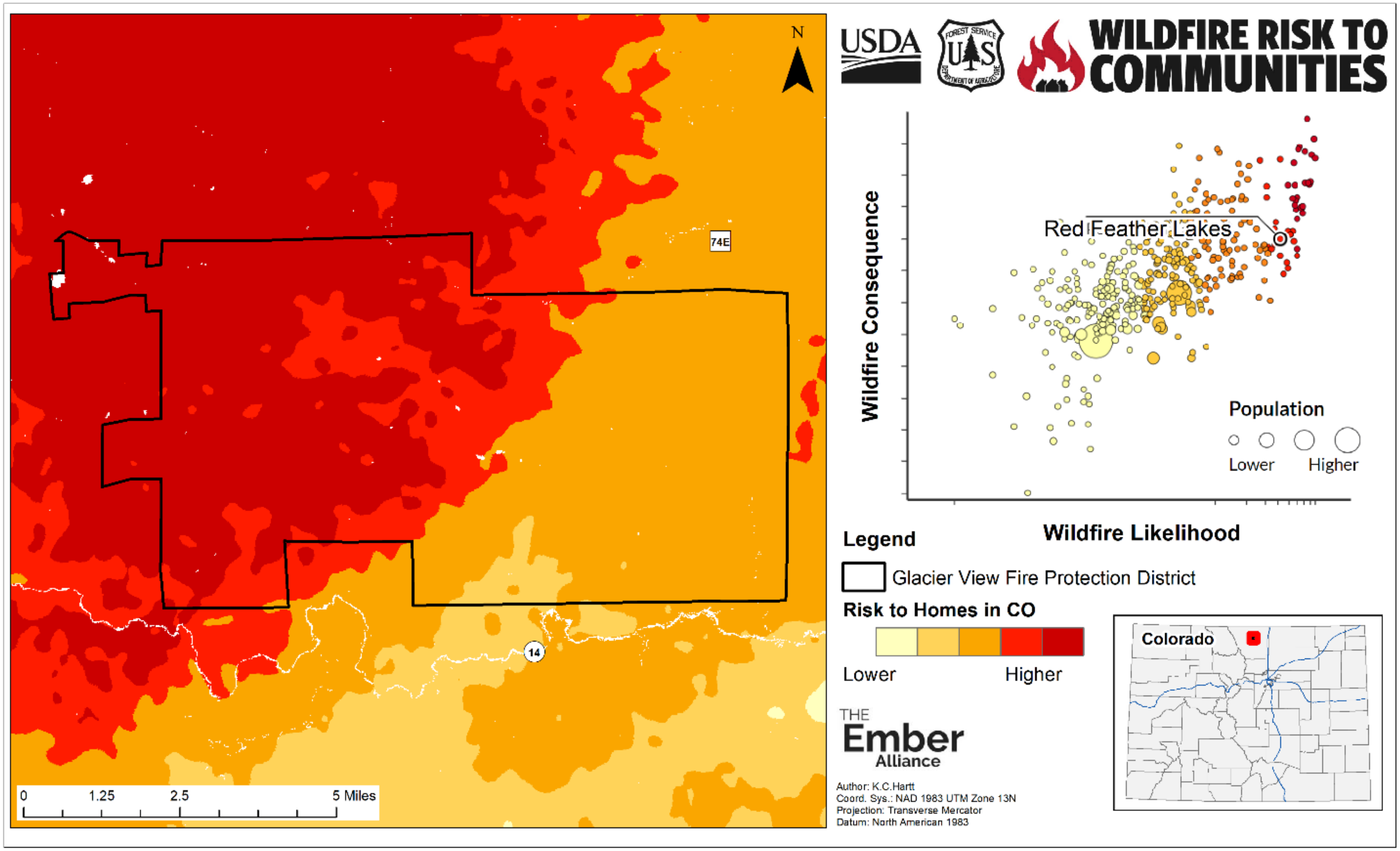


Figure 2.b.2. According to the 2020 Wildfire Risk to Communities analysis by the USFS, the GVFPD and surrounding area are at greater risk of wildfire than 92% of communities in Colorado. (Source: U.S. Department of Agriculture, U.S. Forest Service, https://wildfirerisk.org).

2.c. Resident Preparedness for Wildfire

In 2013, GVFPD secured a Colorado Wildland Interface Mitigation Grant. Mitigation work from this grant treated 150 acres on 57 properties, all single-family homes or cabins. Treatments consisted of mechanical thinning with pile burning in the winter and chipping in the summer. In recent years small scale slash hauling has been conducted in cooperation with community groups. Glacier View Meadows and Red Feather Highlands maintain large community slash piles for residents in these subdivisions. These large piles are burned in the winter under State and Larimer County permits. Glacier View Meadows does not allow private property burning except when contained in an approved outdoor fire pit, including individual slash piles.

GVFPD and TEA evaluated each of the communities in the district during the process of writing this CWPP and discovered that many neighborhoods have no or inadequate defensible space around homes, driveways and roads are too small for a fire engine to drive on, roadways are not adequately cleared to be survivable during a fire, and many residents are unaware of the risk that they are at. A 2021 study from the University of Colorado-Boulder showed that homeowners living in the WUI in Bailey, CO typically underestimated the level of risk their home is at due to wildfire, and tended to overestimate the amount of work they have done to protect their property (Simpkins 2021).

Call to Action

As awareness about wildfire risk continues to grow in GVFPD, it is of utmost importance that residents and HOAs help reduce shared risk. Action and community-building centered around mitigation have reduced wildfire risk and increased community resilience across the mountain west. Mitigation work by residents can spur mitigation by their neighbors (Brenkert-Smith et al. 2013). The cumulative impact of linked defensible space across private properties can improve the likelihood of home survival and protect firefighters during wildfire events (Jolley 2018; Knapp et al. 2021).

2.d. Fire History Along the Colorado Front Range

Colorado's Front Range was influenced heavily by fire before the era of fire suppression This land is the ancestral land of the Cheyenne, Eastern Shoshone, and Arapaho First Nations. These indigenous groups utilized fire as a land management tool. Lightning ignited fires were common in ponderosa pine and dry mixed-conifer forests before European settlement in the 1850's.

Ponderosa pine and mixed-conifer forests were fire-adapted ecosystems and very resilient to wildfires. Low- to mixed-severity fires occurred every 7 to 50 years and occasional severe, stand-replacing fires. Frequent fires would kill many tree seedlings and saplings, thereby preventing the accumulation of ladder fuels and reducing the potential for surface fires to transition into crown fires. Fire spread was more rapid through understory grasses but released far less heat, which allowed many larger trees to survive unscathed. Occasionally dense clumps of trees would experience mortality from passive crown fire, further increasing the diversity of habitat in these ecosystems, which included a mosaic of widely spaced trees and small tree clumps interwoven with grasslands and shrublands, particularly on drier south-facing slopes. North-facing slopes often supported denser forest stands (Addington et al. 2018) (**Figure 2.d.1**). Ponderosa pine ecosystems with fewer trees support more abundant and species-diverse understories of grasses, forbs, and shrubs and provide habitat for a variety of wildlife that prefer more open forest structure (Matonis and Binkley 2018; Kalies et al. 2012; Pilliod et al. 2006).

As the initial ranching and logging activities of Euro-American settlers subsided in the region and government-mandated fire suppression began in the late 1800's, trees grew back in a single age class, resulting in many dense forest stands (**Figure 2.d.2**; Addington et al. 2018). Although many residents consider dense forest as "natural", these conditions are vastly different from the wildfire-resilient ecosystems that existed before. Landscapes of continuous, dense forests are more prone to high-severity fires that are difficult to suppress and can result in catastrophic losses to lives and property (Haas et al. 2015).

Rocky Mountain lower montane-foothill shrublands are also prevalent in this area, dominated by mountain mahogany. Native grass species include mountain muhly, blue grama, sideoats grama, Arizona fescue, and various other grasses. Introduced grasses including cheatgrass, smooth brome, and Kentucky bluegrass are often present (Decker et al. 2020). Shrublands provide important forage to ungulates like mule deer and elk. Fire is a naturally occurring process in Rocky Mountain lower montane-foothill shrubland, and this ecosystem historically experienced wildfires every 14-112 years at a variety of fire severities depending on local site factors (Missoula Fire Sciences Laboratory 2012; Decker et al. 2020). The 2019 McNay Fire east of the GVFPD primarily burned in this shrubland ecosystem.

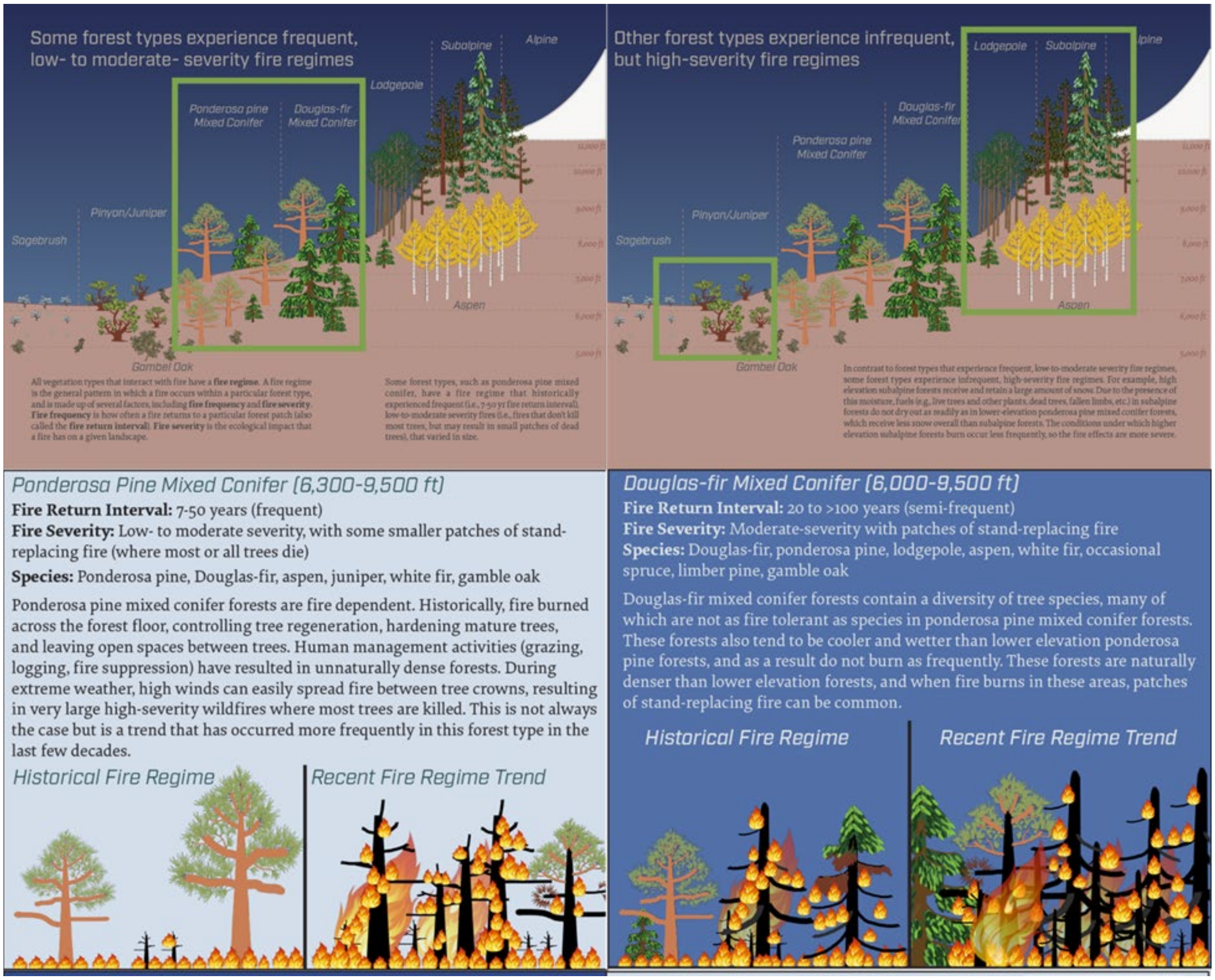


Figure 2.d.1. Ponderosa pine forests along the Colorado Front Range historically experienced frequent fires every 7-50 years and mixed-conifer forests experienced semi-frequent fires every 20 to >100 years, resulting in less dense forest conditions than we see today. (Source: Colorado Forest Restoration Institute)

Clearing in Indian Meadows | **Laramie-Poudre Tunnel Work Site**

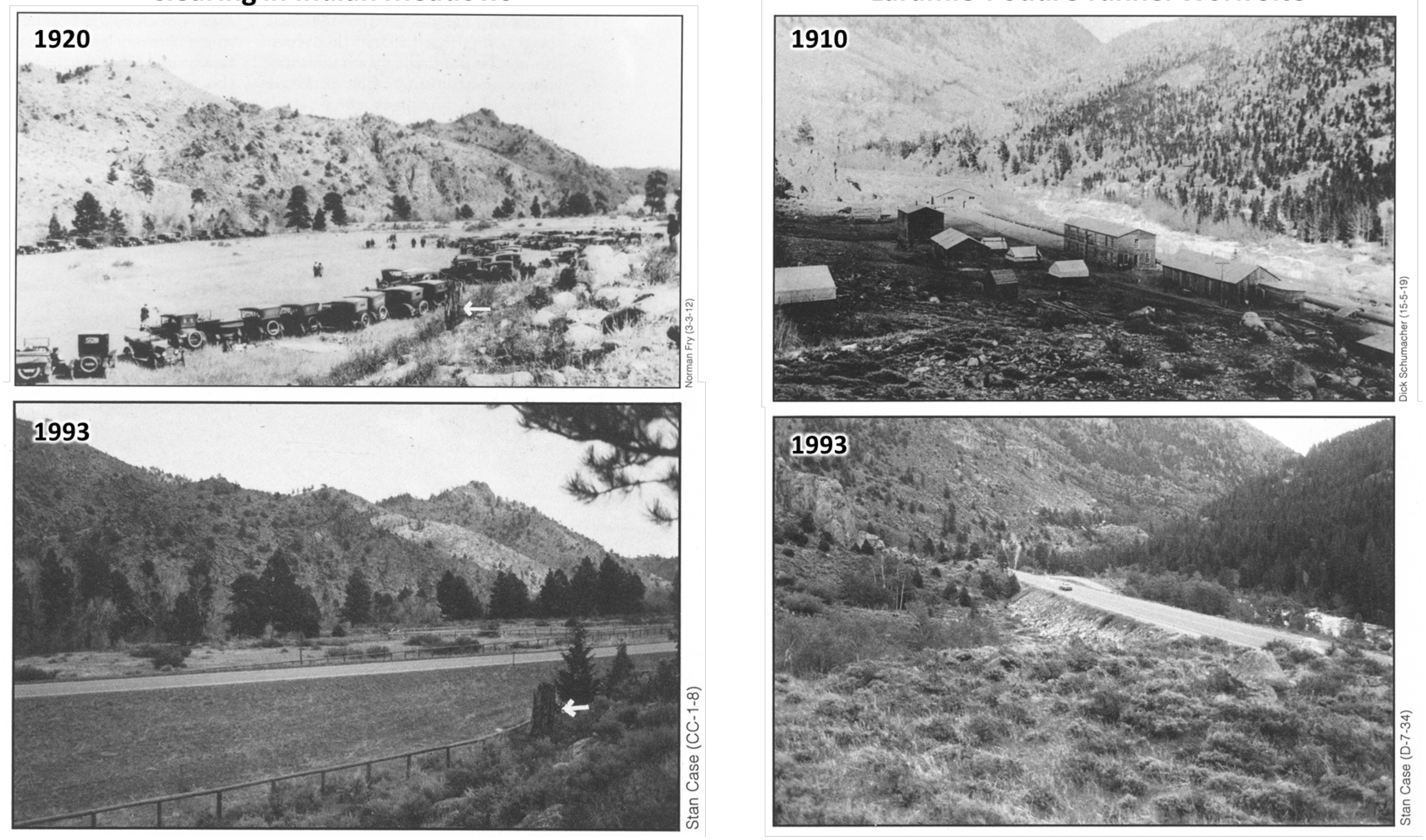


Figure 2.d.2. Tree densities have remained low in some ponderosa pine savannas areas (photos on left), but in other ponderosa pine and mixed-conifer forests, particularly north-facing slopes, tree densities are substantially higher today than they were historically in part due to fire suppression (photos on right). Photos credits: Norman Fry, Stan Case, and Dick Schumacher. (Source: Case 1995)

Along the Front Range of Colorado, a combination of extreme fire weather conditions (extreme heat and high winds), unplanned ignitions, and dry, unmitigated wildland vegetation can create catastrophic wildfire scenarios in the WUI. Climate change is further increasing wildfire risk and lengthening fire seasons (**Section A.6**, Parks et al. 2016). Many catastrophic wildfires in Colorado's history have occurred on dry and windy days, resulting in rapid fire spread over short periods of time. On the Front Range, wind can gust over 62 miles/hour, which makes wildfire suppression nearly impossible (Haas et al. 2015).

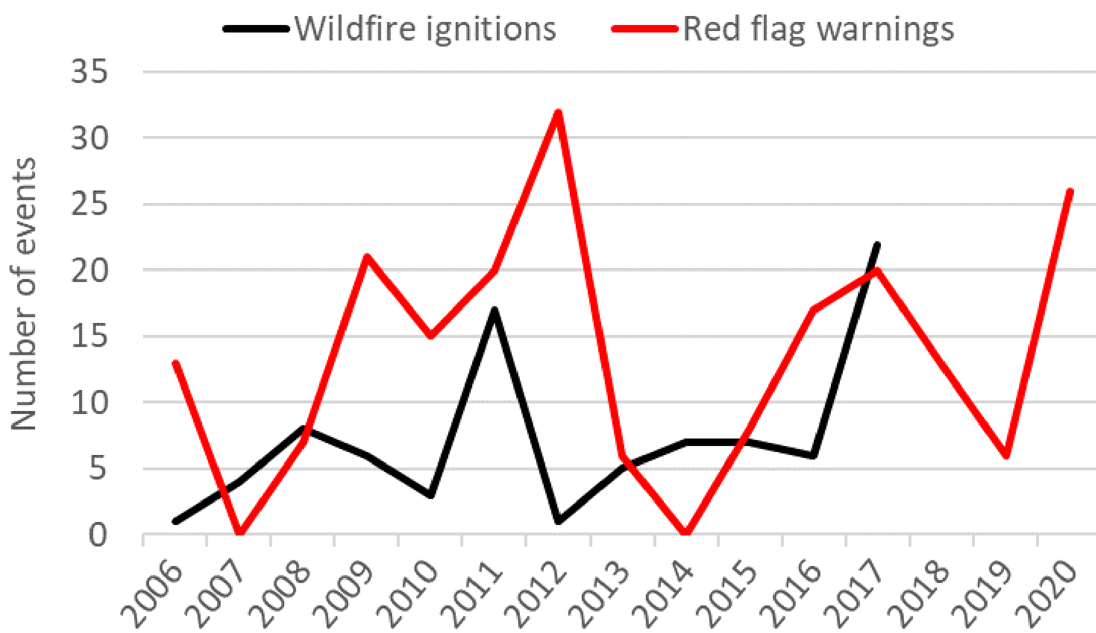
Days with red flag warnings indicate severe fire weather and require extra vigilance by fire departments and residents (see **Table 1.c.1** for red flag warning criteria). The occurrence of red flag warnings is highly variable from year to year due to regional weather patterns and weather anomalies such as El Niño and La Niña. GVFPD experienced between 0 and 32 red flag warnings per year from 2006 to 2020 (**Figure 2.d.3**). The greatest number of red flag warnings occurred in 2012 and 2020, which were the years of the High Park and Cameron Peak Fires. Red flag conditions are most common in March, April, June, September, and October in this area.

Between 2000 and 2017, there were 122 fire starts in and around the GVFPD (**Figure 2.d.4**). A majority of wildfire ignitions in the area do not grow into large wildfires due to rapid response of local firefighters and/or weather conditions conducive to fire suppression. About 75% of these were contained to an acre or less, and only three fires during that time grew to over 100 acres. Complete ignition data is not available past 2017. One notable fire after that time is the McNay Fire that reached 450 acres in 2019.

Four significant wildfires burned in and around the GVFPD from 2004-2020 (**Figure 2.d.5**). The 2012 High Park Fire burned through the southern part of the district and destroyed over 50 homes in the GVFPD. Reduced fuel loads in area burned by the High Park Fire arrested the spread of the 2020 Cameron Peak Fire, which grew to the largest wildfire in Colorado's history at 208,660 acres and destroyed 461 structures, 224 of which were homes.

Take Away Message

GVFPD is at high risk for large, high-severity wildfires due to dense forest conditions, abundance of tall grasses, dry and hot weather, and strong, gusty winds. Increasing drought and warming temperatures exacerbate wildfire risk in the area. GVFPD and residents in the district must prepare for large wildfire events. Proactive work is imperative.



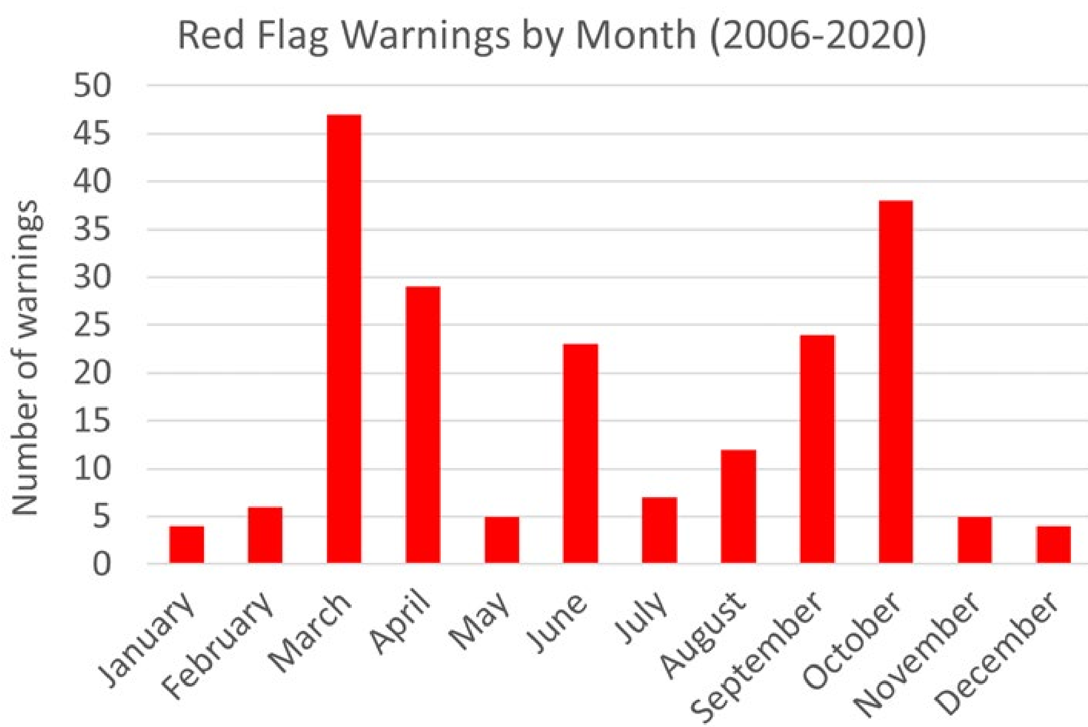


Figure 2.d.3. Top: Red flag days and wildfire ignitions by year. Bottom: Total number of red flag days in each month from 2006 to 2020. March, April, June, September, and October are the most common months for experiencing red flag weather. Data on historical red flag warnings were available for 2006 to 2020 and data on fire ignitions were available for 1992 to 2017. (Sources: Iowa State University, Iowa Environmental Mesonet, and Colorado State Forest Service, Colorado Forest Atlas).

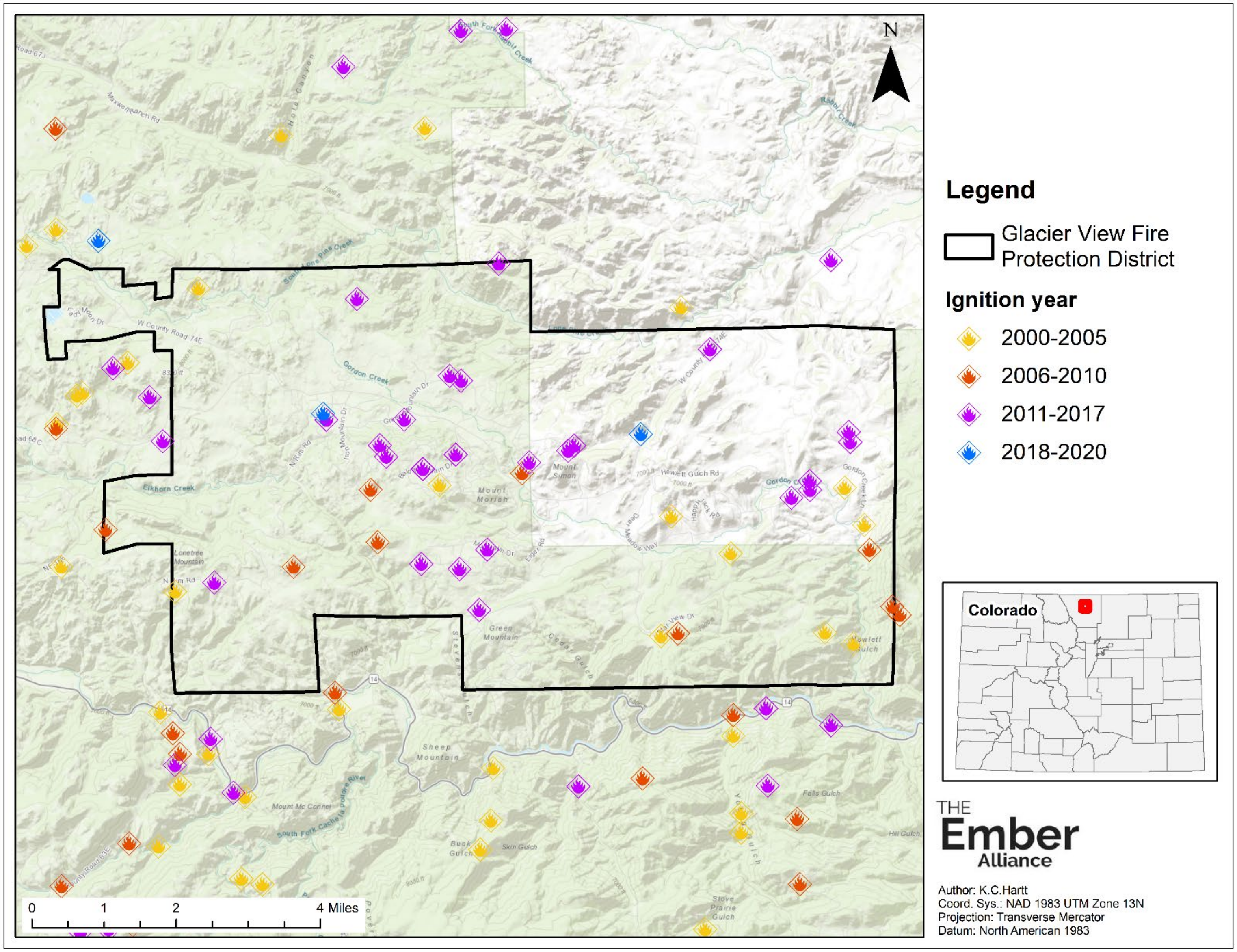


Figure 2.d.4. Between 2000 and 2017, there were 122 fire starts in and around GVFPD. About 75% of these were contained to an acre or less, and only three fires during that time grew to over 100 acres. Additional ignitions from 2018-2020 are also displayed, but ignition data is not complete for this timeframe (Source: Colorado State Forest Service, Colorado Forest Atlas; Chief Warren Jones, GVFPD).

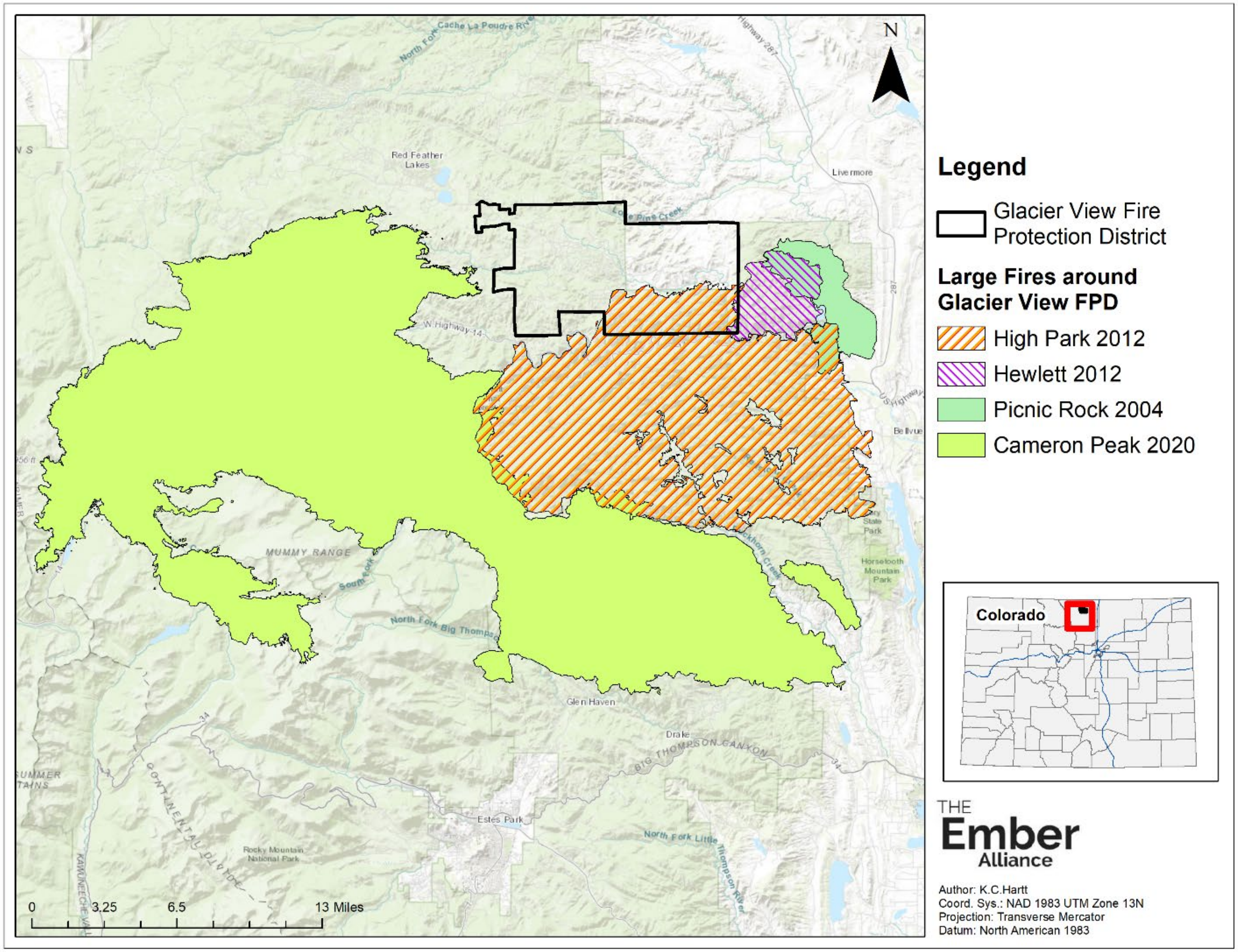


Figure 2.d.5. Four significant wildfires burned in and around the GVFPD from 2004-2020. The 2012 High Park Fire burned through the southern part of the district and destroyed more than 50 homes there. Reduced fuel loads in the area burned by the High Park Fire arrested the spread of the 2020 Cameron Peak Fire. (Source: National Interagency Fire Center).

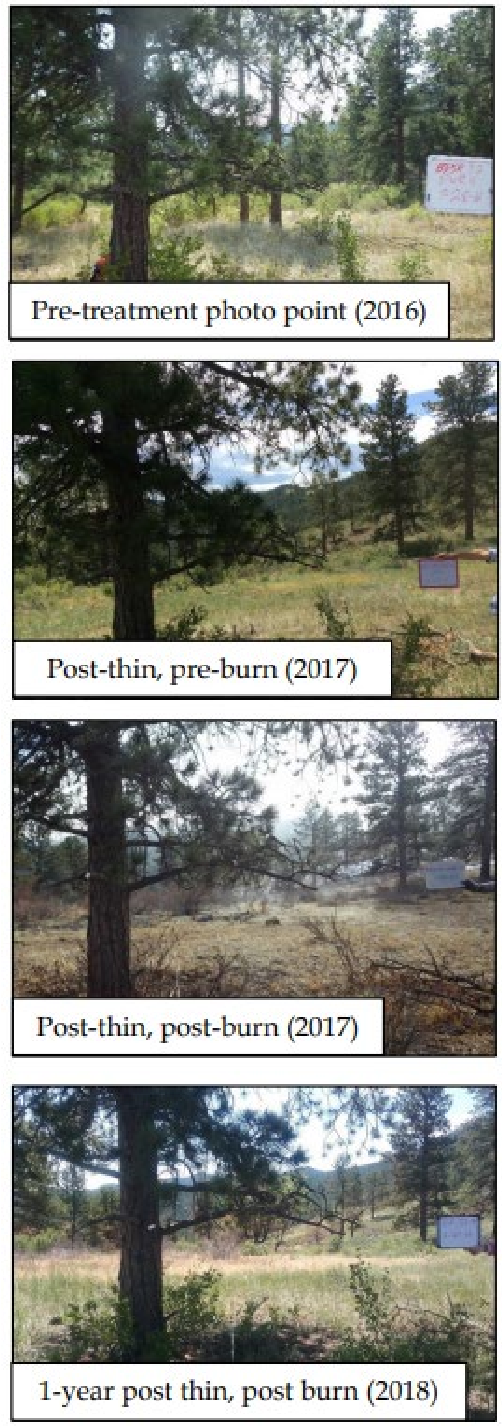
2.e. Fuel Treatment History in and around the GVFPD

Forest management has been a part of the landscape around the GVFPD for decades (**Figure 2.e.2**, **Figure 2.e.1**). Between 2007-2018, the Colorado State Forest Service, USFS, and non-governmental agencies have completed forest health and fuels treatments on almost 10,000 acres of land in and around the district. This work included thinning, pile burning, and broadcast burning.

The USFS conducted broadcast burns nearby on 4,000 acres between 2007-2018 and 4,150 acres in 2019 and 2020 to reduce fuel loads and improve forest health. The agency has also conducted pile burning on over 4,500 acres to remove fuels created during mechanical thinning. Collaborative broadcast burns were conducted on the Ben Delatour Scout Ranch in 2017 and 2019. Fuel treatments created important opportunities for wildland firefighters during the Cameron Peak Fire by reducing the potential for extreme fire behavior in strategic locations, including around the Shambhala Mountain Center (Avitt 2021).

Broadcast prescribed burning can be an extremely effective method to reduce hazardous fuels and restore ecological conditions across a variety of grassland, shrubland, and forest ecosystems (Stephens et al. 2009; Paysen et al. 2000) See **Section 4.d**. However, broadcast burning is not without risk. It is extremely uncommon for prescribed burns to escape containment lines (Weir et al. 2019), and when they do, the wildland fire community soberly reviews those escapes to produce lessons learned (Dether 2005). A local example is the Elkhorn Prescribed Burn which escaped in October 2019 and became the Elk Fire, which resulted in evacuations and destroyed one outbuilding.

The escape of the Elkhorn Prescribed Burn was an unfortunate occurrence and has understandably created fear amongst some members of the public. The prescribed burn community has taken lessons away from the Elk Fire which will reduce the likelihood of future escapes (Colorado Department of Public Safety, 2020). Life safety is always the top consideration when developing and conducting prescribed burns. With proper planning and implementation, qualified firefighters can safely conduct prescribed fires, even in the WUI (Hunter and other 2007, Dether and other 2006). The landscape benefits gained from fuels treatments such as prescribed fire often outweigh the risks and provide several advantages relative to mitigating wildland fire risk and increasing options during wildland firefighting operations.



A restored ponderosa pine ecosystems treated with thinning and burning at the Ben Delatour Scour Ranch. Photo credits: [Colorado Forest Restoration Institute](#).

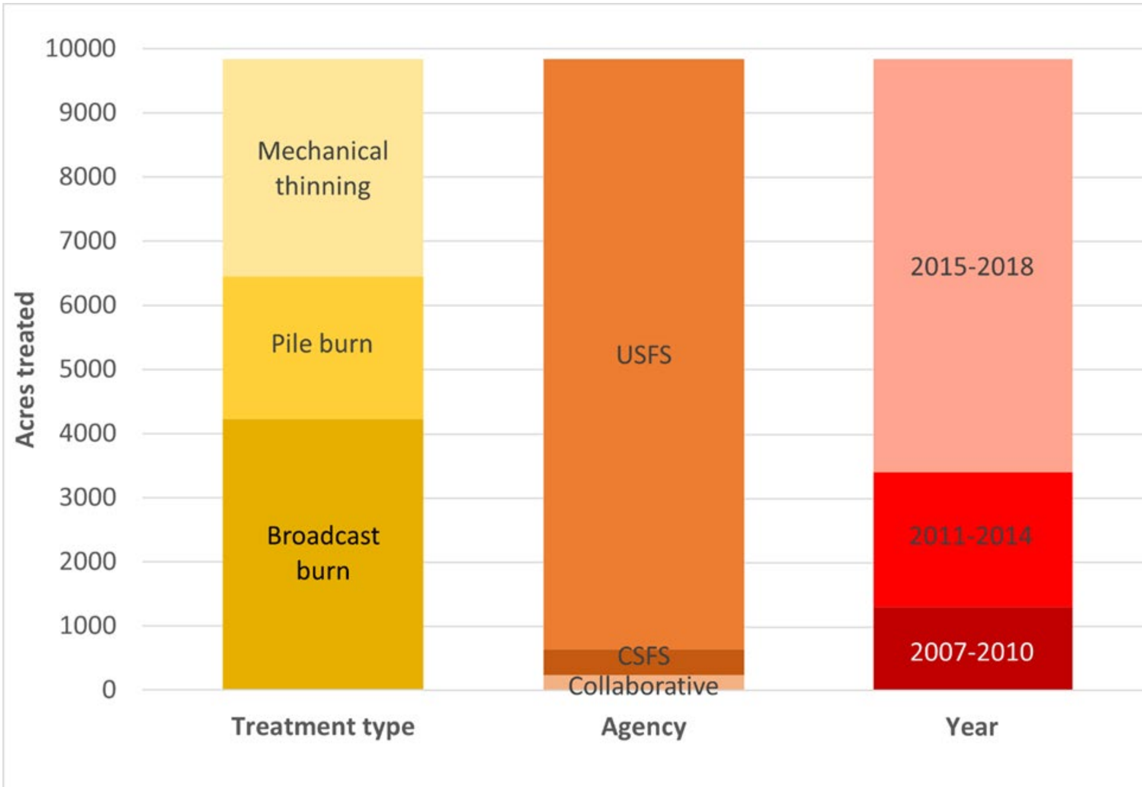


Figure 2.e.1. Acres of forest management treatments in and around the GVFPD District from 2008 - 2018 conducted by the USFS, CSFS, and non-governmental organizations. (Source: Colorado Forest Restoration Institute; data available through 2018).

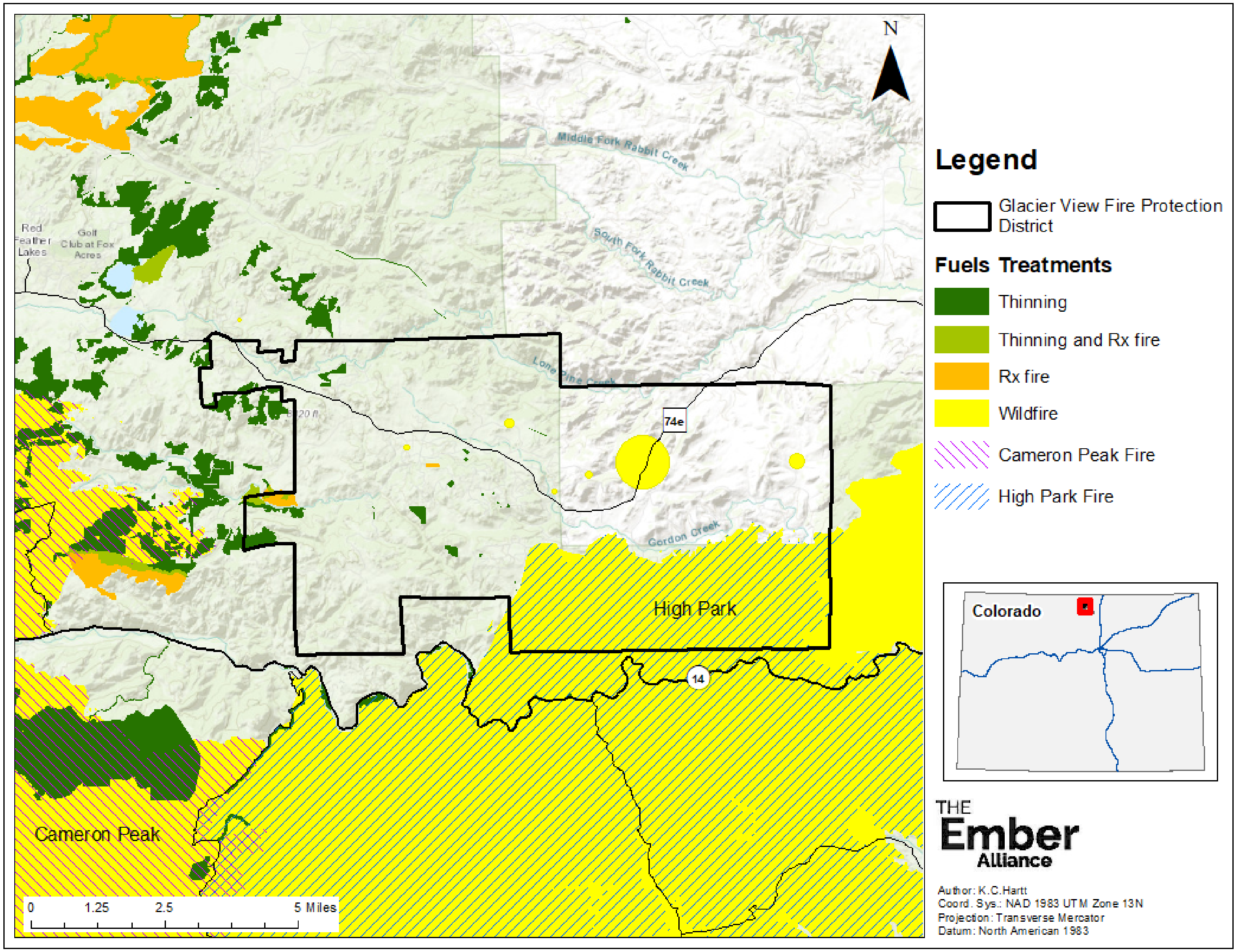


Figure 2.e.2. Locations of forest management treatments and wildfires in and around the GVFPD. Fuel treatments were conducted by the USFS, CSFS, and non-governmental organizations. (Source: Colorado Forest Restoration Institute; data available through 2018). An interactive map with fuel treatment history is available online at https://experience.arcgis.com/experience/225f72cc029c4e37a2acbdefc60b2140/page/Plan-Units/.

2.f. District Capacity

GVFPD is an all-volunteer organization of 22 personnel. It was formed in the late 1980's as a fire protection district under Colorado CRS Title 32. It is governed by a five-member Board of Directors. There is a Fire Chief, three Assistant Chiefs, two Captains, and 18 Firefighters. Six personnel are EMTs. Business operations are managed by a paid half-time Administrator. All GVFPD personnel are trained to NWCG S-130/S-190 level.

GVFPD operates one Type 1 structure engine, two Type 5 wildland/initial attack engines, two water tenders (1500 gallon/750 gpm and 2200 gallon/500 gpm), one Type 3 Colorado Division of Fire Prevention and Control (DFPC) engine, two ATVs, one BLS ambulance and two Squads (pickup or SUV). GVFPD operates from one centrally located fire station and one storage/training building.

GVFPD is dispatched by Larimer County Sheriff dispatch center and has both 800 DTR and VHF radio capabilities. The NOCO Alert emergency notification system is provided by the Larimer Emergency Telephone Authority. The Insurance Services Office (ISO) rating is 8B within five miles of the fire station.

GVFPD is supported by four neighboring volunteer fire districts for initial attack under standard mutual-aid agreements: Livermore to the east, Red Feather Lakes and Crystal Lakes to the west, and Poudre Canyon to the south. These agencies have similar personnel, capabilities, and equipment.

An Emergency Services Technician or Specialist from the Larimer County Sheriff's Office Emergency Services unit responds to all wildfires in the district. This person serves as the linkage to other mutual-aid resources in the county including Poudre Fire Authority, Wellington Fire District, Loveland Fire Rescue Authority, USFS and DFPC. If incident command exceeds district capability, LCSO assumes command and, if necessary, can initiate a Type III incident command organization. A Single Engine Air Tanker (SEAT) is typically available from spring to fall in the northern front range.

GVFPD operates one Type 1 structure engine, two Type 5 wildland/initial attack engines, and one Type 3 Colorado Division of Fire Prevention and Control engine. Photo credit: GVFPD.

3. Becoming a Fire Adapted Community

It is recommended that that GVFPD, HOAs, and residents embrace the concept of Fire Adapted Communities (FAC), which is defined by the National Wildfire Coordinating Group as "a human community consisting of informed and prepared citizens collaboratively planning and taking action to safely coexist with wildland fire". This concept can guide residents, fire practitioners, and communities through a holistic approach to become more resilient to fire (**Figure 3.1**).

Your community's CWPP sets the stage for fire adaptation, and the next step is on-the-ground action and an ongoing commitment to risk mitigation at all levels of the community, from individual homeowners to neighborhoods and HOAs to the GVFPD to land managers and other partners. This section of the CWPP includes recommendations and resources for mitigating wildfire risk and enhancing emergency preparedness. The GVFPD and public land managers have an important role to play in implementing the recommendations in this CWPP, and they have made commitments to take on-the-ground action as outlined in **Section 4. Implementation Recommendations for Fuel Treatments**.

Individual homeowners, neighborhoods, and HOAs also have a vital role to play in addressing shared wildfire risk. Action and community-building centered around mitigation have reduced wildfire risk and increased community resilience across the mountain west. Mitigation work by residents can spur mitigation by their neighbors (Brenkert-Smith et al., 2013). The cumulative impact of linked defensible space across private properties can improve the likelihood of home survival and protect firefighters during wildfire events (Jolley, 2018; Knapp et al., 2021).

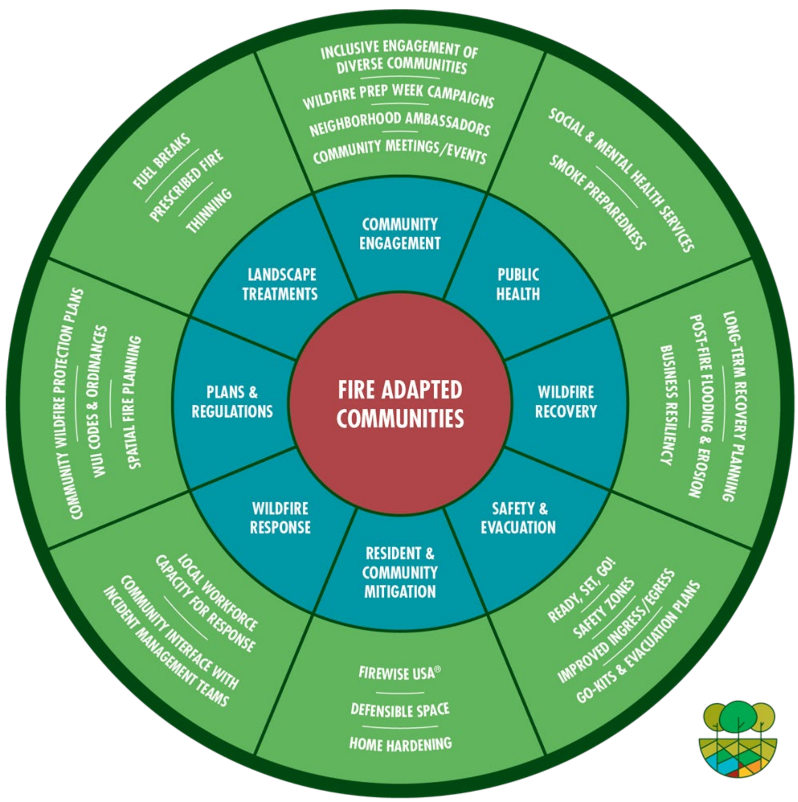


Figure 3.1. The Fire Adapted Communities graphic provides specific programs and activities that communities can take to reduce their wildfire risk and increase their resilience (Source: Fire Adapted Community Learning Network).

3.a. Individual Recommendations

Mitigate the Home Ignition Zone

During catastrophic wildfires, property loss happens mostly due to conditions in the **home ignition zone** (HIZ). The home ignition zone includes your home and other structures (e.g., sheds and garages) and area within 100 feet of each structure. Firefighter intervention, adequate defensible space, and home hardening measures were common factors for homes that survive major wildfires (IIHBS 2019; Maranghides et al. 2022). Research following the 2018 Camp Fire showed that homes were more likely to burn down when they were close to other structures that had also burned, when they had vegetation within about 330 feet of the home, and when they had combustible materials (firewood or propane tanks) near the home (Knapp et al. 2021).

> You can increase the likelihood that your home will survive a wildfire and help protect the safety of firefighters by creating defensible space, replacing, or altering building materials to make your home less susceptible to ignition, and taking steps to increase firefighter access along your driveway.

Defensible space is the area around a building where vegetation, debris, and other types of combustible fuels have been treated, cleared, or reduced to slow the spread of fire and reduce exposure to radiant heat and direct flame. It is encouraged that residents develop defensible space so that during a wildfire their home can stand alone without relying upon limited firefighter resources due to the great reduction in hazards they have undertaken.

Home hardening is the practice of making a home less likely to ignite from the heat or direct contact with flames or embers. It is important to remember that embers can ignite homes even when the flaming front of a wildfire is far away. Home hardening involves reducing this risk by changing building materials, installation techniques, and structural characteristics of a home. Home hardening measures are particularly important for WUI homes; 50 to 90% of homes ignite due to embers rather than radiant heat during wildfires (Babrauskas 2018; Gropp 2019).

Defensible space allowed firefighters to protect this home during the 2016 Cold Springs Fire near Nederland, CO (source: *Cold Springs Fire Success Stories* from Wildfire Partners).

Defensible Space

Residents can create defensible space by reducing the amount of vegetation and flammable materials (i.e., pine needles, stacked firewood, patio furniture) within the HIZ. trees, and shrubs that could ignite during a wildland fire. Defensible space can slow the spread of wildfire, prevent direct flame contact, and reduce the chance that embers will ignite material on or near your home (Hakes et al. 2017). Substantially reducing vegetation within the HIZ and removing vegetation that overhangs decks and roofs can reduce structure loss, especially for homes on slopes (Syphard et al. 2014).

Do not count on firefighters staying to defend your home—your home should be able to survive a wildfire on its own. There are never enough firefighters to stay and defend every single home during large incidents. Properties that are not defensible will not often receive firefighter resources due to unsafe conditions and the higher likelihood of home loss.

Defensible space is divided into multiple zones around a home, and recommended practices vary among zones. The CSFS defines zone one as 0 to 5 feet from the home, zone two as 5 to 30 feet from the home, and zone three as 30 to about 100 feet from the home. Some organizations call zone one the "noncombustible zone" (0 to 5 feet from the home) and zone two the "lean, clean, and green zone" (5 to 30 feet from the home). Residents should establish defensible space around each building on their property, including detached garages, storage buildings, barns, and other structures.

A 2021 study from the University of Colorado-Boulder showed that homeowners living in the WUI in Bailey, CO typically underestimated the level of risk their home is at due to wildfire, and tended to overestimate the amount of work they have done to protect their property (Simpkins, 2021). Make sure you are informed about best practices for protecting your home. See **Figure 3.a.1**, **Table 3.a.1**, and the CSFS publication The Home Ignition Zone for recommendations. See **Section 4.b. Stand-Level Fuel Treatment Recommendations** for specific recommendations by forest type.

It is important for residents to work together as a community to mitigate shared wildfire risk. Structure-to-structure ignition is a major concern in WUI communities and can cause substantial property loss. Almost 60% of homes within the GVFPD are within short-range spotting distance of other homes (**Appendix Figure 9.a.10).** Neighbors can increase their homes' chances of survival during a wildfire if they work together to reduce hazards in their overlapping defensible space.


Some homes in the GVFPD have exemplary defensible space with mowed grass near structures, trees limbed and not overhanging roofs, and non-flammable barriers within home ignition zone one. Photo credit: The Ember Alliance.

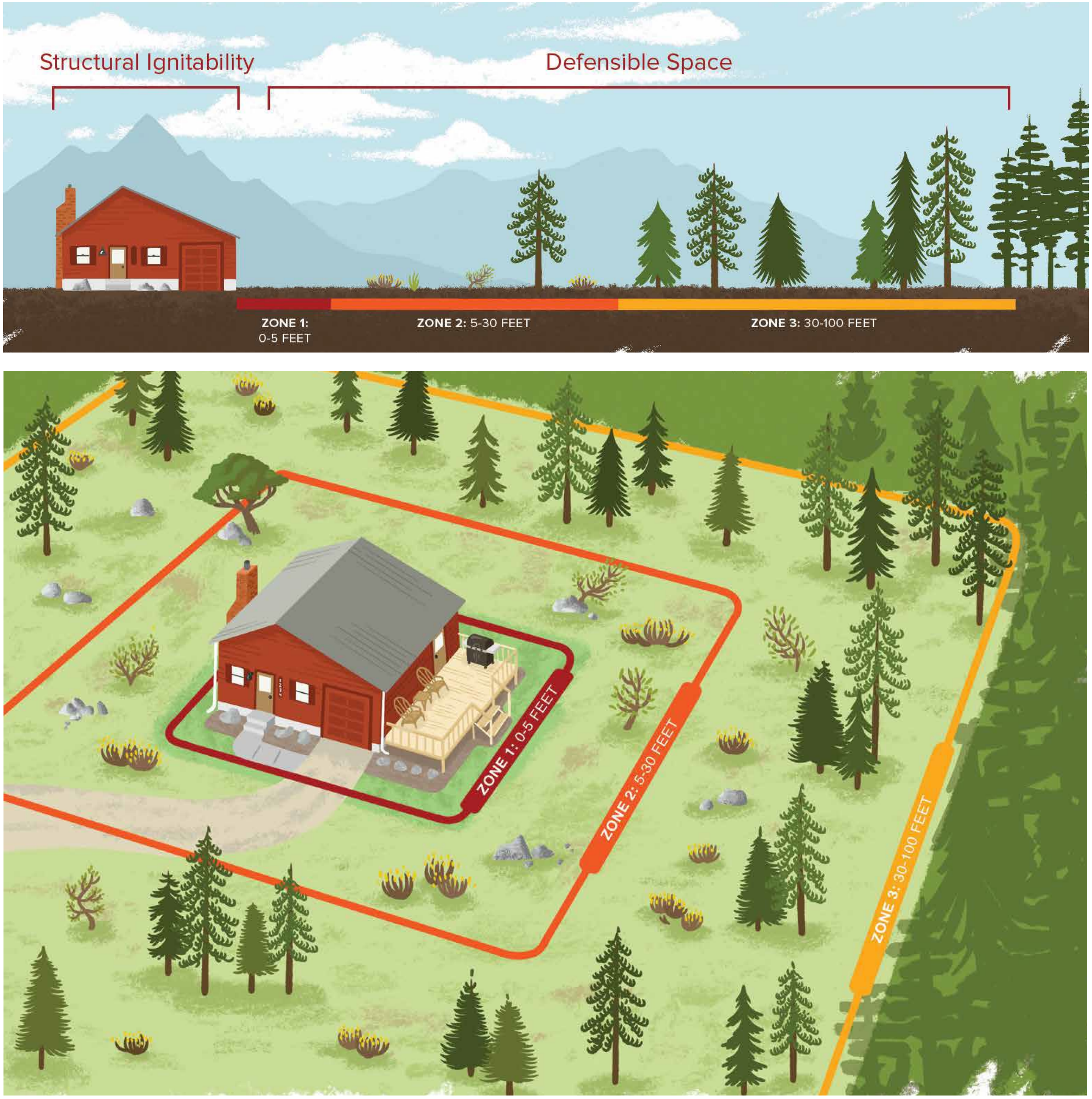


Figure 3.a.1. Defensible space zones recommended by the Colorado State Forest Service. (Source: Colorado State Forest Service, Bonnie Palmatory).

Table 3.a.1. Defensible space recommendations for homes in the WUI based on the CSFS publication The Home Ignition Zone. This is not an all-inclusive list of activities. Specific measures will depend on the placement and condition of your property. Section **4.b. Stand-Level Fuel Treatment Recommendations** includes specific defensible space recommendations by forest type.

Zone 1: 0 to 5 feet from your home – the noncombustible zone.
Goal: Prevent flames from having direct contact with your home.
• Create a noncombustible border 5 feet around your home (aka, hardscaping). Replace flammable wood chips with alternatives like dirt, stone, or gravel. • Remove branches that hang over your roof and drop needles onto your roof and remove all fuels within 10 feet of the chimney. • Remove combustible materials (dry vegetation, wooden picnic tables, juniper shrubs, etc.) from underneath, on top of, or within 5 feet of decks, overhangs, windows, and doors. • Annually remove dead or dry leaves, pine needles, and dead plants withing 5 feet of your home and off your deck, roof, and gutters. Farther than 5 feet from structures, raking material will not significantly reduce the likelihood of ignition and can negatively affect other trees. • Move firewood or other combustible materials to Zone 3. • Do not use space under decks for storage.
Zone 2: 5 to 30 feet from your home – the lean, clean, and green zone.
Goal: Slow the movement of flames approaching your home and lower the fire intensity.
• Irrigate and mow grasses to 4 inches tall or less. When water restrictions limit water use, keep grasses mowed and consider xeriscaping within Zone 2. • Remove any accumulated surface fuels such as logs, branches, slash and mulch • Remove common junipers because they are highly flammable and tend to hold a layer of flammable material beneath them, and replace with plants that have more fire-resistant attributes, like short-statures, deciduous leaves, and higher moisture content. See FireWise Plant Materials from Colorado State University Cooperative Extension for suggestions. • Remove enough trees to create at least 10 feet* of space between crowns. Measure from the outermost branch of one tree to the nearest branch on the next tree. Create even more space between trees if your home is on a slope (Table **3.a.2**). See **Figure 3.a.2** for how to measure crown spacing. • Small groups of two or three trees may be left in some areas of Zone 2. Spacing of 30 feet* should be maintained between remaining tree groups to ensure fire doesn't jump from one group to another. • Remove ladder fuels under remaining trees. This is any vegetation that can bring fire from the ground up into taller fuels. • Prune tree branches to a height of 6-10 feet from the ground or a third of the total height of the tree, whichever is less. See **Figure 3.a.2** for a depiction of how to measure limb height. • Keep spacing between shrubs at least 2-3 times their height. • Relocate wood piles and propane tanks to Zone 3. • Remove stressed, diseased, dead, or dying trees and shrubs. This reduces the amount of vegetation available to burn and improves forest health. • Keep shrubs at least 10 feet* away from the edge of tree branches.

Zone 3: 30 to 100 feet from your home
Goal: Slow movement of flames, move fire to the ground, reduce ember production.
If you live on a slope, this zone may be larger to gain the full benefits of defensible space. • Store firewood and propane tanks at least 30 feet away and uphill from your home and away from flammable vegetation. Store even farther away if your home is on a slope. • Mow or trim grasses to maximum height of 6 inches. Grasses can be taller in zone 3 than zone 2 because of the greater distance from your home, but shorter grass is always better for reducing potential flame lengths and therefore radiant heat exposure. • Remove enough trees to create at least 10-foot spacing between the outermost branches of remaining trees. Create even more space between trees if your home is on a slope (**Table 4.b.1**). See **Figure 3.a.2** for a depiction of how to measure crown spacing. • Remove limbs so branches do not hang below 10 feet above the ground. See **Figure 3.a.2** for a depiction of how to measure limb height. • Remove shrubs and saplings that can serve as ladder fuels. • Remove heavy accumulations of dead trees and branches and piles of fallen leaves, needles, twigs, pinecones, and small branches. Thin trees to increase spacing and remove ladder fuels to reduce the likelihood of torching, crown fires, and ember production. • Consult with a qualified forester to develop a plan to manage your property to achieve fuel reduction and other goals, such as creating wildlife habitat. Follow principles of ecological restoration as outlined in **Stand-Level Fuel Treatment Recommendations**.

*Horizontal spacing recommendations are minimums and can be increased to reduce potential fire behavior, particularly on slopes. Consult a forestry, fire, or natural resource professional for guidance with spacing on slopes.

Table 3.a.2. Minimum recommended spacing between tree crowns and shrubs is greater for properties on steeper slopes due to the exacerbating impact of slope on fire behavior (Dennis 2003).

Percent slope	Minimum spacing between tree crowns	Minimum spacing between shrubs / small clumps of shrubs
0 to 10 %	10 feet	2.5 x shrub height
11 to 20%	15 feet	3 x shrub height
21 to 40%	20 feet	4 x shrub height
>40%	30 feet	6 x shrub height

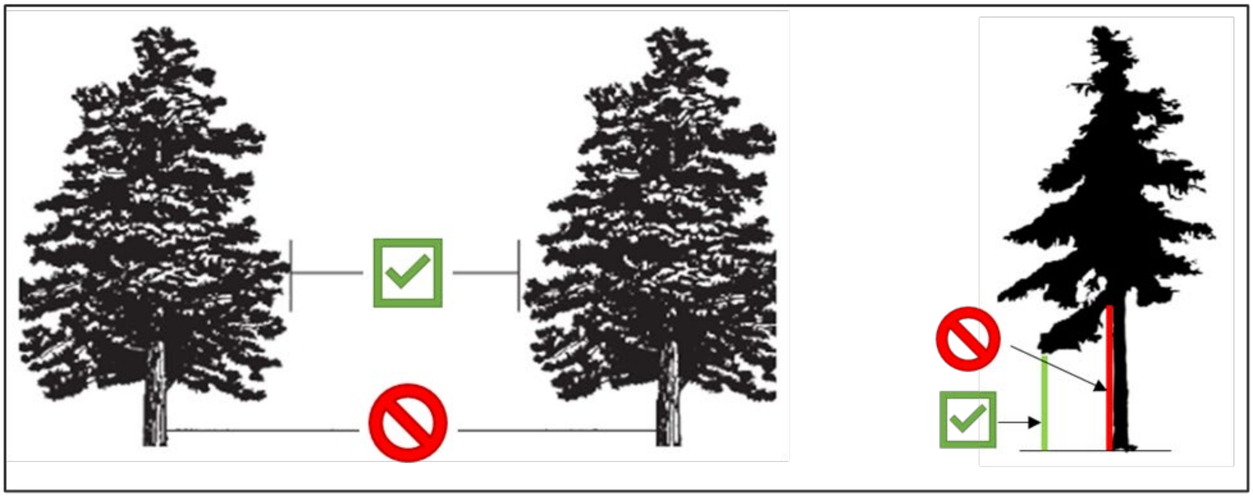


Figure 3.a.2. Spacing between tree crowns is measured from the edge of tree crown to tree crown, NOT from tree stem to tree stem (left). Height of limbs above the ground is measured from the ground to the lowest point of the limb, NOT from where the limb attaches to the tree (right).

Some homeowners in the WUI are concerned that removing trees will destroy the forest and reduce the aesthetic and monetary value of their property. In fact, many dense ponderosa pine forests are unhealthy and greatly diverged from historical conditions that were maintained by frequent wildfires (**Figure 2.d.1**). The reality is that nothing will decrease the aesthetic and monetary value of your home as much as a high-severity wildfire burning all the vegetation in the community, even if your home survives the fire. Forest management can look messy and destructive in the first years following treatment; however, grasses, shrubs, and wildflowers will respond to increased light availability after tree removal and create beautiful ecosystems with lower fire risk (**Figure 3.a.3**).

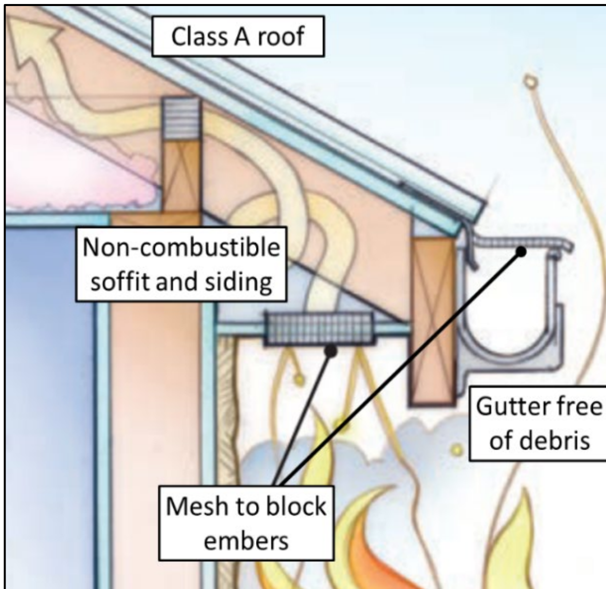
Many residents enjoy their land even more after conducting effective fuel treatments. Removing trees can open incredible views of mountains, rivers, and rock formations, and wildlife are often attracted to forests with lower tree densities and a greater abundance of understory plants. Many residents feel safer in a forest that is less dark and more open, and they rest easier knowing firefighters would have a greater chance of safely defending their home. It might even be said that the more trees you cut, the more trees you save from wildfire. Reducing fuel loads and increasing the spacing between trees also increases the chance that your home and your neighbors' homes will survive a wildfire**.** See **Section 4.b. Stand-Level Fuel Treatment Recommendations** for more information on treatments that achieve ecological and fuel reduction objectives.

Figure 3.a.3. Grasses, shrubs, and wildflowers recovered quickly after tree removal in this ponderosa pine forest at the Shambhala Mountain Center near Red Feather Lakes, CO. This beautiful and restored ecosystem is less susceptible to high-severity crown fire and can help reduce risk of wildfire damage to surrounding communities. The image below shows the diverse understory ecosystem that can recover within 1-3 years of removing trees and increasing light availability in ponderosa pine ecosystems. Photo credit: Larimer Conservation District (https://www.fortcollinscd.org/before-and-after.html).

Home Hardening

Home hardening involves modifying your home to reduce the likelihood of structural ignition. Almost 95% of the homes in the GVFPD are at risk of long-range spotting from nearby burning vegetation under 90% percentile weather conditions, and about 25% of homes are at risk of short-range spotting and 40% to radiant heat as well (**Appendix Figure 9.a.9**). **Buildings cannot be made fireproof, but the chance of your home surviving wildfires increases when you reduce structural ignitability through home hardening in tandem with the creation and maintenance of defensible space. Figure 3.a.4** depicts important home hardening measures.

Roofs, vents, windows, exterior siding, decks, and gutters are particularly vulnerable to wildfires. Research on home survival during wildfires demonstrates that enclosed eaves and vent screens can reduce the penetration of wind-born embers into structures (Hakes et al. 2017; Syphard and Keeley 2019). Multi-pane windows have greater resistance to radiant heat. Windows often fail before a home ignites, providing a direct path for flames and airborne embers to enter a home (CSFS 2021).

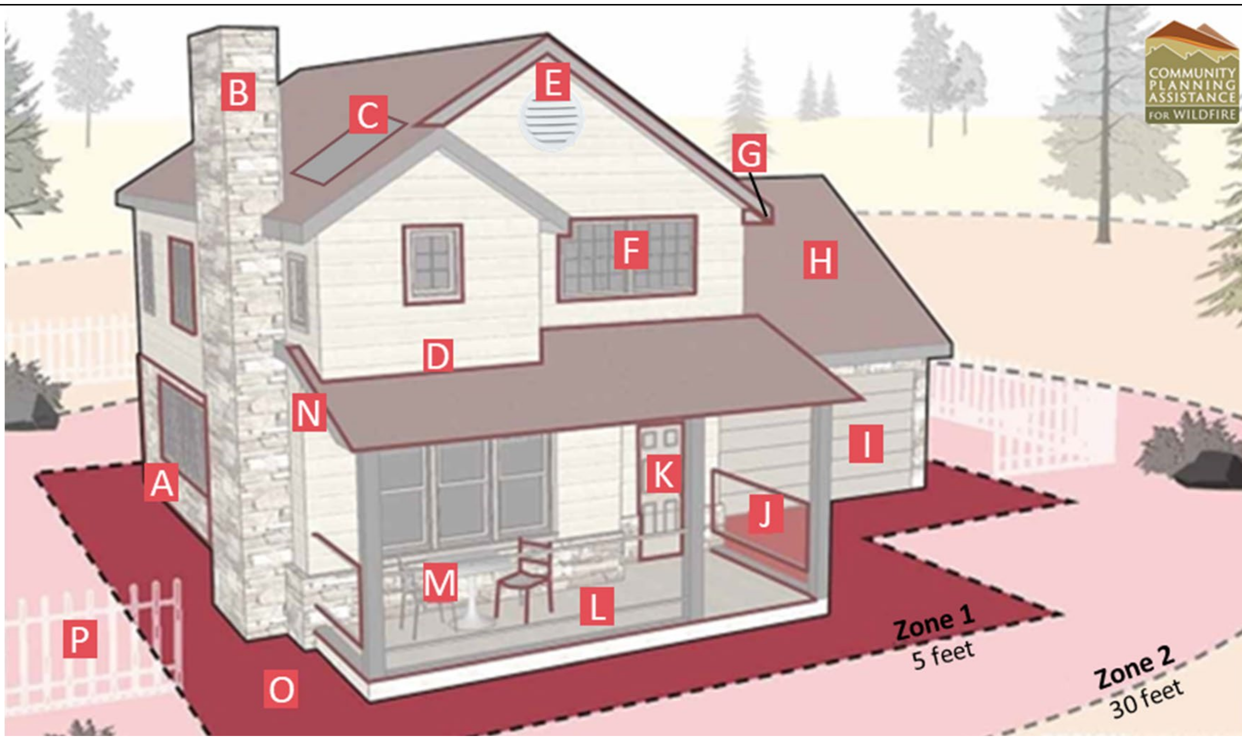


Residents can increase their homes' chance of survival by making it harder for embers to enter and ignite their homes (image from *Healthy Building Science*).

It is important to replace wood or shingle roofs with noncombustible materials [2] such as composition, metal, or tile. Ignition-resistant or noncombustible siding and decking further reduce the risk of home ignition, particularly when homes also have a 5-foot noncombustible border of dirt, stone, or gravel. Non-wood siding and decking are often more durable and require less routine maintenance.

There are many low-cost actions you can start with to harden your home (see **Table 3.a.3**). Keep home-hardening practices in mind and use ignition-resistant materials if you replace a hail-damaged roof or remodel your home. Many home hardening practices are required in Larimer County per building construction regulations effective as of February 2019 for homes within the Wildfire Hazard Area. New construction and expansions adding 50% or more area must comply with the new building standards.

[2] See the **Glossary** for the definition of terms used the describe the performance of building materials when exposed to fire (e.g., wildfire-resistant, ignition-resistant, and noncombustible).



Low-cost actions:

B. Cover chimneys and stovepipe outlets with 3/8th to ½ inch corrosion-resistant metal mesh.
C. Minimize debris accumulation under and next to solar panels.
E. Cover vent openings with 1/16th to 1/8th inch corrosion-resistant metal mesh. Install dryer vents with metal flappers and keep closed unless in use.
G. Clear debris from roof and gutters regularly.
I. Install metal flashing around and under garage doors that goes up at least 6 inches inside and outside the door.
J. Use noncombustible lattice, trellis, or other decorative features.
K. Install weather stripping around and under doors.
L. Remove combustible materials from underneath, on top of, or within 5 feet of deck.
M. Use noncombustible patio future.
N. Cover all eaves with screened vents.
O. Establish and maintain a 5-foot noncombustible buffer around the home.

Actions to plan and save for:

A. Use noncombustible or ignition resistant siding and trim (e.g., stucco, fiber cement, fire-retardant treated wood) at least 2 feet up around the base of your home.
C. Use multipaned glass for skylights, not materials that can melt (e.g., plexiglass), and use metal flashing.
D. Install a 6-inch vertical noncombustible surface on all gables above roofs.
F. Install multi-pane windows with at least one tempered-glass pane and metal mesh screens. Use noncombustible materials for window frames.
G. Install noncombustible gutters, gutter covers, and downspouts.
H. Install ignition-resistant or noncombustible roofs (composition, metal, or tile).
I. Install 1-hour fire rated garage doors.
K. Install a 1-hour fire rated doors.
L. Use ignition-resistant or noncombustible decking. Enclose crawl spaces.
N. Use noncombustible eaves.
P. Replace wooden fences with noncombustible materials and keep at least 8 feet away from the home. Keep double combustible fences at least 20 feet away from the home.

Figure 3.a.4. A home can never be made fireproof, but home hardening practices decrease the chance that flames, radiant heat, and embers will ignite your home. Infographic by Community Planning Assistance for Wildfire with modifications to include information from CALFIRE 2019 and Maranghides et al. 2022.

Annual Safety Measures and Home Maintenance in the WUI

Reviewing safety protocols, creating defensible space, and hardening your home are not one-time actions, but part of *annual* home maintenance when living in the WUI. During a wildland fire, homes that have clear defensible space are identified as sites for wildland firefighters to engage in structure protection, and homes that are not safely defensible will not usually receive firefighter resources.

The **Colorado State Forest Service** provides the following recommendations for annual activities to mitigate risks and increase your wildfire preparedness:

- ✓ Check fire extinguishers to ensure they have not expired and are in good working condition.
- ✓ Review your family's evacuation plan and practice family fire and evacuation drills.
- ✓ Verify that your home telephone number, cell phone, and/or email are properly registered through the NoCo Alert website.
- ✓ Review the contents of your "go-bag" and make sure it is packed and ready to go. Visit the Larimer County Emergency Preparedness page to learn about go-bags and evacuation planning, including tips for preparing your pets and livestock for evacuation. Your go-bag should include supplies to last at least three days, including cash, water, clothing, food, first aid, and prescription medicines for your family and pets. Keep important documents and possessions in a known and easily accessible location so you can quickly grab them during an evacuation.
- ✓ Pay attention to red flag-day warnings from the National Weather Service and stay vigilant. Ensure your family is ready to go in case of an emergency.
- ✓ Walk your property to identify new hazards and ways to maintain and improve current defensible space. Take pictures of your defensible space to help you monitor regrowth and determine when additional vegetation treatments are necessary.
- ✓ Clear roofs, decks, and gutters of pine needles and other debris. Remove all pine needles and flammable debris from around the foundation of your home and deck. Remove trash and debris accumulations within 30 feet of your home. Repeat throughout the year as necessary.
- ✓ Properly thin and prune trees and shrubs that have regrown in your defensible space zones 1 and 2 (0-5 feet and 5-30 feet from your home). Remove branches that overhang the roof and chimney. Prune trees and shrubs that are encroaching on the horizontal and vertical clearance of your driveway.
- ✓ Mow grass and weeds to a height of 4 inches or less within 30 feet of your home. If possible, keep your lawn irrigated, particularly within 30 feet of your home. Repeat throughout the year as necessary.
- ✓ Check the visibility of your address and remove vegetation that obscures it.
- ✓ Check screens over chimneys, eaves, and vents to make sure they are in place and in good conditions.
- ✓ Ensure that an outdoor water supply is available for responding firefighters. Put a hose and nozzle in a visible location. The hose should be long enough to reach all parts of your home.

Mitigation Barriers and Opportunities

Homeowners and residents in the WUI share concerns about creating defensible space and maintaining a defensible HIZ. **Table 3.a.3** proposes opportunities to address these challenges.

Table 3.a.3. Common concerns from residents in the WUI, and potential solutions to encourage mitigation measures in the home ignition zone.

Concern	Potential solutions
I don't know where to start with creating defensible space.	Review **Figure 3.a.1**, **Table 3.a.1**, and read the CSFS publication *Protecting your home from wildfire: Creating wildfire-defensible zones* for mitigation recommendations. Visit the Colorado State Forest Service for useful information and tips about defensible space creation. Reach out to the Colorado State Forest Service or Larimer Conservation District to learn about defensible space and home hardening tactics from their qualified specialists.
I don't have the resources to invest in defensible space.	Creating adequate defensible space can take years and a significant financial investment. Fortunately, there are **effective, low-cost measures** that residents can start with: ✓ Annually remove leaves, needles, and other vegetation from roofs, gutters, decks, and around the base of homes. ✓ Use hand tools like a pole saw to remove tree branches that hang less than 10 feet above the ground. ✓ Remove combustible materials (dry vegetation, wooden picnic tables, juniper shrubs, etc.) from underneath, on top of, or within h5 feet of decks. ✓ Remove vegetation and combustible materials within 5 feet of windows and doors. ✓ Replace wood mulch within 5 feet of all structures with dirt, stone, or gravel. ✓ Remove downed logs and branches within 30 feet of all structures. ✓ Apply for cost-sharing grants with your neighbors to subsidize the creation of defensible space (see **Section 3.f. Funding Opportunities for Wildfire Hazard Mitigation and Emergency Preparedness**). ✓ Research tax credits that will offset the costs or the work you want to do from the Colorado Department of Revenue.
I don't know what to do with slash	The sticks and other debris left from cutting trees and shrubs is called slash. Slash is a fuel for wildfire, so ensure this debris is properly managed on your property. See **Section 4.d** for a discussion of Slash Management. In Glacier View Meadows, some options are limited due to HOA regulations. Recommendations about this are found in **Section 3.d.**

I don't have the resources to invest in home hardening.	Retrofitting an existing home to be wildfire-resistant can be expensive, particularly actions like replacing flammable roofs and siding. Some of these costs can be divided and prioritized into smaller projects. If you are building a new home, the cost of using wildfire-resistant materials is roughly the same as using traditional building materials (Quarles and Pohl 2018). Wildfire-resistant features often come with additional benefits, such as greater durability and reduced maintenance. Many home hardening practices are required in Larimer County per building construction regulations effective as of February 2019 for homes within the Wildfire Hazard Area. New construction and expansions adding 50% or more area must comply with the new building standards. Fortunately, there are **effective, low-cost measures** that residents can start with to harden their homes: ✓ Install noncombustible metal gutter covers. ✓ Cover vent openings with 1/16th- to 1/8th-inch corrosion-resistant metal mesh. ✓ Cover chimney and stovepipe outlets with 3/8th- to ½-inch corrosion-resistant metal mesh to prevent embers from escaping and igniting a fire. ✓ Caulk and plug gaps greater than 1/16th-inch in siding or around exposed rafters. ✓ Install weather stripping around and under garage doors to reduce gaps to less than 1/16th-inch. ✓ Remove combustible materials from underneath, on top of, and within 5 feet of a deck. ✓ Replace wood mulch within 5 feet of all structures with noncombustible products like dirt, stone, or gravel. ✓ Store all combustible and flammable liquids away from potential ignition sources. ✓ Keep a fire extinguisher and tools such as a shovel, rake, bucket, and hose available in your garage for fire emergencies. Suggestions from CAL FIRE's 2020 Low Cost Retrofit List.
I am afraid that removing trees will destroy the forest and reduce the aesthetic and monetary value of my property.	The reality is that nothing will decrease the value of your home as much as a high-severity wildfire burning all the vegetation in the community, even if your home survives the fire. Look for homes that have followed the guidelines in **Figure 3.a.1** and **Table 3.a.1**. Some properties in the GVFPD have both exemplary defensible space and beautiful landscaping. Read FireWise Plant Materials from Colorado State University Cooperative Extension and Firescaping from FIRESafe MARIN for suggestions on beautiful, fire-resistant landscaping. Learn about the ecology of frequent-fire forests along the Colorado Front Range by reading *Back to the future: Building resilience in Colorado Front Range forests using research findings and a new guide*

for restoration of ponderosa and dry-mixed conifer landscapes (Miller 2018). Restored ecosystems can be aesthetically pleasing, benefit wildlife and light-loving wildflowers and grasses, and protect your home from high-severity wildfires.

Fire-resistant landscaping in zone 1 can be aesthetically pleasing. Limbed and thinned trees in zone 2 (as seen in the background of this photo) can create beautiful, open conditions that allow understory vegetation to flourish under higher light conditions and provide habitat for wildlife. Image from Washington State University Master Gardener Program.

Evacuation Preparedness

Residents in the GVFPD are not strangers to wildfire evacuations. Residents were evacuated for a total of 2 weeks during the 2012 High Park Fire, and numerous mandatory and voluntary evacuations were triggered by the 2020 Cameron Peak Fire. Due to the elevated wildfire risk in the GVFPD, future evacuations are likely, underscoring the importance of emergency preparedness by all residents.

The best way to get out quickly and safely during an evacuation is to be prepared. Prepare a go-bag and have a family emergency plan **before** the threat of wildfire is in your area. Talk to children and elderly family members about what they would be expected to do. Visit the Larimer County Emergency Preparedness page to learn about go-bags and evacuation planning, including tips for preparing your pets and livestock for evacuation. Signing up for local emergency notifications can also help you leave quickly. Residents can register their cell phones and email addresses on the NoCo Alert website.[3]

Some residents have family members or neighbors with physical limitations who might struggle to evacuate in a timely manner. Family members or individuals living alone also need to address the

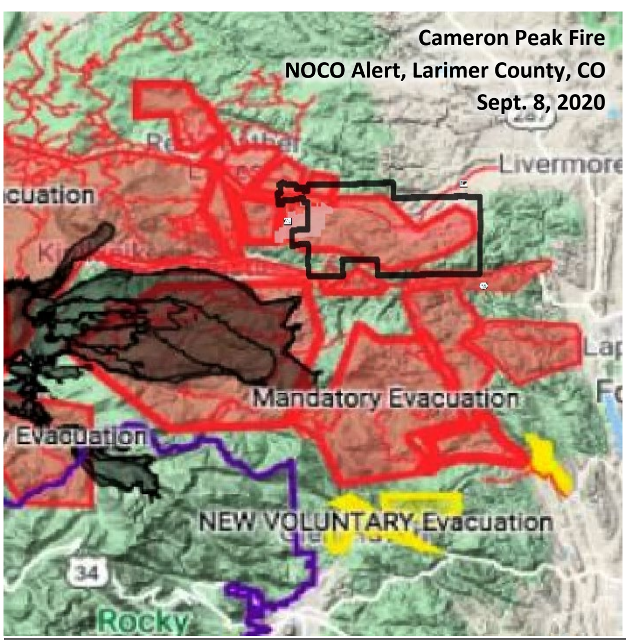
[3] NoCo Alert is the official emergency notification system for Larimer County as of the writing of the GVFPD CWPP in June 2022.

unique needs and vulnerabilities that arise from mobility or hearing impairments during an evacuation. Other residents are concerned about school-aged children who might be home alone during an evacuation. Parents should work with their neighbors to develop a plan for how their children would evacuate if home alone. Residents with livestock trailers or large camper vehicles should plan to leave during voluntary evacuation notices to allow time for their preparations and create more space on the roads for other residents during mandatory evacuation. Having a plan in place ahead of time can ensure prompt evacuations and save lives during wildfires. Families with these concerns should put extra time into having go bags ready and using the earliest evacuation warnings to leave in the event of a wildfire, rather than waiting for mandatory evacuation orders.

Follow evacuation etiquette *to increase the chance of everyone exiting the GVFPD in a safe and timely manner during a wildfire incident:*

- Register for [Larimer County Emergency Alerts] to receive evacuation notifications.
- Leave as quickly as possible after receiving an evacuation notice.
- Have a go-bag packed and ready during the wildfire season, especially on days with red flag warnings.
- Leave with as few vehicles as necessary to reduce congestion and evacuation times across the community.
- Drive safely and with headlights on. Maintain a safe and steady pace. Do not stop to take pictures.
- Yield to emergency vehicles.
- Follow directions of law enforcement officers and emergency responders.

NOCO ALERT



Residents in the GVFPD experienced mandatory and voluntary evacuations during the 2020 Cameron Peak Fire. Following orders of the Larimer County Sheriff's Office during evacuations is critical to keep residents and first responders safe. Photo credit: NoCo Alert (left) and Blaine Howerton/North Forty News (right).

Accessibility and Navigability for Firefighters

Driveways

It is important to ensure emergency responders can locate and access your home. Narrow driveways without turnarounds, tree limbs hanging over the road, and lots of dead and down trees by the road may make firefighters choose to not defend your home during a wildfire event (Brown 1994).

Some roads in the GVFPD have accessibility and navigability issues, such as narrow widths, inadequate vertical clearance for engines, and heavy fuel loading on the sides of the road. These unsafe road and driveway conditions could turn firefighters away from attempting to defend homes. According to the National Fire Protection Association, driveways should have a minimum of 20 feet of clearance horizontally and 13.5 feet of clearance vertically to allow engines to safely access the roads (O'Connor 2021).

Many driveways within the GVFPD do not meet current access requirements and pose safety issues that are difficult to mitigate. Long, narrow, steep driveways lacking turnarounds, and dense trees on the sides of the road can create challenges for emergency response vehicles during wildfires. Home hardening and fuel mitigation are particularly important to reduce wildfire risk around homes with accessibility issues. Photo credit: The Ember Alliance.

Where possible, residents should improve roadway access, and where this is not feasible, it is vital that homeowners take measures to harden their home and create defensible space. Some actions to increase access to your home are simple, such as installing reflective address numbers, and others take time and investment, such as widening driveways to accommodate fire engines.

Private Water Resources

Water resources to fight fire in the foothills can be scarce, especially during the fire season in late summer and fall. Firefighters are skilled at determining the most beneficial ways to use water to protect structures from an approaching fire. Providing clear access to suitable water resources around your home or neighborhood can help them defend your home.

Do not turn sprinklers on around your home as you evacuate. This is counterproductive to protecting your home because continuous use of water before a flame front approaches can drain local wells and cisterns long before the fire reaches your neighborhood. This can leave firefighters with less resources to defend your home, putting their lives and your property at higher risk. Leaving sprinklers out but **turned off** allows the firefighters to determine whether they will be useful or not.

Prepare personal water resources by making them easily accessible and clearly labelling how to access them. Unlock pump house doors and remove vegetation or other obstructions. If you have a generator, leave it in an accessible location in case power is turned off.

Most importantly, create defensible space around your home and buildings so that water resources can be used effectively. Water is not a reliable resource in the Colorado foothills and mountains. Maintaining a property that requires less water and resources to defend is more likely to survive a fire. See **Table 3.a.1** and **Figure 3.a.4** for guides on defensible space and home hardening recommendations.

Steps to enhance firefighter safety and access to your home:

- ✓ Install reflective address numbers on the street to make it easier for firefighters to navigate to your home under smokey conditions. Make sure the numbers are clearly visible from both directions on the roadway. Use noncombustible materials for your address sign and sign supports. **Installing reflective address numbers can save lives and is inexpensive and easy to accomplish.**
- ✓ Address roadway accessibility for fire engines. Long, narrow, steep, and curving private drives and driveways without turnarounds significantly decrease firefighter access to your property, depending on fire behavior.
- ✓ Fill potholes and eroded surfaces on private drives and driveways.
- ✓ Increase fire engine access to your home by removing trees along narrow private drives and driveways so the horizontal clearance is 20 feet wide, and prune low-hanging branches of remaining trees so the unobstructed vertical clearance is at least 13 feet and 6 inches per the National Fire Protection Association (O'Connor 2021).
- ✓ Park cars in your driveway or garage, not along narrow roads, to make it easier for fire engines to access your home and your neighbors' homes.
- ✓ Clearly mark septic systems with signs or fences. Heavy fire equipment can damage septic systems.
- ✓ Clearly mark well houses or water systems. Leave hoses accessible for firefighters to use when defending your home, but **DO NOT** leave the water running. This can reduce water pressure to hydrants across the community and reduce the ability of firefighters to defend your home. Read this post by FIRESafe Marin about why it is dangerous to leave water running when you evacuate during a wildfire.
- ✓ Post the load limit at any private bridges or culverts on your property.
- ✓ Leave gates unlocked during mandatory evacuations to facilitate firefighter entrance to your property.
- ✓ Leave exterior lights on to increase visibility.
- ✓ If time allows, leave a note on your front door confirming that all parties have evacuated and providing your contact name and phone number.

3.b. Neighborhood Recommendations

Linked Defensible Space

During catastrophic wildfires, property loss happens mostly due to conditions in the **home ignition zone** (HIZ). Homes are most likely to ignite because of embers, and structures that are close to a home emitting embers can endanger the homes and structures near them. Research following the 2018 Camp Fire showed that homes were more likely to burn down when they were close to other structures or when they had vegetation within about 330 feet of the home (Knapp et al. 2021).

Some residents in the GVFPD are rightfully concerned about high hazards on their neighbors' properties and surrounding public land. Your home ignition zone might overlap with your neighbor's property. Given the high fire risk in the area, it is important that residents across the GVFPD create defensible space and harden their homes. Collective action by residents will magnify the impact of individual defensible space projects, create tactical opportunities for wildland firefighters, and reduce the likelihood that homes will ignite due to embers produced from adjacent, combusting homes. Linked defensible space has greater strategic value, and projects that span ownership boundaries are better candidates for grant funding.

Defensible space can slow the spread of wildfire, prevent direct flame contact, and reduce the chance that embers will ignite material on or near your home. Defensible space that is connected from home to home provides additional layers of protection for entire neighborhoods and increases the safety of firefighters. Firefighters and residents attest to the important role defensible space played in allowing homes to survive during previous wildfires in Colorado (Jolley 2018). Homes in close proximity, on steep slopes, and/or surrounded by dense trees will benefit significantly from linked defensible space. According to James White, the Prescribed Fire and Fuels Specialist for the Arapaho/Roosevelt National Forests, "Broadcast burning, mechanical thinning, and other treatments are proven to mitigate wildfire risk, but they are even more effective when we work together to integrate treatments across the landscape, across borders and ownerships" (Avitt, 2021).

See **Section 3.a Individual Recommendations** to learn about recommended practices for creating defensible space, and for next steps you can take to inspire collective action across your community.

These two homes are in the Glacier View Meadows 3 plan unit, where the High Park Fire burned in 2012. The home on the left had adequate defensible space and did not burn. The home on the right burned and had to be re-built. Both homes now have adequate and linked defensible space that will provide safe access for firefighters in the event of another wildfire. Photo credit: The Ember Alliance.

Mosaic Landscapes

Varied fuel types are known to slow the spread of fire, and heterogeneous landscapes (landscapes with multiple fuel types and trees of different sizes and ages) are more typical of historical forest conditions (Duncan et al. 2015). Creating a mosaic landscape in neighborhoods can help slow fires spread by changing the fuel types as it moves across a hill or valley. A mosaic landscape can be created many ways, for example a neighborhood could have a few acres of old growth conifer trees next to a couple acres of aspen stands, and a few acres of young regenerating conifer trees by a large grassy meadow. This can be arranged in many ways for aesthetic and tactical purposes and will resemble a patchwork quilt or mosaic art (**Figure 3.b.1**).

The homes in these patches still need to have adequate defensible space, but this would create a more diverse landscape where fire may move slower as it transitions between forest types and unforested locations like shrublands or meadows. Slower fire movement means firefighters have time to defend more homes in the neighborhood. It also creates a diversity of biomes that both residents and wildlife enjoy.

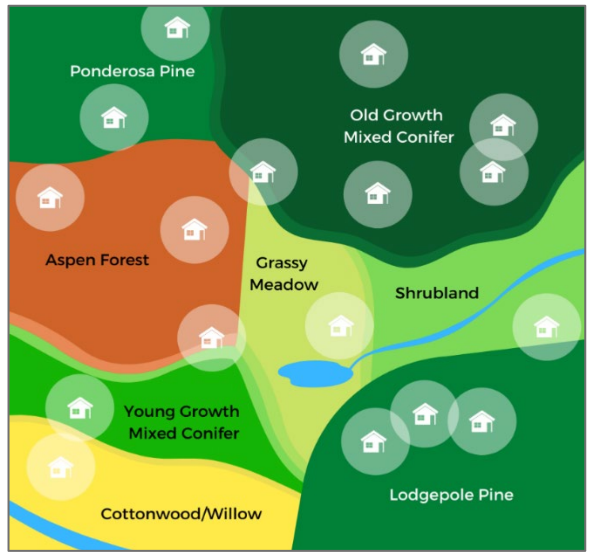


Figure 3.b.1. Example of a mosaic landscape in a neighborhood. Each home has defensible space around it, and the landscape is varied throughout, providing tactical opportunities for firefighters working to defend homes.

Accessibility and Navigability for Firefighters

Shared Driveways and Community Roads

Neighborhoods can work together to ensure emergency responders can locate and access everyone's home. Narrow roads without turnarounds, tree limbs hanging over the road, and lots of dead and down trees by the road may make firefighters choose to not defend your home during a wildfire event (Brown 1994).

Widening shared driveways and private roads can be time-consuming or expensive. Neighbors and HOAs working together to share costs and apply for grants are an effective way to make safer homes for all residents in an area. Many roads in the GVFPD are inaccessible to fire engines. According to the National Fire Protection Association, driveways and roads should have a minimum of 20 feet of clearance horizontally and 13.5 feet of clearance vertically to allow engines to safely access the roads (O'Connor, 2021).

Where feasible, HOAs and road associations should improve roadway access. Some actions to increase access to neighborhoods and homes are simple, such as installing reflective address numbers at driveways and road junctions, and others take time and investment, such as widening road networks and creating turnarounds to accommodate fire engines. A cost-effective place to start is removing trees along driveways and pruning low-hanging branches to increase horizontal and vertical clearance. Working together to update signs and road construction can lower costs for everyone involved as well.

3.c. Priority Plan Unit Recommendations

CWPP Plan Units

TEA and the GVFPD created CWPP Plan Units, which are areas with shared fire risk where residents can organize and support each other to effectively mitigate hazardous fuels (**Figure 3.c.1**). See Appendix **Section 9.a CWPP Plan Units** for methodology used to delineate plan units. Residents within CWPP plan units will be able discuss shared risk and organize joint efforts to reduce risk and enhance emergency preparedness. The CWPP is a useful planning document, but it will only affect real change if residents, neighbors, HOAs, and the entire community come together to address shared risk and implement strategic projects.

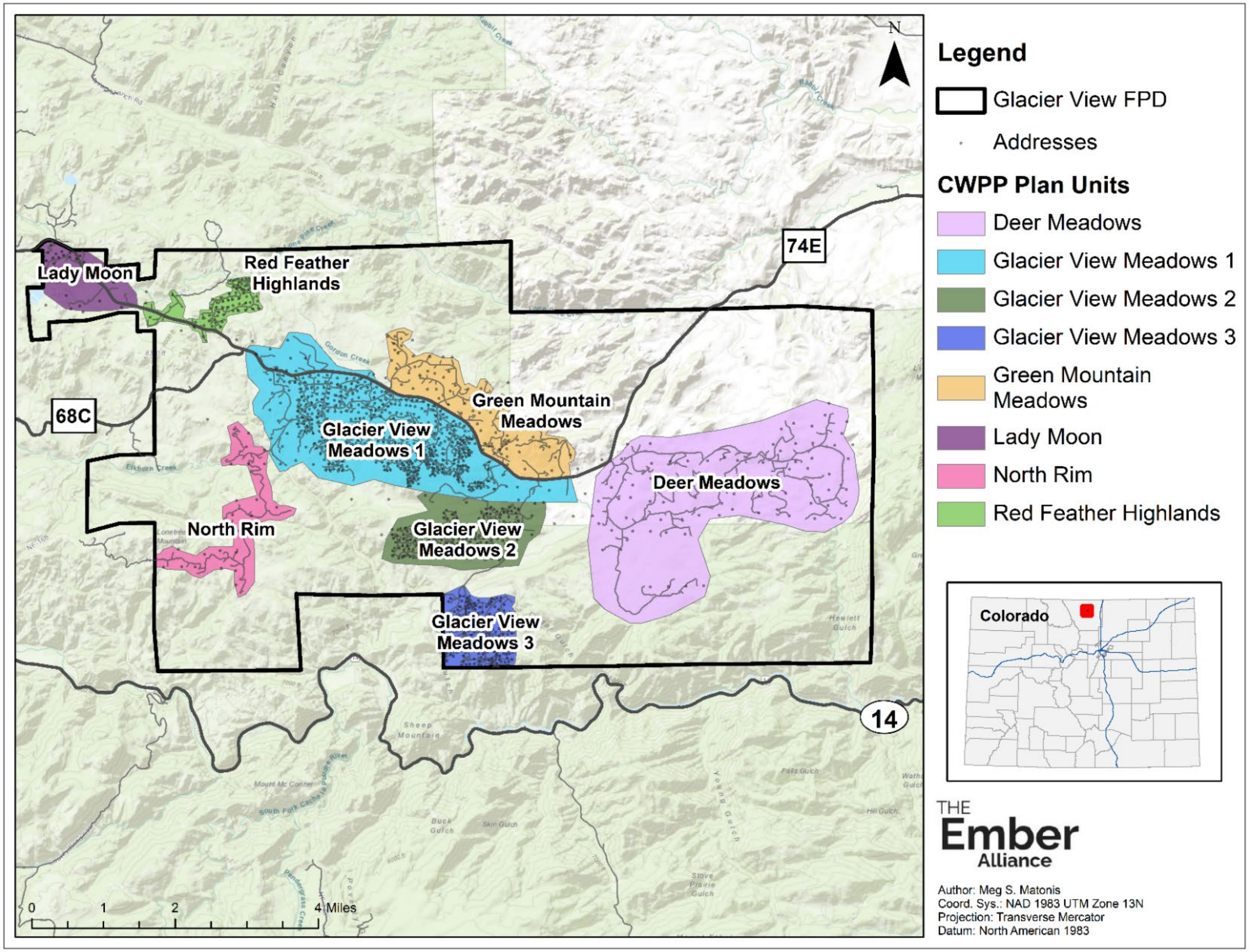


Figure 3.c.1. We assessed relative risk among CWPP plan units and made strategic recommendations to address wildfire risk across the GVFPD. See Appendix **Section 9.a CWPP Plan Units** for methodology used to delineate plan units. An interactive map with the CWPP plan units is available online at https://experience.arcgis.com/experience/225f72cc029c4e37a2acbdefc60b2140/page/Plan-Units/.

Relative Hazard Ratings

Colorado CWPPs must include a relative rating of hazards within the Fire Protection District to help prioritize action. **Plan units with higher relative risk are strong candidates for immediate action to mitigate hazardous conditions; however, plan units with lower relative risk in GVFPD still possess conditions that are concerning for the protection of life and property in the case of a wildfire.**

Keep in mind: The Plan Unit Hazard Assessment describes ***relative*** risk among plan units within the GVFPD. Plan units with moderate relative risk still possess conditions that are concerning for the protection of life and property in the case of a wildfire. The need to mitigate hazardous conditions is ubiquitous across the GVFPD. Plan units with higher relative risk are strong candidates for immediate action to mitigate hazardous conditions.

The Ember Alliance combines on-the-ground observations and summary output from our fire behavior analyses to assess hazards in four categories across CWPP plan units: fire risk, fire suppression challenges, evacuation hazards, and home ignition zone hazards (**Figure 3.c.2**). See **Appendix B.1. Plan Unit Hazard Assessment** for a description of hazard rating methodology. The cutoffs for different relative risk categories are tailored to an individual FPD based on the range of conditions observed. Plan unit hazard ratings are specific to the GVFPD and not suitable for comparing hazards among FPDs.

Table 3.c.1 provides priority recommendations for defensible space, home hardening, and road access within each CWPP plan unit based on our plan unit hazard assessment. Recommendations in **Table 3.c.1** focus on the most glaring issues in each plan unit; however, homeowners, HOAs, and other community groups can benefit from all actions outlined in **Section 3.a Individual Recommendations** and **Section 3.b. Neighborhood Recommendations.** Even homes in the interior of the GVFPD have the potential for ignition from long-range spotting during wildfires.

Plan units with extreme relative risk are Lady Moon, Red Feather Highlands, North Rim, and Glacier View Meadows 2 (**Figure 3.c.2**). Extreme fire risk is more abundant in the western portion of the GVFPD due to dense forest cover. Suppression challenges are extreme in Lady Moon and Glacier View Meadows 2 due to an abundance of narrow roads without turnarounds that would present access challenges to wildland firefighters. Evacuation hazards are extreme in North Rim, Glacier View Meadows 2, and Glacier View Meadows 3 due to a high density of homes and few points of egress onto main roads. Hazards in the home ignition zone are high to extreme in all plan units except for Deer Meadows where homes are mostly constructed from fire-resistant building material and there are few trees near structures.

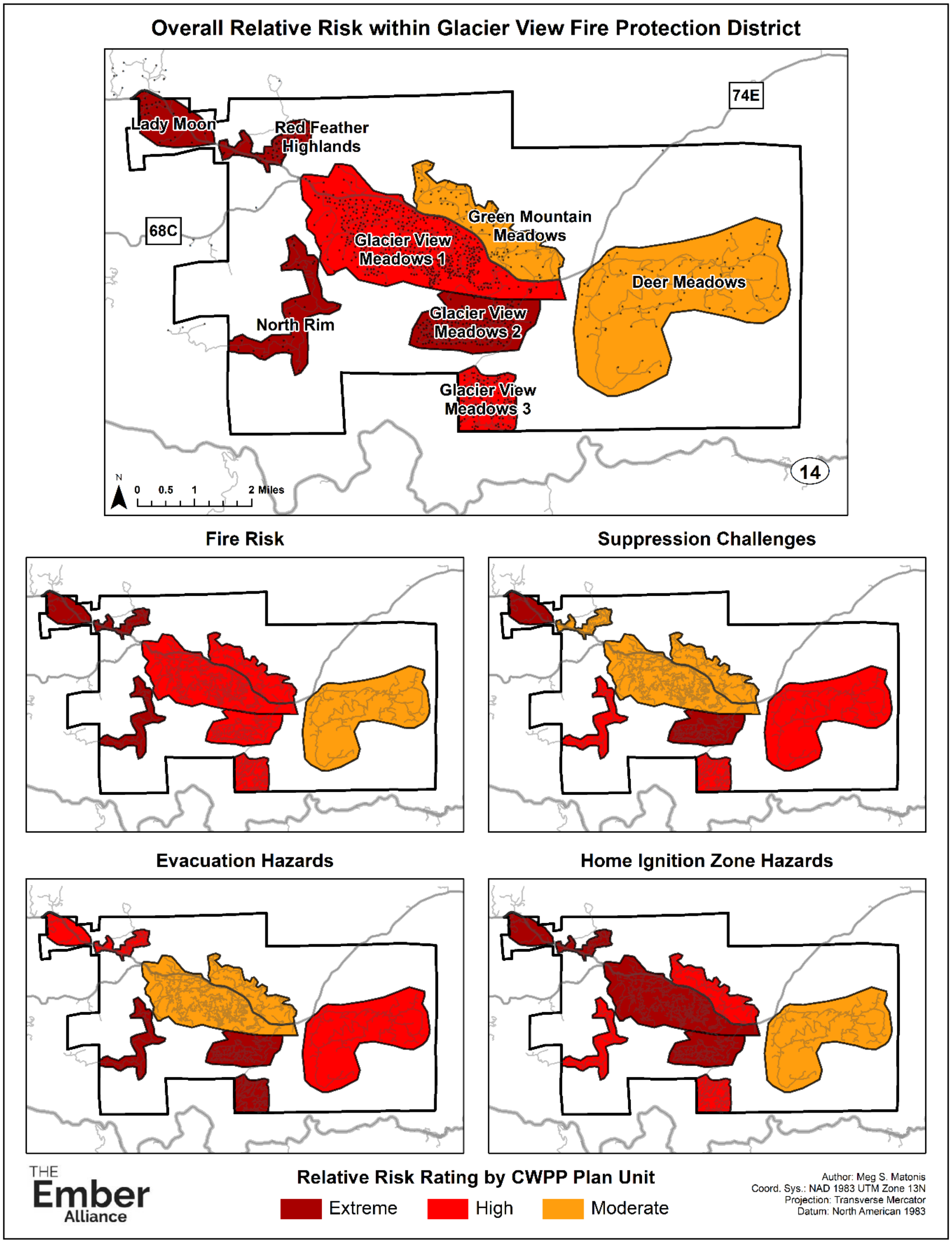


Figure 3.c.2. Relative risk rating for plan units across the GVFPD. "Moderate" risk is a relative term – all plan units and communities within the GVFPD have risk of fire danger and should take recommended actions from **Section 3.a Individual Recommendations** and **Section 3.b. Neighborhood Recommendations** seriously.

Table 3.c.1 Priority recommendations for defensible space, home hardening, and firefighter accessibility within each CWPP plan unit. This table focuses on priority actions for each plan unit; however, homeowners, HOAs, and other community groups across the GVFPD can benefit from all actions outlined in **Section 3.a Individual Recommendations** and **Section 3.b. Neighborhood Recommendations**. Potential fire behavior is presented for 90th percentile fire weather, with flame lengths and crown fire activity summarized for the plan unit and adjacent topographic areas that could contribute to fire behavior within the plan unit.

Plan Unit: Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior and Exposure (90th Percentile)
Deer Meadows: Moderate	Fuel types are predominantly tall grasses and shrubs with some intermixed patches of trees. Tall grasses and shrubs create potential for extreme fire behavior with high flame lengths and rapid rates of spread. There are no areas with dense canopy cover. The southern third of this unit, which is National Forest land, burned in the 2012 High Park Fire. Several homes are located mid-slope and on ridge tops, which increases their potential exposure to extreme fire behavior. Most homes were built with fire-resistant construction materials, except for wood fences within 5 feet of some homes. All homes have adequate mitigation of canopy fuels because there are very few trees in the unit; however, defensible space could be improved by removing pine needles from roofs and gutters, mowing grass, and removing shrubs around homes. Some homes have hazards within 30 ft of the home such as old wooden sheds, wood piles, and propane tanks. All roads in the unit are accessible for a Type 3 engine, but some roads can only accommodate one-way traffic. Legible and reflective signs are present on most roads and homes.	Mow tall grasses, remove shrubs in the home ignition zone, and remove pine needles from roofs and gutters. Move wood piles and propane tanks at least 30 feet away from homes. Remove or rebuild woodsheds and outbuildings with fire-resistant material. Widen roads to accommodate two-way traffic.	Average flame lengths in the unit are 9 feet and can reach a maximum of 190 feet. 25% of the unit is susceptible to passive or active crown fires, 9% of the roads are potentially non-survivable, and 14% of homes have high to extreme exposure to embers and radiant heat.
Glacier View Meadows 1: High	Glacier View Meadows 1 is the largest plan unit in GVFPD with the greatest number of structures and population. Fuels in the unit are tall grasses and mixed conifer. Mixed conifer regeneration is very	Implement stand-level fuels treatments in dense areas of conifer regeneration, especially on steep slopes beneath homes, to	

Plan Unit: Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior and Exposure (90th Percentile)
	dense at higher elevations and presents potential for active crown fire and extreme fire behavior. About 20% of homes are located mid-slope and on ridge tops, which increases their potential exposure to extreme fire behavior. Homes were built with a mixture of fire-resistant and flammable construction materials. Many homes have combustible decks and wooden fences. Few homes have adequate defensible space, putting many properties at risk of damage from wildfires. Some homes have wood piles and propane tanks within 30 ft of homes. All roads are accessible for a Type 3 engine. Most roads are wide enough for 2-way traffic. Legible and reflective signs are present on most roads and homes.	reduce the risk of torching and active crown fire.	Average flame lengths in the unit are 14 feet and can reach a maximum of 105 feet. 45% of the unit is susceptible to passive or active crown fires, 33% of the roads are potentially non-survivable, and 44% of homes have high to extreme exposure to embers and radiant heat.
		Mow tall grasses and remove junipers in the home ignition zone.	
		Reduce ladder and canopy fuels within the home ignition zone, especially trees overhanging roofs and decks.	
		Move wood piles and propane tanks at least 30 feet away from homes.	
		Harden homes with fire-resistant construction materials, particularly by removing or replacing flammable decks and wood fences.	

Plan Unit: Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior and Exposure (90th Percentile)
Glacier View Meadows 2: Extreme	Fuel types are predominantly tall grasses, which create potential for extreme fire behavior with high flame lengths and rapid rates of spread. There are fewer ladder and canopy fuels in this unit relative to others, except for the western part of the unit where there are more trees. The eastern part of this unit burned in the 2012 High Park Fire and 3 structures were lost. Many homes are located mid-slope and several homes are on ridge tops, which increases their potential exposure to extreme fire behavior. Few homes have adequate defensible space, putting many properties at risk of damage from wildfires. Home hardening measures have been taken throughout the unit, with most homes using fire-resistant construction materials. Some homes have additional hazards within 30 ft of the home, such as wood piles and propane tanks. All roads are accessible for a Type 3 engine. Roads are wide with ample pullouts and turnarounds. The only access into this plan unit is from the east.	Mow tall grasses in the home ignition zone. Reduce ladder and canopy fuels within the home ignition zone, especially trees overhanging roofs and decks. Move wood piles and propane tanks at least 30 feet away from homes.	Average flame lengths in the unit are 15 feet and can reach a maximum of 115 feet. 45% of the unit is susceptible to passive or active crown fires, 33% of the roads are potentially non-survivable, and 52% of homes have high to extreme exposure to embers and radiant heat.

Plan Unit: Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior and Exposure (90th Percentile)
Glacier View Meadows 3: High	There is currently low potential for crown fire in Glacier View Meadows 3; most of the trees burned down in the 2012 High Park Fire, which spread across the entire unit and burned 51 primary structures and many outbuildings, campers, and vehicles. However, tall grasses have established throughout the area, creating an opportunity for extreme fire behavior with high flame lengths and rapid rates of spread, especially on steep slopes and in topographic saddles, ravines, and chimneys. Numerous homes are located mid-slope and on ridge tops, which increases heir potential exposure to extreme fire behavior. Many of the homes that survived the High Park Fire and those that were rebuilt are "hardened" with fire-resistant construction materials. Many homes have adequate defensible space maintenance (by far the best defensible space across all plan units). Some homes have additional hazards, such as wood piles and propane tanks within 30 ft of the home. All roads are accessible for a Type 3 engine. Roads are wide and well-maintained throughout the unit, with pullouts and turnarounds present. There are several windy roads and switchbacks. Legible and reflective signs are present on most roads and homes.	Mow tall grasses in the home ignition zone. Move wood piles and propane tanks at least 30 feet away from homes. Use fire-resistant materials for new construction.	Average flame lengths in the unit are 10 feet and can reach a maximum of 135 feet. 34% of the unit is susceptible to passive or active crown fires, 38% of the roads are potentially non-survivable, and 65% of homes have high to extreme exposure to embers and radiant heat.

Plan Unit: Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior and Exposure (90th Percentile)
Green Mountain Meadows: Moderate	Tall grasses are abundant throughout unit, creating an opportunity for extreme fire behavior with high flame lengths and rapid rates of spread. Large, mowed areas with shorter grasses have the potential to slow fire spread. The also area contains patches of trees with minimal ladder fuels. Several homes are located mid-slope and on ridge tops, which increases their potential exposure to extreme fire behavior. Most homes were built with fire-resistant construction materials. Some homes have wood fences within 5 feet of the home. Many homes have adequate mitigation of ladder and canopy fuels, but defensible space could be improved by removing pine needles from roofs and gutters, mowing grass, and removing shrubs around homes. Many homes have propane tanks, wood piles, and old wooden sheds within 30 feet of home. All roads are accessible for a Type 3 engine. Legible and reflective signs are present on most roads and homes.	Mow tall grasses, remove shrubs in the home ignition zone, remove pine needles from roofs and gutters. Move wood piles and propane tanks at least 30 feet away from homes. Remove or rebuild wooden fences, woodsheds, and outbuildings with fire-resistant material.	Average flame lengths in the unit are 15 feet and can reach a maximum of 160 feet. 40% of the unit is susceptible to passive or active crown fires, 8% of the roads are potentially non-survivable, and 15% of homes have high to extreme exposure to embers and radiant heat.

Plan Unit: Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior and Exposure (90th Percentile)
Lady Moon: Extreme	Dense mixed-conifer forests with interlocking canopies and ladder fuels are present throughout unit, creating the potential for active crown fire. There are many overhead powerlines directly over homes which poses a wildfire hazard. Numerous homes are located mid-slope and on ridge tops, which increases their potential exposure to extreme fire behavior. Few homes have adequate defensible space, putting many properties at risk of damage from wildfires. Many homes have wood piles, propane tanks and old, dilapidated wooden sheds or outbuildings within 30 feet of home. Roads throughout unit are narrow and winding, with dense fuels along roadways. Most roads are too narrow for two-way traffic, with few pullouts and turnarounds. Only a few roads are accessible for a Type 3 engine. The only access into this plan unit is from the east. Many homes have long, narrow driveways, and few have visible address signs, which would pose challenges for firefighter intervention during a wildfire.	Implement stand-level fuels treatments in dense forests, especially on steep slopes beneath homes, to reduce the risk of torching and active crown fire. Implement roadside fuel treatments along narrow, winding roads. Reduce ladder and canopy fuels within the home ignition zone, especially trees overhanging roofs and decks. Move wood piles and propane tanks at least 30 feet away from homes. Remove or rebuild woodsheds and outbuildings with fire-resistant material. Install reflective street signs and home addresses. Increase road accessibility for Type 3 engines by creating more pullouts and turnarounds.	Average flame lengths in the unit are 25 feet and can reach a maximum of 145 feet. 74% of the unit is susceptible to passive or active crown fires, 54% of the roads are potentially non-survivable, and 92% of homes have high to extreme exposure to embers and radiant heat.

Plan Unit: Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior and Exposure (90th Percentile)
North Rim: Extreme	There is potential for extreme fire behavior and crown fire activity due to tall grasses, abundant ladder fuels, and dense canopies throughout unit. Numerous homes are located mid-slope and on ridge tops, which increases their potential exposure to extreme fire behavior. Most homes are built with fire-resistant construction materials. Some homes have adequate mitigation of ladder and canopy fuels. Many homes have tall grasses, pine needles, branches, and shrubs within 30 feet of the home. The main access road, North Rim Road, is a long, winding, one-lane road with few pullouts. North Rim Road is located along a steep slope and surrounded by dense vegetation, creating a potential for rapid fire spread upslope towards the road. All roads are accessible with a Type 3 engine, but depending on fire behavior, firefighters may not be able to safely reach homes to protect them during a wildfire. Legible and reflective signs are present on most roads and homes. The only access into this plan unit is from the east.	Implement roadway fuel treatments along North Rim Road. If possible, widen road to create pullouts and turnarounds. Reduce ladder and canopy fuels within the home ignition zone, especially trees overhanging roofs and decks. Mow tall grasses in the home ignition zone.	Average flame lengths in the unit are 24 feet and can reach a maximum of 155 feet. 72% of the unit is susceptible to passive or active crown fires, 46% of the roads are potentially non-survivable, and 60% of homes have high to extreme exposure to embers and radiant heat.

Plan Unit: Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior and Exposure (90th Percentile)
Red Feather Highlands: Extreme	Fuel types are predominantly tall grasses, creating the potential for extreme fire behavior with high flame lengths and rapid rates of spread. Magic Sky Ranch (formerly the Girl Scout Camp, and soon to be the Denver University field campus) comprises the northwestern corner of Red Feather Highlands Unit. Magic Sky Ranch has their own CWPP and has completed extensive fuel mitigation. However, the rest of the unit has not experienced fuel treatments and has dense timber and tall grasses. Several homes are located mid-slope and on ridge tops, which increases their potential exposure to extreme fire behavior. Homes were built with a mixture of flammable and fire-resistant construction materials. Few homes have adequate defensible space, putting many properties at risk of damage from wildfires. Many homes have wood piles, propane tanks and old, dilapidated wooden sheds or outbuildings within 30 feet of home. All roads are accessible with Type 3 engine. Most roads are wide, have pullouts and turnarounds, and can accommodate 2-way traffic. Few roads and homes have legible and reflective signage. The only access into this plan unit is from the east.	Reduce ladder and canopy fuels within the home ignition zone, especially trees overhanging roofs and decks. Mow tall grasses in the home ignition zone. Remove or rebuild woodsheds and outbuildings with fire-resistant material. Move wood piles and propane tanks at least 30 feet away from homes.	Average flame lengths in the unit are 23 feet and can reach a maximum of 145 feet. 72% of the unit is susceptible to passive or active crown fires, 51% of the roads are potentially non-survivable, and 81% of homes have high to extreme exposure to embers and radiant heat.

Table 3.c.2. Resources for suggested mitigation for each CWPP Plan Unit (**Figure 3.c.1**).

Suggestion	Goal	Resources
Home Hardening	Make the home itself less flammable by using non-combustible materials and clearing combustibles away from the home.	See: **Home Hardening**
Defensible Space	Clear combustible materials away from near the home, reduce fire activity and severity as it approaches the home	See**: Defensible Space**
Create linked defensible space	Overlapping HIZs create more opportunity for homes to ignite. Work with neighbors to reduce fire activity and severity near all the homes to protect them all.	See**: Defensible Space; Linked Defensible Space**
Remove flammable material from the HIZ.	Clear combustible materials such as firewood, propane tanks, and wooden lawn furniture away from near the home.	See: **Defensible Space**
Mow grass and clear bushes away from the home	Clear combustible vegetation such as tall grass, bushes, and all junipers away from near the home.	See: **Defensible Space**
Have evacuation plans and go-bags ready	There is significant danger to both life and property in GVFPD. Residents need to be prepared to leave at any time and not rely on the FPD to save them.	See: **Evacuation Preparedness**
Roadside mitigation	Clear vegetation from around the road to improve access and decrease the amount of fuels that could burn across a roadway while residents are evacuating.	See**: Driveways; Roadway Fuel Treatment Recommendations**

Road improvements for accessibility and safety	Create a road network that fire engines can safely access and is less likely to trap residents during an evacuation.	See**:** **Accessibility and Navigability for** Firefighters**; Roadway Fuel Treatment Recommendations**
Install reflective signage for navigation	Make it easier for firefighters to find a home or neighborhood to assist in property defense and evacuations. It can be very difficult to see during major fire events.	See**:** **Accessibility and Navigability for** Firefighters
Landscape-scale mitigation work across the community	Treat forests to prevent intense fire behavior near homes and increase landscape resilience by restoring historical conditions.	See**: Stand-Level Fuel Treatment Recommendations**
Community work to create roadside fuel treatments	Treat forests to prevent intense fire behavior near homes and increase landscape resilience by restoring historical conditions.	See**: Stand-Level Fuel Treatment Recommendations; Roadway Fuel Treatment Recommendations**
Ladder fuel treatments	Prevent fire from moving from the ground to the tree canopy, which reduces fire intensity and speed.	See**: Stand-Level Fuel Treatment Recommendations**
Maintain and continue stand-level fuel treatments near homes	Treat forests to prevent intense fire behavior near homes and increase landscape resilience. Treatments must be maintained to continue to provide defense to homes.	See**: Stand-Level Fuel Treatment Recommendations**

3.d. Community-Wide Recommendations

Slash Management Recommendations

Residents in GVFPD have experienced difficulties with slash management, like many other communities in Colorado. During the community engagement process for this project, some unique challenges were discovered that deserve special consideration and problem-solving. Every member of the community needs to work to find creative solutions to the slash management problem so that this community can reduce its wildfire risk quickly.

Due to HOA restrictions in Glacier View Meadows (GVM), residents within the GVM subdivisions cannot burn slash piles. As an alternative, the FPD has allowed residents to bring their slash to central locations within GVM to build large community slash piles. Historically these piles were burned on an annual basis. However, due to recent changes in winter weather conditions and stricter smoke regulations from the Colorado Department of Public Health and Environment, these piles have become increasingly difficult to burn. This has led to a backlog of large, unburned slash piles that have created hazardous conditions in the GVM subdivisions. Moving forward, these community slash piles may not be the best solution for residents. The HOA should consider lifting restrictions on pile burning, or residents should use other slash management methods.

Residents that live outside of the GVM subdivisions should use pile burning to deal with their slash, as it is one of the most effective slash management methods (see **Section 4.d** for slash management specifications). Many residents throughout GVFPD have been building piles but not burning them due to misconceptions around the steps required to burn slash piles. We recommend that the FPD increases education around the permitting process that property owners must go through to burn their piles (e.g., what permits they need to acquire, who they need to contact the day of the burn, etc.).

GVFPD and the Glacier View Meadows have some reservations about allowing residents to pile burn. To address these concerns, it is recommended that residents who want to burn take the state's training offered by the Colorado Division of Fire Prevention and Control (DFPC) that will ensure those burners are prepared for the risks of pile burning. DFPC describes this program: "By training and certifying private entities to plan and implement prescribed fire in a more systematic and educated manner, similar to that required by policy for natural resource and fire management agencies at, all levels of government, the end result would be to promote the relatively safe and efficient use of fire as a management tool regardless of land ownership. The program is also designed to provide some level of civil liability protection for those trained and certified entities." Residents can take this course to be trained and earn legal protections. Pile Burn Workshops are events The Ember Alliance hosts to provide even further hands on experience and training to residents and could be hosted in this district if desired.

A major concern from GVFPD is the capacity required to accomplish many wildfire mitigation projects, assist homeowners, and manage slash. LCSO has some resources for residents to get guidance about wildfire mitigation, but this program has limited capacity as well. It is recommended that Glacier View partners with Red Feather, Crystal Lakes, Livermore and Poudre Canyon fire districts to support a paid position that creates additional capacity in this location and can bring forward some of the recommendations in **Section 3.e** about outreach and education and to help residents implement the Plan Unit Recommendations in **Section 3.c.** Managing slash at this regional level could also be a great benefit to all communities to encourage and support wildfire mitigation projects by residents.

Evacuation Planning and Capacity

Residents in the GVFPD are not strangers to wildfire evacuations. Residents were evacuated for a total of 2 weeks during the 2012 High Park Fire, and numerous mandatory and voluntary evacuations were triggered by the 2020 Cameron Peak Fire. Due to the elevated wildfire risk in the GVFPD, future evacuations are likely, underscoring the importance of emergency preparedness by the community.

There is a high likelihood of evacuation congestion and long evacuation times during a wildfire. Evacuation times for individual residents could exceed 3 hours in some parts of the GVFPD due to the limited number of egress routes from many neighborhoods (see **Appendix A.4. Evacuation**).

Reliable technology to provide warnings and information about evacuations can help residents feel confident in their ability to evacuate during a wildfire. The Larimer Emergency Telephone Authority, LETA-911 uses NoCo Alert, also known as reverse 911, to communicate evacuation orders to residents. HOAs, and residents should actively extend awareness about NoCo Alert to neighbors that are unaware of the program.

NoCo Alert is the reverse 911 system used by LETA-911 to contact residents during emergencies, including during wildfire evacuations. Residential landlines are automatically registered unless their phone uses VoIP (voice-over internet protocol). Residents can register their cell phones and email addresses on the NoCo Alert website.

We recommend the following steps for residents, HOAs, community groups, GVFPD, and the Larimer County Sherriff's Office to address evacuation concerns in the GVFPD:

- Conduct tree removal, cut low limbs, and mow grass along roadways to increase the likelihood of survivable conditions during a wildfire. Prioritize the roads with the most traffic and congestion and work out to the less congested roads. (See **Section 4.c Roadway Fuel Treatment Recommendations**).
- Coordinate with the Larimer County Sherriff's Office to conduct evacuation drills to practice safe and effective evacuation for the entire GVFPD.
- Coordinate with LETA-911 to increase participation in NoCo Alert across the GVFPD. Regularly test the system to ensure timely and accurate communication could occur during an evacuation.
- Educate residents about warning systems, protocols for evacuation orders, and evacuation etiquette prior to the need to evacuate the community. Communicate the importance of following evacuation orders; **failing to leave the community in a timely manner during a wildfire emergency can put first responders at risk.**
- Encourage residents to leave with only one vehicle per household to reduce congestion for everyone.
- Encourage all households to develop family evacuation plans and to pack go-bags that are at the ready. Residents should work with their neighbors to develop a plan for helping each other with evacuation if a resident is not at home, school-aged children or pets might be home alone, or residents have mobility impairments and need special assistance. Review the contents of your "go-bag" and make sure it is packed and ready to go. Visit the Larimer County Emergency Preparedness page to learn about go-bags and evacuation planning, including tips for preparing your pets and livestock for evacuation.
- Encourage residents to evacuate whenever they feel unsafe, even before receiving mandatory evacuation orders. All residents should leave promptly when they receive a mandatory evacuation order. This means having a family emergency plan already in place and having go-bags prepacked.

- Evaluate the efficacy of alternate methods of warnings and alerts, such as warning sirens. Research suggests that individuals trust and are more likely to respond to sirens than other warning systems like social media (National Academies of Sciences, Engineering, and Medicine 2018).
- Make sure warnings and alerts can be understood by all residents, including those with English as a second language and with hearing impairments.

3.e. Outreach and Education

GVFPD should continue to engage with community members using a variety of methods, including their website, social media, and education materials for residents. The recommendations in this plan should be consulted and shared with residents. It is the intention of this project that language and guidance is all compiled in this document and can be easily referenced and shared. As described in **Section 3.d**, a shared position among local fire districts is a recommended method to carry forward these recommendations and provide capacity for outreach and education.

As your community makes progress on the top-priority actions outlined below, refer to the fire adapted communities' "wheel" (**Figure 3.1**) and seek additional ideas and resources from the Fire Adapted Community Learning Network and Fire Adapted Colorado (FACO). Visit their websites for more information on their programs and upcoming events.

Community Self-Organization

The GVFPD has started a new volunteer support group that can form a CWPP implementation committee—consider volunteering to inspire change in your community! Visit the GVFD website for more information. See **Table 3.e.1** for next steps that you can take to gain traction and inspire action across your community.

Table 3.e.1. Next steps that residents can take to gain traction and inspire action to reduce wildfire risk across their community. Many of these suggestions come from *Fire adapted communities neighborhood ambassador approach: Increasing preparedness through volunteers* (Wildfire Adapted Partnership 2018).

Goal / objective	Suggested activities[1]
Increase support for wildfire risk mitigation across the community.	Volunteer to be a community organizer and leader around wildfire risk mitigation and emergency preparendess. Contact your HOA and participate in current working groups or form new working groups focused on wildfire education and risk reduction, or volunteer with the GVFPD on the new CWPP implementation committee. Invitie your neighbors over for a friendly conversation about the risk assessment in this CWPP. Review resources about defensible space together, discuss each other's concerns and values, and develop joint solutions to address shared risk. Contact the Colorado State Forest Service for publications and other educational material to learn about wildfire risk mitigation and share these resources with your neighbors. Organize walking tours to visit the property of residents with exemplary defensible space. Witnessing the type of work that can be done, and seeing that a mitigated property can still be aesthetically pleasing, can encourage others to follow suit. Volunteer during GVFPD's FireWise Education Day during the summer to encourage residents to implement home hardening and defensible space. Encourage your neighbors to attend the event. Visit the GVFD website for more information.
Reduce barriers to mitigation wildfire risk in the GVFPD. Residents in the GVFPD identified HOA regulations, a lack of slash disposal options, and financial resources as barriers to creating defensible space. You can step up to help address these barriers and inspire change across the community.	Contact HOA board members to ask questions about regulations. You might perceive barriers to mitigation that do not exist or are easily addressed. Serve on HOA working teams and speak with HOA leadership to support community-wide action around wildfire mitigation. Advocate for HOA regulations that align with home hardening practices and FireWise landscaping. Work with your HOA and the GVFPD to raise money for a chipper that can be used for slash management across the community. Contact the University of Denver Mountain Campus to pursue options to utilize their chipper.

	Advocate with other public leaders such as Larimer County Commissioners and state legislators for regional approaches to slash management. Take the Certified Burner B course from the Colorado Division of Fire Prevention and Control so you can safely implement pile burns on your property (where allowed by local regulations).
Create linked defensible space to reduce wildfire risk to entire neighborhoods. Collective action by residents will magnify the impact of individual defensible space projects, create tactical opportunities for wildland firefighters, and reduce the likelihood that homes will ignite due to embers produced from adjacent, combusting homes. Linked defensible space has greater strategic value, and projects that span ownership boundaries are better candidates for grant funding.	Start reducing risks on your own property by following recommendations outlined in **Section 3.a Individual Recommendations**. Work with your HOA or create your own neighborhood working group to identify individuals willing to conduct mitigation work on their property. Use information from this CWPP to determine areas of high-risk in your community (see priority locations in **Priority Plan Unit Recommendations** and **Priority Treatment Locations).** Develop a joint proposal for wildfire mitigation grants with your neighbors and HOA (see **Section 3.f. Funding Opportunities for Wildfire Hazard Mitigation and Emergency Preparedness**). Contact the Coalition for the Poudre River Watershed, Larimer Conservation District, Larimer County Conservation District, or Colorado State Forest Service to discuss your plans for creating linked defensible space and to ask for guidance and available resources for implementation.
Create safer conditions along driveways and roadways to protect residents during evacuations and firefighters during suppression operations and structure defense. Narrow roads without turnarounds, tree limbs hanging over the road, and lots of dead and down trees by the road can create non-survivable conditions along roads during a wildfire and prevent access to and from your neighborhood.	Work with neighbors to identify roads and driveways with potentially non-survivable conditions using insights from the CWPP (see **Priority Locations**). Contact your HOA and the Larimer County Road and Bridge Department to determine who owns rights-of-way along roadways and to discuss opportunities for mitigation projects. Develop a joint proposal for wildfire mitigation grants with your neighbors and HOA (see **Section 3.f. Funding Opportunities for Wildfire Hazard Mitigation and Emergency Preparedness**). Contact the Coalition for the Poudre River Watershed, Larimer Conservation District, Larimer County Conservation District, or Colorado State Forest Service to discuss your plans for mitigating wildfire risk along roadways.

Encourage emergency preparedness so you, your neighbors, wildfires, and other first responders are safer during the next wildfire emergency. The best way to get out quickly and safely during an evacuation is to be prepared with a go-bag and a family emergency plan.	Start with your own family's emergency preparedness. See the CWPP section on **Evacuation Preparedness**. Work with the GVFPD CWPP implementation committee or your HOA to organize an event with firefighters and law enforcement personnel where residents can ask questions about emergency preparedness and procedures. Encourage residents to work with their neighbors to develop a plan for evacuation if a resident is not at home, school-aged children or pets might be home alone, or residents have mobility impairments and need special assistance. Work with your HOA and the GVFPD to organize a community evacuation drill with the Larimer County Sherriff's Office.

[1] See **Section 5. Contact Information** for emails of HOAs and other organizations supporting wildfire mitigation and emergency preparedness in and around the GVFPD.

FireWise Community

GVFPD has been a designated FireWise Community since 2018. This is a great foundation to build off for planning community outreach and education events. The Fire Protection District hosts an annual education day every summer to talk to residents about wildfire preparedness and mitigation. Visit the GVFD website for more information about when and where this event will take place in 2022.

Social Media

Social media is a powerful tool when used properly to connect with audiences. FEMA has a Wildfire and Outdoor Fire Safety Social Media Toolkit that is a great starting place for fire protection districts to begin gaining an audience with their constituents and sharing important fire safety information. Put Fire to Work highlights programs and organizations that are successfully engaging audiences around wildland and prescribed fire work. CalFire's Ready for Wildfire campaign is active and collaboratively created to engage and encourage people to take action on wildfire preparedness.

Collaboration

Collaboration with stakeholders, landowners, local governments, business owners, and community members is the best way to ensure good outcomes from this plan. Stakeholders outlined **in Section 1.b Partners and Stakeholder Engagement** were engaged in the development of this CWPP and offered input on the recommendations set forth in this CWPP. It is recommended that the GVFPD continue meetings with major stakeholders in the district to provide accountability on projects and continue to participate in cross-boundary mitigation programs such as the Northern Colorado Fireshed Collaborative (NCFC), the Elkhorn Creek Forest Health Initiative (ECHI), and the Upper Poudre Watershed Resilience Plan.

Stakeholders in and around the GVFPD must work to move mitigation projects from paper to on the ground action, keep lines of communications open and messaging consistent, and to support each other's work in the community. Where some organizations may be able to offer incentives to homeowners, others may be able to provide structure and requirements that must be met to keep life safety for residents and firefighters a priority. This multi-faceted approach is only possible through compromise, mutual respect, and collaboration on shared goals.

3.f. Funding Opportunities for Wildfire Hazard Mitigation and Emergency Preparedness

There are many funding opportunities from federal, state, and local agencies as well as non-profits to assist in forest health and wildfire mitigation projects. These funds can increase capacity but cannot cover all the costs of fire mitigation needed within the valley. Local residents and stakeholders must put forth funds and time to complete this work."

Opportunities from Local and State Agencies in Colorado

- The Colorado State Forest Service (CSFS) **Forest Restoration and Wildfire Risk Mitigation (FRWRM)** is a competitive grant program designed to assist with funding community-level actions across the entire state to: reduce the risk to people, property and infrastructure from wildfire in the wildland-urban interface; promote forest health and the utilization of woody material including for traditional forest products and biomass energy; and encourage forest restoration projects. Eligible applicants include local community groups, local government entities such as fire protection districts, public and private utilities, state agencies, and non-profit groups.
- CSFS administers programs for landowner and community assistance, including the **Colorado Forest Ag Program** and **Colorado Tree Farm Program.**
- CSFS regularly updates their **Natural Resources Grants & Assistance Database** to help residents, agencies, and other partners find funding for natural resource projects.
- The Colorado Department of Revenue provides a **Wildfire Mitigation Measures Subtraction** whereby individuals, estates, and trusts may claim a subtraction on their Colorado income tax return for certain costs incurred in performing wildfire mitigation measures on property in the WUI.
- The **Larimer County Office of Emergency Management** offers community mitigation grants to increase a community's long-term resilience to natural hazards.

Funding from the Federal Emergency Management Agency (FEMA)

- **Building Resilient Infrastructure and Communities (BRIC) grant program** supports states, local communities, Tribes, and territories as they undertake large-sale projects to reduce or eliminate risk and damage from future natural hazards. Homeowners, business operators, and non-profit organizations cannot apply directly to FEMA, but they can be included in sub-applications submitted by an eligible sub-applicant (local governments, Tribal governments, and state agencies).
- **Hazard Mitigation Assistance Grants Program (HMGP)** provides funding to state, local, Tribal, and territorial governments so they can rebuild in a way that reduces, or mitigates, future disaster losses in their communities. This grant funding is available after a presidentially declared disaster.
- **Assistance to Firefighters Grants (AFG)** help firefighters and other first responders obtain critical resources necessary for protecting the public and emergency personnel from fire and related hazards.
- **Fire Prevention & Safety (FP&S) Grants** support projects that enhance the safety of the public and firefighters from fire and related hazards.
- **Staffing for Adequate Fire and Emergency Response (SAFER)** grants directly fund fire departments and volunteer firefighter organizations to help increase their capacity.

Opportunities from Non-Governmental Organizations

- Coalitions and Collaboratives, Inc. manages the **Action, Implementation, and Mitigation Program (AIM)** to increase local capacity and support wildfire risk reduction activities in high-risk communities. AIM provides direct support to place-based wildfire mitigation organization with pass-through grant funding, on-site engagement, technical expertise, mentoring, and training on mitigation practices to help high-risk communities achieve their wildfire adaptation goals.
- **Coalition for the Poudre River Watershed** (CPRW) can aid with small-acreage wildfire mitigation projects on private property. Reach out to the CPRW Forester, Daniel Bowker, for more information.
- Fire Adapted Colorado (FACO) manages the **FACO Opportunity Fund**, which is a matching mini-grant program to support projects, build capacity, and address local needs with funding from the National Fire Adapted Communities Learning Network.

Supporting the Fire Protection District

- GVFPD strives to be supportive of forestry projects that improve forest health and wildfire safety. Creating, managing, and implementing fuels mitigation projects takes time and effort that is often unfunded to the district. Education and outreach are incredibly important to the district – connecting with their constituents is a vital part of building relationships and providing the highest quality services. This work requires time and resources that the FPD does not always have to spare.
- The **Staffing for Adequate Fire and Emergency Response (SAFER)** grants can help fund staff capacity for fire departments.
- The **Assistance to Firefighters Grants (AFG)** can provide critical response resources for firefighters and emergency responders.
- Community support is also vital to the success of the fire stations:
    - GVFPD is supported by volunteer responders who respond to fires, medical emergencies, and rescues every day of the year. Learn more about how you can volunteer by contacting your local fire department.
    - Financial support in the form of monetary donations or support of local ballot measures that provide tax revenue for the FPD is vital to their success in responding to residents in their time of need.
    - Attend events hosted by the FPD. Seeking out information to protect your home from fire danger can also help protect your local firefighters. Sharing this information within your community can build community resilience and can help lower implementation costs for individual homeowners for many projects.

4. Implementation Recommendations for Fuel Treatments

4.a. General Objectives and Implementation of Fuel Treatments

"Given the right conditions, wildlands will inevitably burn. It is a misconception to think that treating fuels can 'fire-proof' important areas... Fuel treatments in wildlands should focus on creating conditions in which fire can occur without devastating consequences, rather than on creating conditions conducive to fire suppression" (Reinhardt and others 2008).

Fuel treatments are a land management tool for reducing wildfire hazard by decreasing the amount and altering the distribution of wildland fuels. Fuel treatment methods include tree thinning, pruning, pile burning, broadcast prescribed burning, and fuel mastication (Hunter et al. 2007). Strategic fuel treatments, in tandem with work by individual residents to mitigate hazards in their home ignition zone (see **Section 3.a Individual Recommendations**), can help protect life and property. Many residents, HOAs, and local agencies that manage land within and around the GVFPD are actively reducing wildland fuels. Additional strategic work is required to mitigate wildfire risks across the GVFPD (see **Section 3.c. Priority Plan Unit Recommendations** and **4.b. Priority Treatment Locations**).

Many fuel treatments focus on reducing the risk of active or passive crown fires and reducing the intensity of the fire. This is primarily achieved by treatments that decrease the tree density, increase crown spacing, and decrease ladder and surface fuels. However, it should be noted that removing trees can increase the growth of grasses, forbs, and shrubs and dry out these fuels by increasing their exposure to sun and wind. Fires burning through abundant, dry grasses have rapid rates of spread; however, the fundamental goal of many fuel treatments is not to reduce the rate of fire spread but to reduce burn severity or increase opportunities for suppressing wildfires (Reinhard et al. 2008).

Strategically located, high-quality fuel treatments can create tactical options for fire suppression (Plucinski 2019; Jolley 2018; Reinhardt et al. 2008). <u>Fuel treatments are most effective when used in conjunction with suppression actions.</u> Reduced fire intensity within treated areas allows firefighters opportunities to use direct or indirect suppression techniques. Firefighters benefitted from using fuel treatments in the Red Feather Lakes area as tactical features during the Cameron Peak Fire (Avitt 2021).

All fuel treatments are not created equal, and there is no "one size fits all" fuel treatment design (Reinhardt and other 2008). Specific fuel treatment recommendations are dependent on forest type, tree density, fuel loads, terrain, land use, and management objectives. The location and purpose of treatments also matter. Treatments in defensible space zone three are typically more intensive than treatments outside of the defensible space zones because of the importance of substantially reducing fuels closer to homes. Treatments along roadways often require removal of many trees to create safe and survivable conditions, whereas treatments in large, forested areas can achieve fuel objectives by following principles of ecological restoration in frequent-fire forests and principles of fire mimicry and mosaic landscapes in infrequent-fire forests.

Local knowledge and professional expertise are needed to design effective, site-specific fuel treatments. Science of fuels treatments continues to evolve, so it is recommended to always work with local practitioners to apply the best available science to any new fuels treatment. **Homeowners are responsible for fuel mitigation on their own lands – you as a landowner must initiate and follow through on this work, but that does not mean you must do it alone.** For assistance in planning and implementing a new fuels treatment, contact the Larimer Conservation District, Colorado State Forest Service, or other wildfire mitigation specialists.

Treatment Categories

Home Ignition Zone mitigation: HIZ mitigation is intended to make the protection of structures such as homes less susceptible to ignition. This includes hardening the home, which involves making it more difficult for embers or radiant heat to light the structure on fire, and creating defensible space, which involves treating the vegetation and other fuels in the area surrounding the home to decrease the intensity of fire activity as it nears the home. The recommendations for this work are standardized and outlined in this document as well as in publications from the Colorado State Forest Service. HIZ mitigation recommendations are designed for individual homeowners and HOAs and neighborhoods to work on with the assistance of the GVFPD.

Stand-level fuel treatments: Stand-level fuel treatments are designed to reduce surface fuels, reduce tree density, and increase the distance between surface and canopy fuels within forest stands (Agee and Skinner 2005). These treatments are designed to reduce the likelihood of high-severity, active crown fires. Ideally stand-level fuel treatments follow the principles of ecological restoration and achieve both ecological and fuel reduction objectives. However, stand-level fuel treatments and ecological restoration are not synonymous; some ecosystem restoration treatments reduce fuel hazards, but not all fuel treatments restore ecosystems (Reinhard et al. 2008). A forest with widely, evenly spaced trees could serve as an effective fuel treatment, but this configuration would not achieve ecological objectives in most forest types. Ecological restoration is the process of assisting the recovery of an ecosystem that has been damaged, degraded, or destroyed (SER 2004). In ponderosa pine and mixed-conifer forests along the Colorado Front Range, ecological restoration usually achieves fuel reduction objectives (Ziegler et al. 2017). Treatments involve converting dense forests into a mosaic of single trees, clumps of trees, and meadows similar to historical forests that were maintained by wildfires and very resilient to them (Addington et al. 2018). Stand-level fuel treatments are designed for large landowners, public land managers, and collaborating neighborhoods to implement.

Roadway fuel treatments: Roadway fuel treatments are buffers along roadways with reduced fuel loads to improve fire control opportunities and reduce the chance that non-survivable conditions develop along roadways during a wildfire. Tree removal along narrow roadways can also increase access for fire engines and provide safer egress for firefighters. Fuel treatments along trails, ridgelines, and other features can be utilized by firefighters to contain fire spread. This work can be done by all collaborators in the district. Individuals can implement these recommendations along their driveways, Coordinate with your HOA, Larimer County Road & Bridge, and the Colorado Department of Transportation to learn about regulations and opportunities to mitigate hazards along roadways in your community.

Treatment Costs

The cost of fuel treatment depends on management objectives, treatment specifications, slope, accessibility, and treatment method (e.g., mechanical thinning, hand thinning, or prescribed burning). Costs of $2,500 to $10,000 per acre are not uncommon along the Colorado Front Range where there is little biomass or timber industry to provide financial return (Gannon and other 2019). Higher costs can be expected on steeper slopes and at greater distances from roads. Costs for follow-up treatments are generally lower than the initial entry and help maintain the original investment in fuel treatments. The cost of fuel treatments underscores the importance of conducting strategic, well-designed, landscape-scale treatments to increase the likelihood that fuel treatments moderate fire behavior.

Fuel treatments can save lives and ecosystems and provide economic returns. Fuel treatments can reduce property damages by making wildfires less damaging and easier to control; this is especially true for prescribed burning which is often cheaper and more effective at altering forest fuel loads than mechanical thinning alone (Prichard et al. 2020; Loomis et al. 2019; Fulé and other 2012). Fuel treatments can reduce the cost of rehabilitating water sources when wildfires are followed by large storm events that result in massive erosion (Jones et al. 2017). In some instances, fuel treatments can reduce suppression costs due to the increased efficiency of firefighting (Loomis and other 2019).

Fuel treatments do not always have positive financial returns on investment. Some treatments are never encountered by wildfires, fuel treatments can be ineffective at altering fire behavior during severe fire weather conditions, and suppression expenditures are often driven by values at risk, fire size, and landownership rather than fuel characteristics (Reinhardt et al. 2008). However, when fuel treatments follow the principles of ecological restoration, they result in positive ecological benefits regardless of economic costs.

4.b. Stand-Level Fuel Treatment Recommendations

Effective Treatment Design

Restoration-style treatments can meet both ecological and fuel reduction objectives in ponderosa pine and dry-mixed conifer forests along the Front Range of Colorado (Addington et al. 2018; Fulé et al. 2012). Most of the forested area within and around the GVFPD are ponderosa pine and mixed-conifer forest types (**Figure 2.a.4**), and many of these forests had far fewer trees prior to Euro-American settlement due to a higher frequency of wildfires (**Figure 2.d.1**; Addington et al. 2018).

The Larimer Conservation District and other land management agencies encourage an approach to forest management that transforms dense ponderosa forests into a strong and healthy woodland with single trees, clumps of trees, and meadows similar to historical forests that were maintained by wildfires and very resilient to them. According to James White, the Prescribed Fire and Fuels Specialist for the Arapaho/Roosevelt National Forests, "Broadcast burning, mechanical thinning, and other treatments are proven to mitigate wildfire risk, but they are even more effective when we work together to integrate treatments across the landscape, across borders and ownerships" (Avitt, 2021).

A holistic approach to forest restoration reduces crown-fire hazard, increases the abundance and diversity of grasses, shrubs, and wildflowers, and improves habitat for many wildlife species, including deer and elk. This approach is backed by decades of forest, wildlife, and fire ecology research, which is summarized in *Principles and practices for the restoration of ponderosa pine and dry mixed-conifer forests of the Colorado Front Range* published by the U.S. Forest Service Rocky Mountain Research Station (Addington et al. 2018). We suggest that foresters, other land managers, and landowners reference this document when preparing and implementing forest treatments in and around the GVFPD. Another useful tool for designing restoration treatments is *Visualization of heterogenous forest structures following treatments in the Southern Rocky Mountains*—a document with pictures, graphs, and simulations of different pre- and post-treatment forest structures (Tinkham et al. 2017).

Table 4.b.1. Minimum recommended spacing between tree crowns is greater for properties on steeper slopes due to the exacerbating impact of slope on fire behavior (Dennis 2003). When treatments are designed to achieve ecological restoration objectives, it is important to avoid evenly spacing trees. Retaining small clumps of trees with interlocking crowns is acceptable so long as they are adequately spaced from adjacent individual trees and tree clumps.

Percent slope	Minimum spacing between tree crowns
0 to 10 %	10 feet
11 to 20%	15 feet
21 to 40%	20 feet
>40%	30 feet

Treatment Methods

Trees can be removed manually or mechanically, providing for considerations of safety, slope, road access, cost, and potential damage to soil. Use of mechanical equipment is often infeasible on slopes greater than 35% (Hunter et al. 2007). Handcrews with chainsaws can operate on steeper slopes, but handcrews usually cover less ground each day than mechanical thinning. Sometimes the only option for tree removal on steep, inaccessible slopes is expensive helicopter logging. Tree cutting with a chainsaw and other forestry equipment should be done by experienced and certified individuals. The Colorado State Forest Service provides guidance for how to select a contractor to conduct forest management treatments on your property.

Broadcast prescribed burning can be an extremely effective method to reduce hazardous fuels and restore ecological conditions across a variety of grassland, shrubland, and forest ecosystems (Stephens et al. 2009; Paysen et al. 2000). Prescribed burning is challenging in the WUI due to diverse fuel types, proximity to homes, risk of visibility impairments on roads from smoke, health impacts of smoke, and political and social concerns. However, with proper planning and implementation, qualified firefighters can safely conduct prescribed fires, even in the WUI (Hunter and other 2007).

Prescribed burning is generally cheaper to implement than mechanical treatments across large landscapes (Hartsough et al. 2008; Hunter et al. 2007), and fire has unique impacts on vegetation and soils that cannot be replicated by mechanical treatments alone (McIver et al. 2013). Thinning and burning treatments tend to achieve fuel reduction objectives and modify fire behavior to a greater extent than thinning alone (Prichard et al. 2020; Fulé and other 2012).

Thinning operations often increase surface fuel loads and can fail to achieve fire mitigation objectives if fuels created by the harvest activities (also known as slash) are not addressed (Agee and Skinner 2005). See **Section 4.d. Slash Management** for options to mitigate surface fuel loads created by fuel management.

Ponderosa Pine and Dry Mixed Conifer

Ponderosa pine forests are called woodlands because they grow in open stands with many understory species and room between the trees. Dry mixed conifer forests are usually found are warm, dry south-facing slopes in this area and contain ponderosa pine, Douglas-fir, and Rocky Mountain juniper, with occasional blue spruce.

Treatments for Ponderosa Pine

Ponderosa pine stand treatments are centered around ecological restoration, or restoring the site to historic conditions. Thinning to create wide spacing between trees with a focus on preserving the largest and oldest trees is common and results in healthier forests post-treatment. Ponderosas and most dry mixed conifer forests respond well to selective thinning and regular maintenance that keeps regeneration levels low and keeps just the healthiest trees.

Broadcast burning is also a highly effective treatment for ponderosa and dry mixed conifer forests. The more mature trees can withstand the fire while the understory is cleared out. Ponderosa pine forests had regular fire intervals of 7-50 years before colonial settlement and restoring that fire regime is ideal. When planning treatments for ponderosa pine and dry mixed conifer sites, we recommend the following:

- Follow the principles of ecological restoration as outlined in Addington et al. (2018) to help achieve fuel reduction and ecosystem restoration objectives. Restoration treatments in Ponderosa pine and dry mixed conifer forests will result in mosaic patterns of single trees, clumps of trees, and interspersed meadows.
- Increase the spacing between tree crowns to decrease the risk of active crown fire. If the goal is only to reduce fuel loads, remove trees to create at least 15-foot crown spacing. Wider spacing is required on steeper ground due to the exacerbating impact of slopes on fire behavior (**Table 4.b.1**). If treatment objectives also include ecological restoration, it is important to avoid evenly spacing trees. Retaining small clumps of trees with interlocking crowns is acceptable so long as they are adequately spaced from adjacent individual trees and tree clumps.
- Determine appropriate post-treatment tree density depending on ecological and fuel treatment objectives, forest type, and aspect. As a general principle, the more trees removed, the more effective the fuel treatment and the closer the treatment recreates historical, fire-resilient forest structure. Along the Colorado Front Range at lower montane elevations (5,500 to 8,530 feet), tree densities in ponderosa pine forests average 4.5 times higher today than they were in the mid-1800s, and basal areas average 2.8 times higher. Many ponderosa pine forests had less than 100 trees per acre and basal areas less than 40 $feet^2$/acre in the mid-1800s (Battaglia et al. 2018). Forests on north-facing slopes historically had higher tree densities, but it might be necessary to substantially reduce tree densities on some north-facing slopes to protect homes and other values at risk from potential fire effects.
- Reduce ladder fuels to decrease the risk of torching. Remove a substantial portion of seedling, saplings, and shrubs, especially those near overstory trees. Pruning branches that hang less than 10 feet above the ground can further reduce the risk of torching, but it can be expensive and inefficient in areas outside defensible space zones 1 and 2. The pruning height required to effectively reduce the risk of torching is influenced by the moisture content of needles and branches, wind speed, slope, and surface fuel loads. The necessary pruning height can be exorbitant; for example, tree limbs hanging below 20 feet must be removed to prevent dry canopy fuels from igniting when exposed to radiant heat from 8-foot flames (Agee 1996a).
- Reduce surface fuels to decrease fire intensity and flame lengths. Thinning operations produce significant amounts of slash, and rearranging fuels from tree crowns to the surface

without reducing the overall fuel load will rarely achieve fuel reduction objectives. Slash decomposes very slowly in Colorado and proper disposal is essential. See **Section 4.d. Slash Management** for guidance on slash management.

- Strategically place treatments to facilitate firefighter access, help firefighters establish control lines, and reduce the intensity of wildfires as they spread towards homes and other values at risk.
- Mitigate impacts of tree removal on soil compaction and erosion when treatments occur near streams and riparian ecosystems. The Colorado State Forest Service recommends streamside management zones of at least 50 feet (CSFS 2010).
- Commit to monitoring and maintenance of fuel treatments. Benefits of fuel treatments are transient and decrease overtime, with treatment "lifespan" depending on forest type, topography, rates of seedling regeneration (which is often influenced by precipitation), and the number of trees removed during treatments. Many forests require more than one treatment to reduce fuels and restore ecosystem structure. Some areas might require mechanical tree removal followed by prescribed burning, and then a maintenance treatment with tree removal and/or prescribed burning 10 to 20 years later. With a single pulse of tree regeneration, the risk of torching returns to near pre-treatment levels within 10 to 35 years in ponderosa pine forests in Colorado. As the number of regenerating seedlings increases, treatment longevity decreases by about 5 years per 550 seedlings (Tinkham et al. 2016).
- Monitor treatments for invasive, weedy plant species that might require control after forest treatments.
- Take pictures of the treatment before and after to help evaluate effectiveness and monitor changes over time (see **Figure 3.a.3** for an example of repeat photographs pre- and post-treatment).

Ponderosa Pine in Defensible Space

Ponderosas are well adapted to living in spaced out woodlands and are easily thinned to create beautiful and effective defensible space. Homeowners often enjoy the more open forest around their home because it lets in more light which encourages more understory grasses and shrubs to grow and, in turn, can increase wildlife sightings near their home. Clear all ponderosa pines from sone 1, and thin and limb all ponderosas in zones 2 and 3 to create a minimum of 15-foot crown spacing and at least 6 feet of vertical clearance to the lowest hanging branches.

Rocky Mountain Lower Montane-Foothill Shrublands

Wildfires in shrublands have high rates of spread, particularly when there are continuous grasses, and burning shrubs can emit significant radiant heat. Shrubs should be managed as a ladder fuel in the HIZ. They should be kept away from defensible space zone 1 and cleared from under trees in zones 2 and 3. Dense shrubs should be thinned and cleared around a structure, especially on hillslopes below a home. Grasses in zone 2 should be irrigated and mowed to 4 inches tall or less.

Aspen and Other Riparian Hardwood Species

Aspen groves are important food and habitat for mountain fauna. They are fire resistant and do not respond well to fuel treatments. Aspen groves should be left alone and not thinned or managed for fire, unless they are right next to or hanging over a structure. Aspen is a resilient, early-succession species that will grow in quickly after fuels treatments in other forest types, such as lodgepole patch cuts.

Cottonwood and willow trees are excellent at stabilizing riverbanks and wetland habitat. They grow quickly and provide habitat and forage for many species. These trees should generally be left alone unless they are very close to or hanging over a structure. More information can be found in the Cottonwood Management publication from the Colorado State Forest Service.

Priority Treatment Locations

We located and prioritized potential locations for ecological restoration and/or stand-level fuel treatments within and around the GVFPD (**Figure 4.b.1**). In February 2022 we shared our assessment with land managers and other partners with the Ben Delatour Scout Ranch, Coalition for the Poudre River Watershed, Colorado State Parks and Wildlife, Colorado State Forest Service, Larimer County Office of Emergency Management, Larimer County Sherriff's Office Emergency Services, Larimer Conservation District, Larimer County Conservation Corps, The Nature Conservancy, and U.S. Forest Service for their input. **These treatment areas cross ownership boundaries and will require collaboration between private landowners, public land managers, and forestry professionals to create successful outcomes.**

Our prioritization scheme was based on predicted fire behavior, the abundance of threatened structures, presence of non-survivable roadway conditions, and operability based on slope The boundaries of the proposed treatment units follow topographic features and major roadways. See **Appendix B.2. Fuel Treatment Prioritization Methodology** for a full description of our prioritization methods.

We identified 36 first-priority treatment units that are fully or partially within the GVFPD for a total of 7,740 acres (**Figure 4.b.1**). There are 150 second-priority treatment units (19,020 acres) and 193 third-priority units (27,700 acres) within and surrounding the GVFPD in which treatments could reduce the risk of high-severity wildfires, protect lives, and enhance safety within the GVFPD. Priority treatment locations are abundant in the western half of the GVFPD and across the Arapaho Roosevelt National Forest due to the abundance of dense forests that increase the risk of high-severity fires to structures. Creation of defensible space, home hardening measures, and maintenance of the HIZ are important for all landowners regardless of the location of priority fuel treatment locations.

GVFPD, local land managers, and other partners identified four key treatment areas for immediate action: North Rim Road, Ben Delatour Scout Ranch, Cherokee State Wildlife Area, and Glacier View Meadows 1, 2, and 3 (**Table 4.b.2**). Large portions of these areas were identified as first or second-priority fuel treatment locations. There is previous and ongoing fuel mitigation work at the Ben Delatour Scout Ranch that can be leveraged and expanded upon to magnify treatment benefits to the community. Stakeholders outlined the potential roles they could play in implementation (**Table 4.b.2**). The willingness of multiple organizations to work together to protect lives, safety, and property within the GVFPD is tremendous.

We focus on high-priority treatment recommendations, but this does not discourage ecological restoration and fuel mitigation in other areas. Prior to treatment, forestry professionals should visit these locations to assess current conditions and delineate unit boundaries. GVFPD, HOAs, residents, and land managers should re-evaluate fire risks and re-prioritize treatment units as conditions change over time. Many areas not identified as priority locations in **Figure 4.b.1** could benefit from treatments to reduce fire risks and protect homes and other values at risk. If multiple neighbors work together to mitigate fire risk across ownership boundaries, it could attract funding and increase the priority and effectiveness of treating those areas.

Altering potential wildfire behavior and restoring ecological conditions requires a landscape-scale approach to treatments (Addington et al. 2018). Most of the priority treatment units fall on privately-owned land and span multiple ownerships, which can create a challenge for designing and implementing treatments. Community-wide commitment and coordination are required to implementing strategic treatments that decrease shared fire risk.

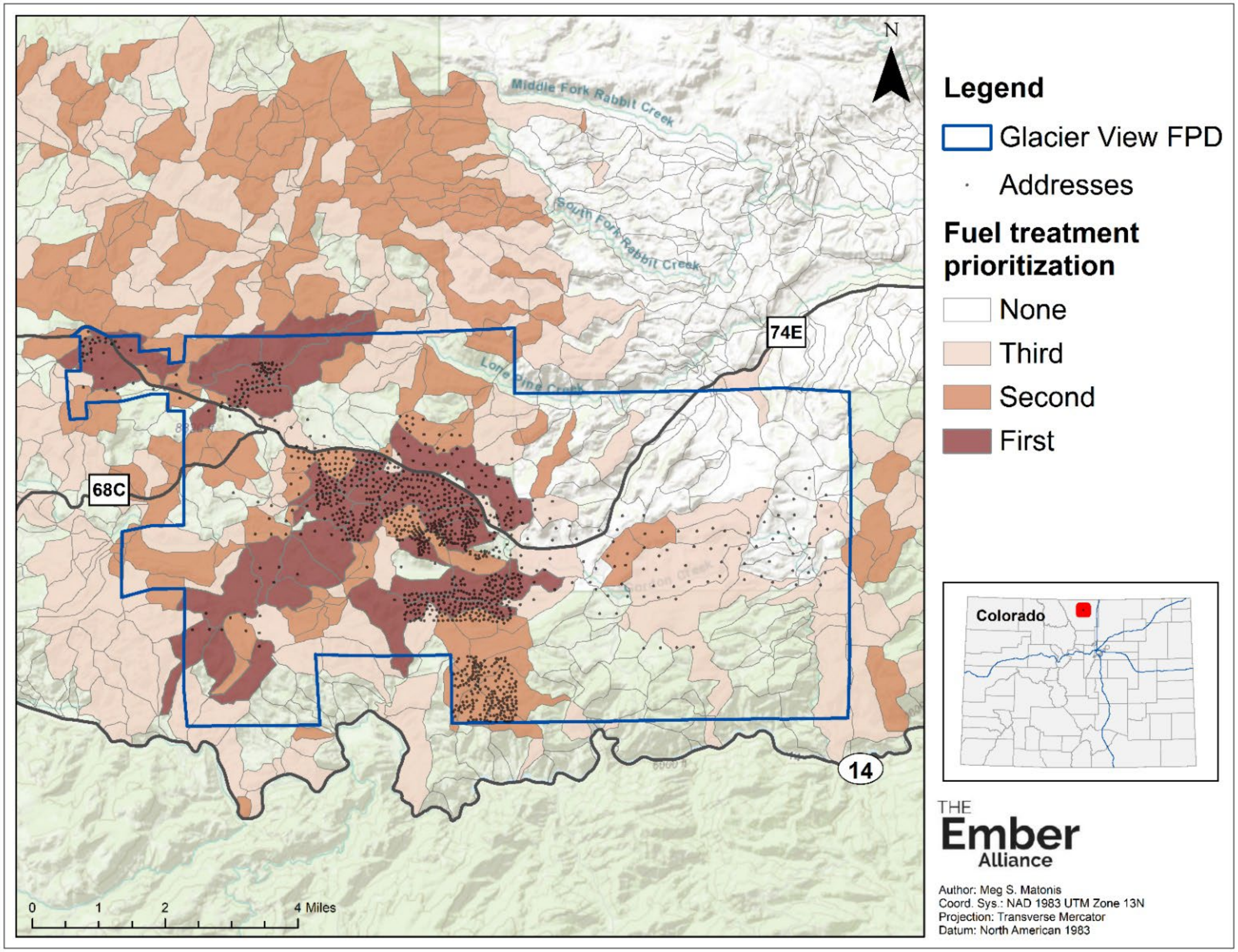


Figure 4.b.1. Potential priority locations for ecological restoration and/or stand-level fuel treatments based on predicted fire behavior, the abundance of threatened structures, presence of non-survivable roadway conditions, and operability based on slope. See **Appendix B.2. Fuel Treatment Prioritization Methodology** for a description of hillslopes and a full description of our prioritization method. An interactive map with fuel treatment prioritization is available online at https://experience.arcgis.com/experience/225f72cc029c4e37a2acbdefc60b2140/page/Treatments/.

Table 4.b.2. Priority locations for new and ongoing fuel treatment projects as agreed upon by the GVFPD and local land managers and other partners. See footnote below the table for acronyms used in the table. * denotes implementation project leader who will work to move this project forward and convene the necessary stakeholders.

Project Area	Description of Project Area	Stakeholder Responsibilities
North Rim Road (**Figure 4.b.2**)	Long portions of North Rim Road are in first-priority treatment areas due to the potential for extreme fire behavior. Steep slopes and dense forest conditions along North Rim Road could result in potentially non-survivable conditions for residents evacuating during a wildfire (**Figure 4.c.2**; **Figure 9.a.15**). This road is the only point of egress for residents in the North Rim CWPP plan unit. Portions of North Rim Road pass through private property and other portions through the Arapaho Roosevelt National Forest.	**USFS**- Use Good Neighbor Authority to implement treatment adjacent to private land **CPRW**- Build relationships with landowners adjacent to previous implementation and help them attain grant funding **LCD**- Identify landowners with good accessibility for heavy equipment and help them attain grant funding **CSFS**- Invest in education & outreach to improve social license in N Rim Rd area **GVFPD***- Invest in education & outreach to improve social license in N Rim Rd area
Ben Delatour Scout Ranch (**Figure 4.b.2**)	Over half of the BDSR is in second- and third-priority treatment areas due to the potential for extreme fire behavior. Between 2017-2019, BDSR, other NGOs, and the USFS have partnered together to treat over 250 acres with mechanical thinning and prescribed fire. These treatments helped slow the spread of the 2020 Cameron Peak Fire.	**BDSR***- Continue burning slash piles **LCCC**- Continue assigning crews to do mechanical treatments **CPRW**- Continue working with Elkhorn Creek Forest Health Initiative to coordinate efforts at BDSR; Build social license by sending out pile burn notifications **USFS**- Magic Feather Rx project implementation
Cherokee State Wildlife Area **(Figure 4.b.3)**	The Lone Pine Unit of the Cherokee State Wildlife Area (SWA) falls within the GVFPD and the Roy Brown, Roy Brown/Circle Ranch, and Lower Units are directly north of the district. Several second- and third-priority treatment areas fall within the Cherokee SWA, and CPW is pursuing mechanical treatments to reduce fire risk. The Cherokee SWA is an important recreational area surrounded by private land, the Arapaho Roosevelt National Forest, conservation easements maintained by TNC, and property administered by the Colorado State Land Board.	**CPW***- Implement 120 acres of mechanical treatment; Coordinate with adjacent land managers to connect treatments across property boundaries **LCD**- Implement cheatgrass removal in Lone Pine unit USFS – Coordinate with CPW and work on adjacent federal lands.

Project Area	Description of Project Area	Stakeholder Responsibilities
Glacier View Meadows 1, 2 & 3 (Figure 4.b.4)	Over half of Glacier View Meadows 1 and 2 contained first-priority treatment units as well as numerous second- and third-priority units. All of Glacier View Meadows 3 falls within second-priority treatment units. Glacier View Meadows 2 was identified as a CWPP plan unit with extreme relative risk and Glacier View Meadows 1 and 3 as high relative risk due to the potential for extreme fire behavior, long evacuation times, and structure loss due to a lack of defensible space around homes (**Figure 3.c.2**). Portions of the Arapaho Roosevelt National Forest fall within or abut these plan units. The 2012 High Park Fire burned all of the Glacier View Meadows 3 and the southeastern edge of Glacier View Meadows 2, resulting in the loss of several homes. Rebuilding continues, providing an opportunity to create homes and properties more resistant to wildfire.	**LCSO ES/ LCOEM-** Assist FPD with slash management; Conduct home assessments in residential areas **CSFS-** Assist homeowners to find funding for home hardening and defensible space **GVFPD** – Coordinate with residents and promote these fuel treatment projects. Develop community buy in and funding required to complete this work.

[1]BDSR = Ben Delatour Scout Ranch; CPRW = Coalition for the Poudre River Watershed; CPW = Colorado State Parks and Wildlife; CSFS = Colorado State Forest Service; LCCC = Larimer County Conservation Corps; LCD = Larimer Conservation District; LCOEM = Larimer County Office of Emergency Management; LCSO ES = Larimer County Sherriff's Office Emergency Services; USFS = United States Forest Service

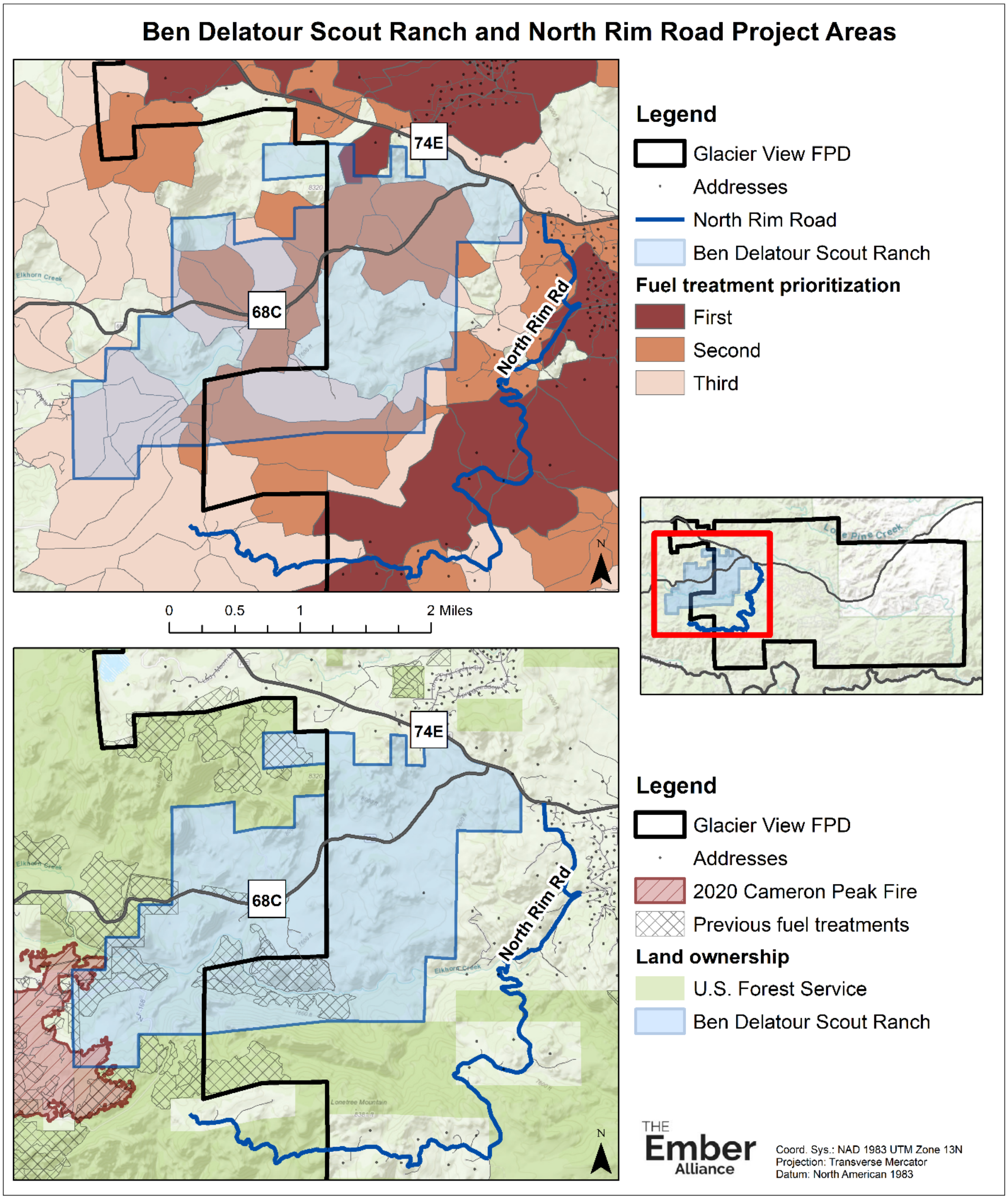


Figure 4.b.2. The GVFPD, local managers. and other partners identified the Ben Delatour Scout Ranch and North Rim Road area as locations for immediate fuel reduction activities.

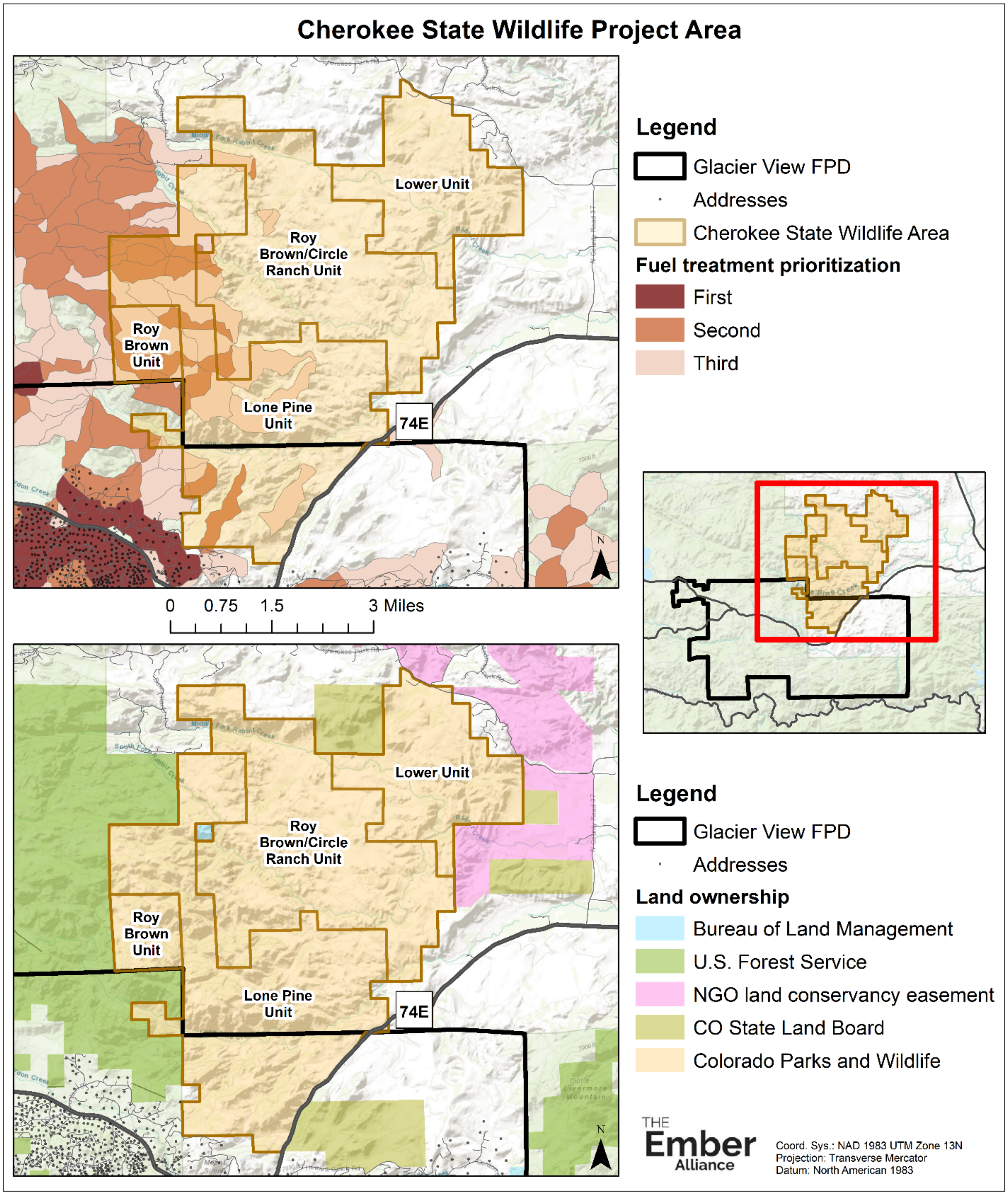


Figure 4.b.3. The GVFPD, local managers. and other partners identified the Cherokee State Wildlife Area as a location for immediate fuel reduction activities.

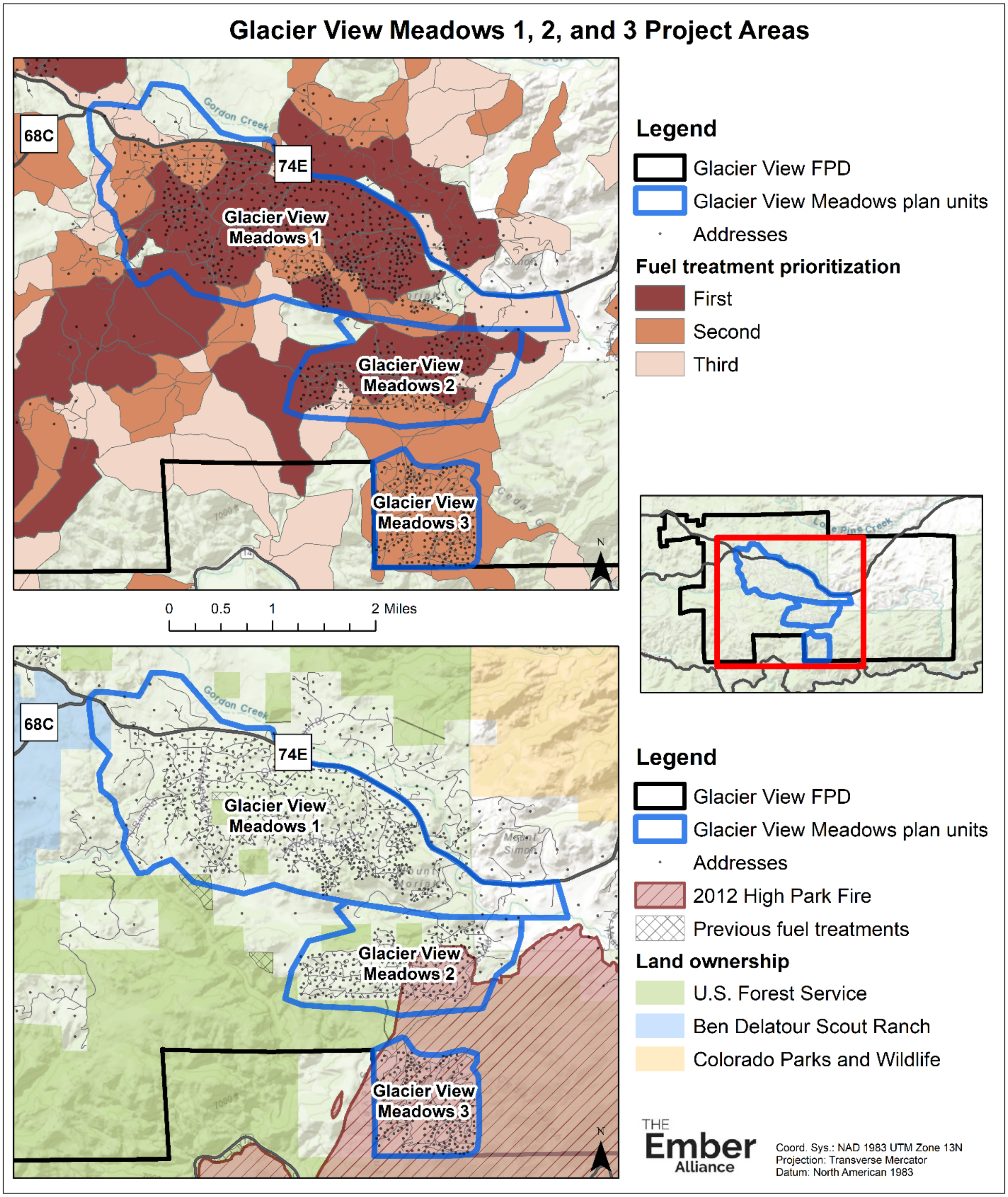


Figure 4.b.4. The GVFPD, local managers. and other partners identified Glacier View Meadows 1, 2, and 3 plan units as locations for immediate fuel reduction activities.

4.c. Roadway Fuel Treatment Recommendations

Effective Treatment Design

The primary objective within fuel treatments is to dramatically reduce fuels to create potentially survivable conditions along roadways during wildfires to allow for safer evacuation. Treatments can follow principles of ecological restoration, but guidelines for shaded fuelbreaks (Dennis 2005) or even complete removal of trees is sometimes the most appropriate approach, especially in evacuation pinch points. General guidelines for creating and maintaining roadway fuel treatments are provided below. **Table 4.c.1** includes pictures of roadways from GVFPD with suggestions for improvement.

- Coordinate with your HOA, Larimer County Road & Bridge, and the Colorado Department of Transportation to learn about regulations and opportunities to mitigate hazards along roadways in your community.
- The width of an effective roadway fuel treatments (distance to the left and right of a road) is dependent on slope, forest type, stand density, and the amount and arrangement of fuels. CSFS recommends that treatments extend 150 to 240 feet off the downhill side of the road and 100 to 150 feet off the uphill side (**Figure 4.c.1**). Wider treatments are necessary on the downhill side on steeper slopes due to the exacerbating effect of slope on fire intensity when fires travel uphill (Dennis 2005; **Table 4.c.2**).
- Eliminate ladder fuels by removing seedlings, sapling, and tall shrubs to reduce the risk of torching. Prune branches on remaining trees to at least 10 feet.
- Facilitate fire engine access by removing trees along narrow driveways so the horizontal clearance is at least 20 feet. Prune low-hanging branches of remaining trees so the unobstructed vertical clearance is at least 13 feet and 6 inches.
- Increase the spacing between tree crowns to decrease the risk of active crown fire. Remove trees to create at least 15-foot crown spacing on flat ground. Wider spacing is required on steeper ground due to the exacerbating impact of slopes on fire behavior (**Table 4.b.1**).
- Remove trees that are leaning over roads and all dead trees near roads that could fall and block access during a wildfire.
- Reduce surface fuels to decrease fire intensity and flame lengths. Thinning operations produce significant amounts of slash, and rearranging fuels from tree crowns to the surface without reducing the overall fuel load will rarely achieve fuel reduction objectives. Slash decomposes very slowly in Colorado and proper disposal is essential. See **Section 4.d, Slash Management** for guidance on slash management.
- Reduce the height of flashy fuels every year by burning or mowing grasses that are close to the road.
- Strategically place treatments to provide tactical opportunities for firefighters, increase the chance of survivable conditions along high-use roadways, and facilitate greater firefighter access to properties.
- Mitigate potential impacts of tree removal on soil compaction and erosion when treatments occur near streams and riparian ecosystems. The Colorado State Forest Service recommends streamside management zones of at least 50 feet (CSFS 2010).
- Commit to monitoring and maintenance of fuel treatments. Benefits of fuel treatments are transient and decrease overtime, with treatment "lifespan" depending on forest type, topography, rates of seedling regeneration (which is often influenced by precipitation), and the number of trees removed during treatments.
- Monitor treatments for invasive, weedy plant species that might require control after forest treatments.

- Take pictures of the treatment before and after to help evaluate effectiveness and monitor changes over time (see **Figure 3.a.3** for an example of repeat photographs pre- and post-treatment).

Thinning operations often increase surface fuel loads and can fail to achieve fire mitigation objectives if fuels created by the harvest activities (also known as slash) are not addressed (Agee and Skinner 2005). See **Section 4.d. Slash Management** for options to mitigate surface fuel loads created by fuel management.

Table 4.c.1. Examples of conditions occurring along roadways in the GVFPD and suggestions for improvement.

Roadway example	Suggestions for improvement
	• Remove trees to increase crown spacing. Effective crown spacing and fuel treatments depth from road depends on slope (**Table 4.b.1**; **Table 4.c.2**). • Remove limbs on remaining trees to above 10 feet. • Remove small trees and shrubs that could act as ladder fuels. • Ensure clear, reflective road signs are visible. • Create space for emergency vehicles to turnaround.
	• Remove trees to increase crown spacing. Effective crown spacing and fuel treatments depth from road depends on slope (**Table 4.b.1**; **Table 4.c.2**). • Remove limbs on remaining trees to above 10 feet. • Remove small trees and shrubs that could act as ladder fuels. • Install mirrors on switchbacks to improve visibility. • Ensure clear, reflective road signs are visible. • Create space for emergency vehicles to turnaround.

- Remove trees to increase crown spacing. Effective crown spacing and fuel treatments depth from road depends on slope (**Table 4.b.1**; **Table 4.c.2**).
- Remove limbs on remaining trees to above 10 feet.
- Remove small trees and shrubs that could act as ladder fuels.
- Do not park alongside narrow roads in order to ensure enough horizontal clearance for emergency vehicles.

- Road is survivable due to mowed grass.
- Roads are flat and relatively wide, and driveways offers turnarounds for emergency vehicles.
- Continue mowing along the side of the road.
- Ensure clear, reflective road signs are visible.

- Driveway is likely survivable due to tree spacing and removal of lower limbs.
- Driveway is wide, flat, and offers turnarounds for emergency vehicles.
- Maintain vertical clearance and eliminate ladder fuels by limbing trees to above 10 feet as they regrow.
- Remove more trees to increase crown spacing to at least 10 feet along the road and within the home ignition zone.
- Ensure clear, reflective road signs are visible.

Table 4.c.2. Minimum fuel treatments width uphill and downhill from roads depend on the slope along the roadway[1]. Recommendations from the Colorado State Forest Service (Dennis 2005).

Percent slope (%)	Downhill distance (feet)	Uphill distance (feet)	Total fuel treatment width (feet)
0	150	150	300
10	165	140	305
20	180	130	310
30	195	120	315
40	210	110	320
50	225	100	325
60	240	100	340

[1]Measurements are from the toe of the fill for downhill distances and above the road cut for uphill distances. Distances are measured parallel to flat ground, not along the slope. See **Figure 4.c.1** for a visual representation of measurements for roadway fuel treatments.

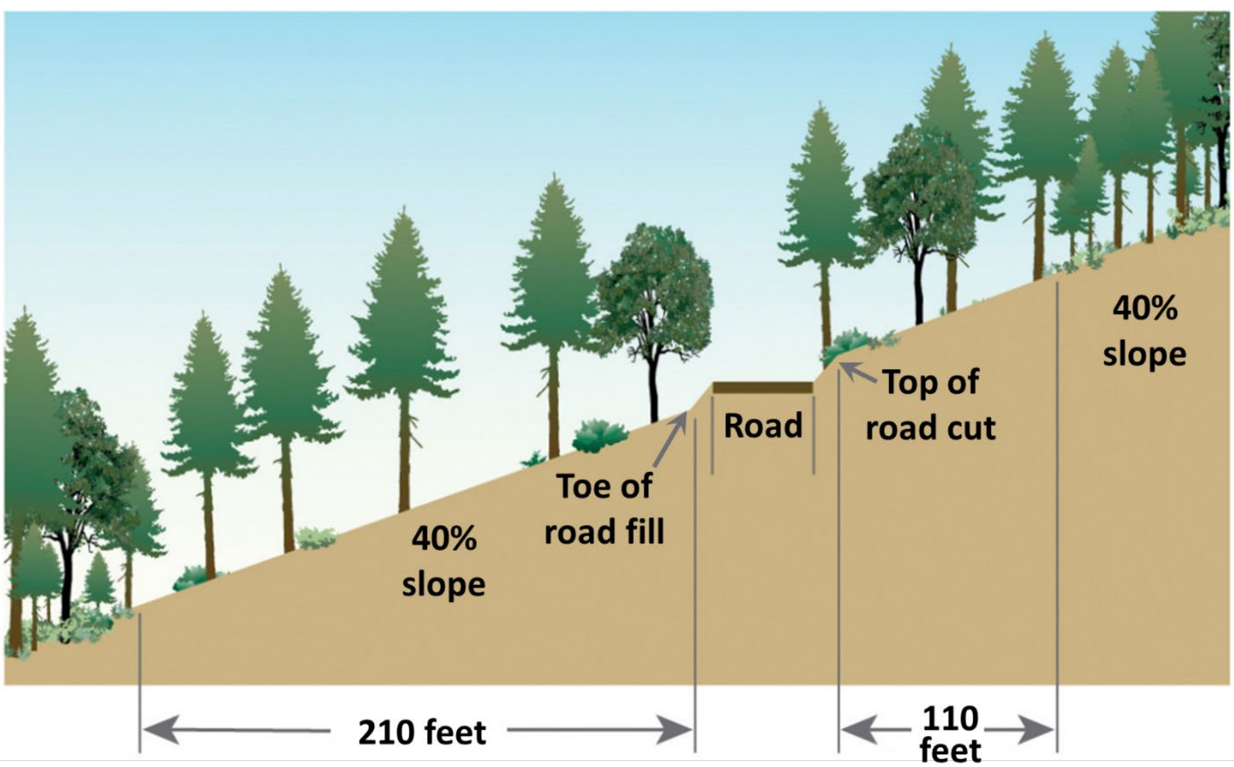


Figure 4.c.1. Fuel treatment width must be greater on the downhill side of the road due to the exacerbating impact of slope on fire intensity when fires travel uphill. Figure modified from Bennett et al. (2010).

Priority Locations

Proactive work to reduce fuel loads along roadways can increase the chance of survival for residents in the horrible instance that they become stranded in their vehicles during a wildfire. Clearing vegetation along narrow roads can also increase access for fire engines and create safer egress for firefighters. We located and prioritized potential locations for fuel treatments along roads, private drives, and driveways within and around the GVFPD (**Figure 4.c.2**). We prioritized treatments along roadway corridors based on predicted roadway survivability under 90th percentile fire weather conditions and evacuation congestion. It is important to reduce fuels along roadways where evacuation could proceed slowly due to congestion. See **Appendix B.2. Fuel Treatment Prioritization Methodology** for a full description of our prioritization methods.

Priority road locations were concentrated in the western portion of the GVFPD where there is a greater potential for extreme fire behavior due to fuel types and high to extreme evacuation congestion due to housing density and configuration of the road networks. (**Figure 4.c.2**). We identified 6.7 miles of first priority locations for roadside fuel treatment, including portions of County Road 68C, County Road 74E, Green Mountain Drive, and Iron Mountain Drive (**Table 4.c.3**). Portions of North Rim Road were identified as first, second, and third priority treatment areas. Emergency personnel and forestry professionals should visit these priority locations to assess current conditions and determine specific locations for fuel treatments. Our fire behavior analyses occurred at the scale of 0.2 acres (30 x 30 meters), so locations of priority treatments are approximate.

Table 4.c.3. Total length of first, second, and third priority roads, private drives, and driveways for roadside fuel treatments within the GVFPD, and the names of roads with at least 0.25 miles identified as a priority location. Roads are ordered by the length of their prioritized segments.

Treatment priority	First priority	Second priority	Third priority
Total length of road segments	6.7 miles	13.0 miles	5.2 miles
Road names	County Road 74E Green Mountain Drive Iron Mountain Drive County Road 68C Montcalm Drive Mount Champion Drive North Rim Road Mount Massive Drive	North Rim Road Green Mountain Drive Springmeadow Way Manhead Mountain Drive Hewlett Gulch Road Lone Pine Creek Drive Montcalm Drive Le Conte Drive Eiger Road Cucharas Mountain Drive Meadow Mountain Drive Bald Mountain Drive Crestone Way Mount Champion Drive Haystack Drive Mount Simon Drive Turkey Roost Drive	North Rim Road Chimney Road Drive Whispering Pines Road Castle Mountain Drive

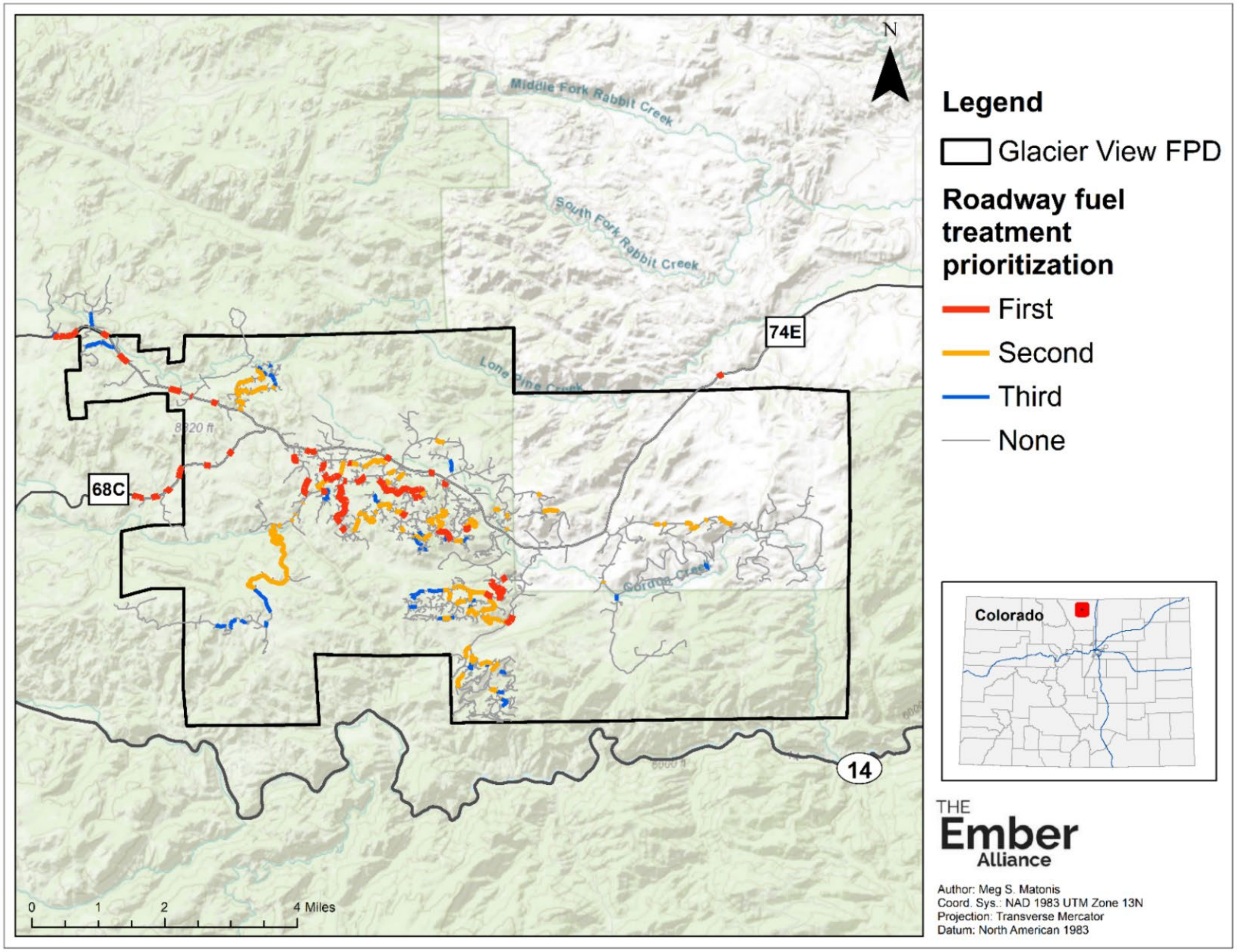


Figure 4.c.2. Priority locations for fuel treatments along roadways and driveways based on potential fire behavior and evacuation congestion. Our fire behavior analyses occurred at the scale of 0.2 acres (30 x 30 meters), so locations of priority treatments are approximate. See **Appendix B.2. Fuel Treatment Prioritization Methodology** for a full description of our prioritization methods. An interactive map with roadway fuel treatment prioritization is available online at https://experience.arcgis.com/experience/225f72cc029c4e37a2acbdefc60b2140/page/Treatments/.

4.d. Slash Management

Thinning, harvesting, or other forest management operations often increase surface fuel loads and can fail to achieve fire mitigation objectives if fuels created by the harvest activities (also known as slash) are not addressed (Agee and Skinner 2005). Slash can include small trees, limbs, bark, and treetops. Slash management is a critical step in the forest management process, and it is unwise, ineffective, and even dangerous to conduct poor-quality fuels treatments that fail to reduce canopy fuels, result in increased surface fuel loads, and do not receive maintenance treatments. Such treatments can lead to a false sense of security among residents and fire suppression personnel (Dennis 2005), and they divert limited funds away from more effective, strategic projects.

Leaving untreated slash within roadway fuel treatments is particularly counterproductive. The risk of active crown fire might be lower after a thinning operation, but untreated slash in fuel treatments can burn at high intensities and endanger the lives of residents stuck on roadways during a wildfire. Slash is easier and cheaper to manage along roadways due to access, and roads can serve as highly effective holding features for controlled burning of grass in the spring and fall and pile burning in the winter.

Slash removal in this part of Colorado is quite difficult due to limited biomass and timber industries. Methods for managing slash come with different benefits and challenges (**Table 4.d.1**). Lop-and-scatter and mastication are common methods; however, these approaches do not remove surface fuels from the site, they only rearrange them. It can take a decade or more for slash to decompose to a point where it no longer poses a significant fire hazard. Broadcast prescribed burning and pile burning are more effective at removing surface fuels.

Broadcast Prescribed Burning

Broadcast prescribed burning is the most effective method to manage biomass, generate healthy forest conditions, and reduce wildfire risk. Prescribed burning mimics naturally occurring wildfire, can treat hundreds of acres at a time, consumes much of the surface fuel, and is relatively cost-effective (Prichard et al. 2020; Fulé and other 2012). Prescribed burning can be conducted safely by highly qualified individuals operating under a carefully constructed burn plan. It is extremely uncommon for prescribed burns to escape containment lines (Weir et al. 2019), and when they do, the wildland fire community soberly reviews those escapes to produce lessons learned and make improvements (Dether 2005). Unfortunately, one example is the escape of the Elkhorn Prescribed Burn. This experience has understandably created fear amongst some members of the public. The prescribed burn community has taken lessons away from the Elk Fire which will reduce the

Prescribed burning can remove surface fuels and ladder fuels and return ecological processes to frequent-fire ecosystems. Firefighters who plan and implement burns must hold rigorous certifications as set by the National Wildfire Coordinating Group (photo credit: Daniel Godwin, The Ember Alliance).

likelihood of future escapes (CO Department of Public Safety 2020). Life safety is a top consideration when developing and conducting prescribed burns.

Agencies have frequently and successfully conducted prescribed burns in WUI areas (Hunter et al. 2007). Where appropriate, it does still need to be a tool to reduce wildfire risks at a landscape scale due to areas of inaccessibility, cost per acre, and the benefits to fire-adapted ecosystems including wildlife habitat (McIver et al. 2013). Prescribed burns can reduce property damage during wildfires because they are so effective at altering forest fuel loads (Loomis et al. 2019).

Broadcast burning is carefully regulated in Colorado by the Division of Fire Prevention and Control (DFPC), the Colorado Department of Public Health and Environment, local sheriff's offices, and fire departments as outlined in the *Colorado Prescribed Burning Act of 2013* and *2019 Colorado Prescribed Fire Planning and Implementation Policy Guide*. Firefighters who plan and conduct prescribed burns are highly qualified under national standards set forth by the National Wildfire Coordinating Group.

Pile Burning

Pile burning is different from broadcast burning; the overall complexity of pile burn operations is lower because fire activity is limited to discrete piles, and piles can be burned when snow covers the ground. Burning piles can produce embers, but the risk of these embers igniting spot fires or structures is low. Piles are typically burned on days with snowpack, high fuel moistures, and low to moderate wind speeds. Embers from burn piles travel shorter distances than embers from passive and active crown fires because the burning material is closer to the ground (Evans and Wright 2017). In the rare occurrence that a wildfire encounters unburned piles, unintended ignition of the pile can exacerbate fire behavior, as was observed during the 2010 Fourmile Canyon Fire in Colorado (Evans and Wright 2017).

Pile burning can be a safe and effective method to consume slash created by thinning operations (photo credit: The Ember Alliance).

It is critical to properly construct piles either by hand or with machines and to burn them as soon as conditions allow (see the 2015 *Colorado pile construction guide* from the DFPC and CSFS for guidance). Burning older piles is less effective and does not consume as much material because piles become compact and lose fine fuels over time (Wright et al. 2019). Mitigation measures, such as raking the burnt soil and seeding native plants, are sometimes warranted after pile burning if the soil was completely sterilized by extreme heat or if invasive species are prevalent in the area (Miller 2015). The Ember Alliance offers pile building and pile burning workshops, if this support is desired.

Individuals must apply for smoke permits from the Colorado Department of Public Health and Environment to burn piles and apply for open burn permits from the Larimer County Department of Health and Environment. In Larimer County, pile burning above 6,000 feet in elevation can only occur between October 1st and May 1st, when winds are less than 10 mph, and there are at least 3 inches of snow on the ground.

DFPC administers a certified burner program that provides civil liability protection to individuals planning and leading burns if smoke or flames cause damage. The burn must have been properly planned, approved, and executed to receive liability protection. The rigorous certification program requires individuals to complete 32-hours of training, pass an exam, lead at least three pile burns, complete a task book, and comply with all legal requirements for pile burning in Colorado.

Alternative Methods

There are communities in Glacier View that currently do not allow the use of burning as a tool to remove slash. A discussion of challenges unique to Glacier View can be found in **Section 3.d** and **Table 4.d.1** describes alternate methods. Other slash removal options frequently leave materials behind so they are not as highly recommended, but they are good options when burning is not permitted.

Table 4.d.1. Several methods are available to remove slash created by forest thinning, each with their own benefits and challenges.

Method	Description	Benefits	Challenges
Broadcast prescribed burning	Broadcast prescribed burning is generally the most effective method to manage slash. Prescribed burning mimics naturally occurring wildfire, can treat hundreds of acres at a time, consumes the surface fuel, and is relatively cost-effective (Prichard et al. 2020; Fulé et al. 2012). Broadcast burning is regulated in Colorado by the Division of Fire Prevention and Control, Department of Public Health and Environment, local sheriff's offices, and fire departments as outlined in the *2019 Colorado Prescribed Fire Planning and Implementation Policy Guide*.	Extremely effective at reducing surface, ladder, and canopy fuel loads (Prichard et al. 2020; Fulé and other 2012). Can restore ecosystem function in frequent-fire forests (McIver et al. 2013; Addington et al. 2018). Generally cheaper than mechanical treatments (Prichard et al. 2020). Can be safely and successfully conducted with proper planning and implementation by qualified firefighters. Can reduce property damage during wildfires by effectively reducing fuel loads (Loomis et al. 2019).	Requires careful planning and tactical decisions to prevent smoke from impacting sensitive populations and roadways. Public concerns about risk from flames, embers, and smoke. Limited opportunities to conduct burns under appropriate fire weather conditions. Limited resource availability to conduct burns during the wildfire season.
Pile burning	Pile burning involves placing, laying, heaping, or stacking slash into piles that are then ignited to consume the material. Piles can be constructed by hand or with mechanical equipment. See the 2015 *Colorado pile construction guide* for guidance on planning, constructing, and burning piles. See regulations for pile burning on the burn permit website for the Larimer County Department of Health and Environment.	Reduces surface fuel loads. Generally cheaper than removing material from the site. Lower complexity than broadcast prescribed burning because fire activity is limited to discrete piles and burns can be conducted when snow covers the ground. Can be safe and successful with proper planning and implementation.	Old and improperly constructed piles can be difficult to ignite and experience poor consumption. Unburnt slash piles can become a hazard during wildfires, especially if loose logs catch fire and roll down slopes. Limited opportunities to conduct burns because of requirements for snowpack and wind ventilation. In Glacier View Meadows, HOA regulations currently prevent pile burning.

Air curtain burner	Air curtain burners are machines that burn woody material cleanly in contained space. They typically consist of a box or trench into which slash is loaded and ignited. A strong fan blows a curtain of air down and over the burning material in a way that keeps oxygen flowing through the fire and keeps smoke from escaping out the top. Carbon from the smoke is filtered out of the air and kept inside the box.	Air curtain burners can be used under a much wider range of conditions and locations than pile burning or broadcast burning and can be contained and extinguished quickly and easily. They produce significantly less smoke than open burns and can be placed in accessible locations in the WUI. Air curtain burners can burn more kinds of slash than pile burning, including green wood, lumber, and general yard waste. They can be an acceptable form of burning slash where there is not social license for pile or broadcast burning. Ash from the burner can be redistributed and return nutrients to the ground.	Air curtain burners are expensive to obtain and require professionals to operate them. Slash material needs to be transported from locations throughout the community to where the burner is located. If the ash is not distributed, it won't return the nutrients to the ground.
Community slash piles	Residents take slash from their property to a designated location that is managed by the community. The community manages the slash for the residents via pile burning or chipping.	Residents are not responsible for burning or chipping their own material. It immediately reduces the fuel loading on their properties. If the material is chipped or burned, it can be redistributed to the community as mulch or ash to return the nutrients to the ground.	The success of this is dependent on the managers of the community slash piles to properly burn the piles. The community piles must have a plan to be burned. If they are left in the community, they can pose a fire risk. If the material is not distributed, it won't return the nutrients to the ground.

Lop-and-scatter	Lopping involves cutting limbs, branches, treetops, smaller-diameter trees, or other woody plant residue into shorter lengths, and scattering involves spreading lopped slash so it lies evenly and close to the ground. Cut into pieces less than 24 inches long. This method is better suited to areas with low slash accumulations. **Lop-and-scatter should not be used in defensible space zones 1 or 2 or along roadways.**	Reduces the height of slash relative to untreated slash, therefore increasing the distance between surface and canopy fuels (but not as effectively as broadcast prescribed burning or pile burning). Breaks slash up into smaller pieces and distributes it closer to the forest floor, which can encourage faster decomposition.	Does not remove surface fuels from the site, it just restructures the way fuels are arranged. Can contribute to more intense fire behavior by not addressing increased surface fuel loads created by thinning (Hunter et al. 2017; Agee and Skinner 2005).
Mastication or chipping	Mastication involves using specialized machines like a tow-behind chipper or a hydro-ax to grind up standing saplings and shrubs and cut slash into medium-sized chips. Chipping involves processing slash through a mechanical chipper to break slash into small chips or shreds. Operators should follow mastication guidance.	Reduces the height of slash relative to untreated slash, therefore increasing the distance between surface and canopy fuels (but not as effectively as broadcast prescribed burning or pile burning). Breaks slash up into smaller pieces and distributes it closer to the forest floor, which can encourage faster decomposition. Can produce landscape mulch to be used offsite. Can reduce fire intensity and slow rates of spread, enhancing suppression efficacy (Kreye et al. 2014). If chips are removed from the site, this is a very effective tool to completely remove fuels from a location.	Does not remove surface fuels from the site, it just restructures the way fuels are arranged. Masticated and chipped fuels are unlike natural surface fuels in terms of their shape, depth, and highly compact nature (Kreye et al. 2014). Masticated and chipped fuels can impede plant regeneration, particularly when the depth of masticated and chipped fuels exceeds 4 inches (Jain et al. 2018). When chips or masticated materials are not removed, smoldering fires in masticated and chipped fuels can be difficult to suppress, produce abundant smoke, kill tree roots, and lead to spot fires if high winds reignite masticated fuels and blow them across containment lines (Kreye et al. 2014).

Utilizing material for firewood	Wood leftover from thinning operations can be used as firewood for home fireplaces or outdoor fire pits. Firewood needs to be "seasoned" before use, which involves splitting the wood into usable logs and drying it for 6-18 months so it burns cleanly and doesn't produce much smoke. **Firewood that is aging or ready for use should not be stored in defensible space zones 1 or 2.**	Can be an inexpensive way to reduce fuel loading on the property. Locally sourced firewood reduces the chances of introducing non-native insects and diseases to the ecosystem that cause outbreaks and damage forest health. Homeowners can often manage preparing firewood themselves.	Improperly stored firewood can create hazardous conditions near structures during a wildfire event. While firewood is being stored, it does not reduce the fuel load of the land. Firewood does not use all the woody material from felled trees. Needles, bark, and small branches need to be dealt with separately.
Hauling material away	Hauling material away involves loading the thinned fuels on trucks and removing them completely from the site. The materials can be taken to mills to be turned into boards, taken to yard waste disposal sites where it is composted and turned into garden soil or mulch, or taken to a landfill. Wherever it is taken, the material is completely removed from the site.	This is an extremely effective way to reduce fuel loading. The fuel is completely removed, not just rearranged. The fuel load decrease is immediate. There is no waiting period for ground fuels to decompose or become unburnable.	Not feasible in areas far from roads. Can spread insects like mountain pine beetles and emerald ash borer to other locations. This can be expensive and difficult depending on the size and location of the project.
Mowing / grazing	Mowing involves using equipment or grazing animals to trim the height of grasses and forbs. Some equipment can mow down shrubs and small saplings. Mowing is primarily used to reduce flashy fuels in defensible space zones 1 and 2 and along roadways.	Can decrease flame length by reducing the height and volume of fine flashy fuels (Harper 2011). Can stimulate the regeneration and growth of some native plants.	Does not address woody surface fuels. Labor intensive and cannot be implemented across large areas or in areas with poor access. Requires annual maintenance. Can spread invasive plant species, decrease the regeneration of some native plants, and cause soil compaction (Kerns et al. 2011).

4.e. The Future of the CWPP and Implementation Plan

The CSFS requires CWPPs to be updated on a regular basis. It is recommended to update them every 5 years, at minimum. CWPPs greater than 10 years old are outdated and can exclude communities from successfully applying for competitive funding opportunities.

The update to this plan can either be a preface to this document or a new document that integrates with this one. The update to this plan must include:

- A description of progress made since the CWPP was created
- A description of demographic changes in the community and other important infrastructure changes.
- Identification of new risks in the community.
- Updated risk analysis if major changes have happened between revisions.
- Updated and prioritized projects for the community with maps and descriptions

The suggested review process by CSFS involves:

- Reviewing the existing CWPP
- Engaging stakeholders that have a vested interest in the plan
- Hosting collaborative meetings
- Documenting completed projects and demographic and landscape changes
- Developing updated wildfire risk reduction priorities
- Updating maps
- Distributing updated drafts to key stakeholders for review and input prior to final approval
- Finalizing with core team signatures and submit to CSFS State Office

5. Contact Information

As you embark on efforts to mitigate wildfire risk on your property and organize coordinated action with your neighbors, the following organizations can provide useful guidance and information on available resources. If you live in a subdivision with a Homeowners Association, you can contact them to help you organize action in your neighborhood. The contact information below is current as of April 2022.

Fire Protection District and Other Emergency Managers

- Glacier View Fire Protection District – Chief Dan Knox; gvfdchief1@gmail.com; Warren Jones; gvfd.cwpp@gmail.com
- GVFD Website – https://www.glacierviewfire.gov/
- Larimer County Sherriff's Office of Emergency Services – Derek Rosenquist; rosenqdc@co.larimer.co.us

Land Managers and Other Stakeholders that Support Wildfire Mitigation

- Coalition for the Poudre River Watershed – Daniel Bowker; daniel@poudrewatershed.org
- Colorado State Forest Service – Max Erickson; max.erickson@colostate.edu
- Larimer Conservation District – Gretchen Reuning; gretchen@larimercd.org
- Larimer County Conservation Corps – Maelly Oropeza; oropezma@co.larimer.co.us
- U.S. Forest Service, Canyon Lakes Ranger District – (970) 295-6700 / visitarp@usda.gov
- Ben Delatour Scout Ranch – Bob Sturtevant; robert.sturtevant@colostate.edu
- University of Denver Mountain Campus – John Parker; john.parker@du.edu

6. Glossary

20-foot wind speed: The rate of sustained wind over a 10-minute period at 20 feet above the dominant vegetation. The wind adjustment factor to convert surface winds to 20-foot wind speeds depends on the type and density of surface fuels slowing down windspeeds closer to the ground (NWCG 2021).

Active crown fire: Fire in which a solid flame develops in the crowns of trees and advances from tree crown to tree crown independently of surface fire spread (NWCG 2018b).

ArcCASPER: An intelligent capacity-aware evacuation routing algorithm used in the geospatial information system mapping program ArcMap to model evacuation times and congestion based on roadway capacity, road speed, number of cars evacuating per address, and the relationship between roadways congestion and reduction in travel speed (Shahabi and Wilson 2014).

Basal area: Cross sectional area of a tree measured at breast height (4.5 feet above the ground). Used as a method of measuring the density of a forest stand in units such as ft^2/acre (USFS 2021b).

Broadcast prescribed burning (aka, prescribed burn, controlled burn): A wildland fire originating from a planned ignition in accordance with applicable laws, policies, and regulations to meet specific objectives (NWCG 2018b).

Canopy base height (CBH): The average height from the ground to a forest stand's canopy bottom. CBH is the lowest height in a stand at which there is sufficient forest canopy fuel to propagate fire vertically into the canopy. Ladder fuels such as lichen, dead branches, and small trees are incorporated into measurements of CBH. Forests with lower canopy base heights have a higher risk of torching (NWCG 2019).

Canopy cover: The ground area covered by the crowns of all trees in an area as delimited by the vertical projection of their outermost crown perimeters (NWCG 2019).

Canopy fuels: The stratum of fuels containing the crowns of the tallest vegetation (living or dead), usually above 20 feet (NWCG 2018b).

Canopy: The more or less continuous cover of branches and foliage formed collectively by adjacent tree crowns (USFS 2021b).

Canyon: A long, deep, very steep-sided topographic feature primarily cut into bedrock and often with a perennial stream at the bottom (NRCS 2017).

Chain: Chains are commonly used in forestry and fire management as a measure of distance. 1 chain is equivalent to 66 feet. Chains were used for measurements in the initial public land survey of the U.S. in the mid-1800s.

Chute: A steep V-shaped drainage that is not as deep as a canyon but is steeper than a draw. Normal upslope air flow is funneled through a chute and increases in speed, causing upslope preheating from convective heat, thereby exacerbating fire behavior (NWCG 2008).

Community Wildfire Protection Plan (CWPP): A plan developed in the collaborative framework established by the Wildland Fire Leadership Council and agreed to by state, Tribal, and local governments, local fire departments, other stakeholders, and federal land management agencies in the vicinity of the planning area. CWPPs identify and prioritize areas for hazardous fuel reduction treatments, recommend the types and methods of treatment on Federal and non-Federal land that will protect one or more at-risk communities and essential infrastructure, and recommend measures to reduce structural ignitability throughout the at-risk community. A CWPP may address issues such as wildfire response, hazard mitigation, community preparedness, and structure protection (NWCG 2018b).

Conduction: A type of heat transfer that occurs when objects of different temperatures contact each other directly and heat conducts from the warmer object to the cooler one until their temperatures equalize. During wildfires, flames in contact with a metal structure rapidly conduct heat into the rest of the structure. Wood is a poor conductor of heat, as illustrated by the fact that a wooden handle on a hot frying pan remains cool enough to be held by bare hands. Conduction has a limited effect on the spread of fires in wildland fuels.

Convection: A type of heat transfer that occurs when a fluid, such as air or a liquid, is heated and travels away from the source, carrying heat along with it. Air around and above a wildfire expands as it is heated, causing it to become less dense and rise into a hot convection column. Cooler air flows in to replace the rising gases, and in some cases, this inflow of air creates local winds that further fan the flames. Hot convective gases move up slope and dry out fuels ahead of the flaming front, lowering their ignition temperature and increasing their susceptibility to ignition and fire spread. Homes located at the top of a slope can become preheated by convective heat transfer. Convection columns from wildfires carry sparks and embers aloft.

Crown (aka, tree crown): Upper part of a tree, including the branches and foliage (USFS 2021b).

Defensible space: The area around a building where vegetation, debris, and other types of combustible fuels have been treated, cleared, or reduced to slow the spread of fire and reduce exposure to radiant heat and direct flame. It is encouraged that residents develop defensible space so that during a wildfire their home can stand alone without relying upon limited firefighter resources due to the great reduction in hazards they have undertaken. The Colorado State Forest Service defines three zones of defensible space: zone 1 (0 to 30 feet from a home), zone 2 (30 to 100 feet from a home), and zone 3 (greater than 100 feet from a home). Some organizations further divide zone 1 into zone 1a (0 to 5 feet from a home) (CSFS 2021).

Direct attack: Any treatment applied directly to burning fuel such as wetting, smothering, or chemically quenching the fire or by physically separating the burning from unburned fuel (NWCG 2018b).

Draws: Topographic features created by a small, natural watercourse cutting into unconsolidated materials. Draws generally have a broader floor and more gently sloping sides than a ravine or gulch (NRCS 2017).

Ecological restoration: The process of assisting the recovery of an ecosystem that has been damaged, degraded, or destroyed (SER 2004). In ponderosa pine and dry mixed-conifer forests of the Colorado Front Range, ecological restoration involves transforming dense forests into a mosaic of single trees, clumps of trees, and meadows similar to historic forests that were maintained by wildfires and very resilient to them (Addington et al. 2018).

Ember: Small, hot, and carbonaceous particles. The term "firebrand" is also used to connote a small, hot, and carbonaceous particle that is airborne and carried for some distance in an airstream (Babrauskas, 2018).

Ember cast: The process of embers/firebrands/flaming sparks being transported downwind beyond the main fire and starting new spot fires and/or igniting structures. Short-range ember cast is when embers are carried by surface winds and long-range ember cast is when embers are carried high into the convection column and fall out downwind beyond the main fire. The number of embers reaching an area decreases exponentially with distance traveled, and the likelihood of structure ignition increases with the number of embers landing on receptive fuels (Caton et al., 2016). The distance used to differentiate short-range and long-range ember cast varies among sources. NWCG (2018b) classifies short-range ember cast as embers that travel less than 0.25 miles and long-range ember cast as embers that travel more than 0.25 miles, whereas Beverly et al., (2010) use a threshold of 0.06 miles. We use the Beverly et al., (2010) definition in this CWPP.

Fire behavior: The manner in which a fire reacts to the influences of fuel, weather, and topography. Characteristics of fire behavior include rate of spread, fire intensity, fire severity, and fire behavior category (NWCG 2018b).

Fire history: A general term referring to the historic fire occurrence in a specific geographic area (NWCG 2018b).

Fire intensity (aka, fireline intensity): (1) The product of the available heat of combustion per unit of ground and the rate of spread of the fire, interpreted as the heat released per unit of time for each unit length of fire edge, or (2) the rate of heat release per unit time per unit length of fire front (NWCG 2018b).

Fire regime: Description of the patterns of fire occurrences, frequency, size, and severity in a specific geographic area or ecosystem. A fire regime is a generalization based on fire histories at individual sites. Fire regimes can often be described as cycles because some parts of the histories usually get repeated, and the repetitions can be counted and measured, such as fire return interval (NWCG 2018b).

Fire severity. Degree to which a site has been altered or disrupted by fire; loosely, a product of fire intensity and residence time (NWCG 2018b). Fire severity is determined by visually inspecting or measuring the effects that wildfire has on soil, plants, fuel, and watersheds. Fire severity is often classified as low-severity (less than 20% of overstory trees killed) and high severity (more than 70% of overstory trees kills). Moderate-severity or intermediate fire severity falls between these two extremes (Agee 1996b). Specific cutoffs for fire severity classifications differ among researchers. For example, Sherriff et al. (2014) define high-severity fires as those killing more than 80% of overstory trees.

Fire weather conditions: Weather conditions that influence fire ignition, behavior, and suppression, for example, wind speed, wind direction, temperature, relative humidity, and fuel moisture (NWCG 2018b).

Firebreak: A natural or constructed barrier where all vegetation and organic matter have been removed down to bare mineral soil. Firebreaks are used to stop or slow wildfires or to provide a control line from which to work (NWCG 2018b; Bennett et al. 2010).

FireFamilyPlus: A software application that provides summaries of fire weather, fire danger, and climatology for one or more weather stations extracted from the National Interagency Fire Management Integrated Database (NWCG 2018b).

Fireline: (1) The part of a containment or control line that is scraped or dug to mineral soil, or (2) the area within or adjacent to the perimeter of an uncontrolled wildfire of any size in which action is being taken to control fire (NWCG 2018b).

Flame length: The distance between the flame tip and the midpoint of the flame depth at the base of the flame (generally the ground surface). Flame length is measured on an angle when the flames are tilted due to effects of wind and slope. Flame length is an indicator of fire intensity (NWCG 2018b).

FlamMap: A fire analysis desktop application that can simulate potential fire behavior and spread under constant environmental conditions (weather and fuel moisture) (Finney 2006). FlamMap is one of the most common models used by land managers to assist with fuel treatment prioritization, and it is often used by fire behavior analysts during wildfire incidents.

Fuel model: A stylized set of fuel bed characteristics used as input for a variety of wildfire modeling applications to predict fire behavior (Scott and Burgan 2005).

Fuel reduction: Manipulation, combustion, or removal of fuels to reduce the likelihood of ignition and/or to lessen potential damage from wildfires and resistance to control (NWCG 2018b).

Fuelbreak: A natural or manmade change in fuel characteristics which affects fire behavior so that fires burning into them can be more readily controlled. Fuelbreaks differ from firebreaks due to the continued presence of vegetation and organic soil. Trees in shaded fuelbreaks are thinned and pruned to reduce the fire potential but enough trees are retained to make a less favorable microclimate for surface fires (NWCG 2018b).

Fuels mitigation / management: The act or practice of controlling flammability and reducing resistance to control of wildland fuels through mechanical, chemical, biological, or manual means, or by fire, in support of land management objectives (NWCG 2018b).

Fuels: Any combustible material, most notably vegetation in the context of wildfires, but also including petroleum-based products, homes, and other man-made materials that might combust during a wildfire in the wildland-urban interface. Wildland fuels are described as 1-, 10-, 100-, and 1000-hour fuels. One-hour fuels are dead vegetation less than 0.25 inch in diameter (e.g., dead grass), ten-hour fuels are dead vegetation 0.25 inch to 1 inch in diameter (e.g., leaf litter and pine needles), one hundred-hour fuels are dead vegetation 1 inch to 3 inches in diameter (e.g., fine branches), and one thousand-hour fuels are dead vegetation 3 inches to 8 inches in diameter (e.g., large branches). Fuels with larger diameters have a smaller surface area to volume ratio and take more time to dry out or become wetter as relative humidity in the air changes (NWCG 2018b).

Handcrews: A number of individuals that have been organized and trained and are supervised principally for operational assignments on an incident (NWCG 2018b).

Handline: Fireline constructed with hand tools (NWCG 2018b).

Hazards: Any real or potential condition that can cause injury, illness, or death of personnel, or damage to, or loss of equipment or property (NWCG 2018b).

Home hardening: Steps taken to improve the chance of a home and other structures withstanding ignition by radiant and convective heat and direct contact with flames or embers. Home hardening involves reducing structure ignitability by changing building materials, installation techniques, and structural characteristics of a home (California Safe Council 2020). A home can never be made fireproof, but home hardening practices in conjunction with creating defensible space increases the chance that a home will survive a wildfire.

Home ignition zone (HIZ): The characteristics of a home and its immediate surroundings within 100 feet of structures. Conditions in the HIZ principally determine home ignition potential from radiant heat, convective heat, and embercast (NWCG 2018b).

Ignition-resistant building materials: Materials that resist ignition or sustained flaming combustion. Materials designated ignition-resistant have passed a standard test that evaluates flame spread on the material (Quarles 2019; Quarles and Pohl 2018).

Incident Response Pocket Guide (IRPG): Document that establishes standards for wildland fire incident response. The guide provides critical information on operational engagement, risk management, all hazard response, and aviation management. It provides a collection of best practices that have evolved over time within the wildland fire service (National Wildfire Coordinating Group 2018a).

Indirect attack A method of suppression in which the control line is located some considerable distance away from the fire's active edge. Generally done in the case of a fast-spreading or high-intensity fire and to utilize natural or constructed firebreaks or fuelbreaks and favorable breaks in the topography. The intervening fuel is usually backfired; but occasionally the main fire is allowed to burn to the line, depending on conditions (NWCG 2018b).

Initial attack: An aggressive action to put the fire out by the first resources to arrive, consistent with firefighter and public safety and values to be protected (NWCG 2018b).

Insurance Services Office (ISO) rating: ISO ratings are provided to fire departments and insurance companies to reflect how prepared a community is for fires in terms of local fire department capacity, water supply, and other factors (see more information online at https://www.isomitigation.com/ppc/fsrs/).

Ladder fuels: Fuels that provide vertical continuity between strata, thereby allowing fire to carry from surface fuels into the crowns of trees with relative ease. Ladder fuels help initiate torching and crowning and assure the continuation of crowning. Ladder fuels can include small trees, brush, and lower limbs of large trees (NWCG 2018b).

LANDFIRE: A national program spearheaded by the U.S. Department of the Interior and the U.S. Department of Agriculture to provide spatial products characterizing vegetation, fuels, fire regimes, and disturbances across the entire United States. LANDFIRE products serve as standardized inputs for fire behavior modeling. More information about the program is available online at https://www.landfire.gov/.

Lop-and-scatter: Cutting (lopping) branches, tops, and unwanted boles into shorter lengths and spreading that debris evenly over the ground such that resultant logging debris will lie close to the ground (NWCG 2018b).

Mastication: A slash management technique that involves using a machine to grind, chop, or shred vegetation into small pieces that then become surface fuel (Jain et al. 2018).

Mitigation actions: Actions that are implemented to reduce or eliminate (mitigate) risks to persons, property, or natural resources. These actions can be undertaken before and during a wildfire. Actions before a fire include fuel treatments, cvegetation modification in the home ignition zone, and structural changes to increase the chance a structure will survive a wildfire (aka, home hardening). Mitigation actions during a wildfire include mechanical and physical tasks, specific fire applications, and limited suppression actions, such as constructing firelines and creating "black lines" through the use of controlled burnouts to limit fire spread and behavior (NWCG 2018b).

Mosaic landscape: A heterogeneous area composed of different communities or a cluster of different ecosystems that are similar in function and origin in the landscape. It consists of 'patches' arranged in a 'matrix', where the patches are the different ecosystems and the matrix is how they are arranged over the land (Hansson and other 1995).

National Wildfire Coordinating Group (NWCG): An operational group established in 1976 through a Memorandum of Understanding between the U.S. Department of Agriculture and Department of the Interior to coordinate programs of the participating agencies to avoid wasteful duplication and to provide a means of constructively working together. NWCG provides a formalized system and agreed upon standards of training, equipment, aircraft, suppression priorities, and other operational areas. More information about NWCG is available online at https://www.nwcg.gov/.

Noncombustible building materials: Material of which no part will ignite or burn when subjected to fire or heat, even after exposure to moisture or the effects of age. Materials designated noncombustible have passed a standard test (Quarles 2019; Quarles and Pohl 2018).

Non-survivable road: Portions of roads adjacent to areas with predicted flame lengths greater than 8 feet under severe fire weather conditions. Potentially non-survivable flame lengths start at 8 feet according to the Haul Chart, which is a standard tool used by firefighters to relate flame lengths to tactical decisions (NWCG 2019). Drivers stopped or trapped on these roadways would have a low chance of surviving radiant heat from fires of this intensity. Non-survivable conditions are more common along roads that are lined with thick forests, particularly with trees that have limbs all the way to the ground and/or abundant saplings and seedlings.

Overstory: Layer of foliage in a forest canopy, particularly tall mature trees that rise above the shorter immature understory trees (USFS 2021b).

Passive crown fire: Fire that arises when surface fire ignites the crowns of trees or groups of trees (aka, torching). Torching trees reinforce the rate of spread, but passive crown fires travel along with surface fires. (NWCG 2018b).

Pile burning: Piling slash resulting from logging or fuel management activities into manageable piles that are subsequently burned during safe and approved burning conditions (NWCG 2018b).

Radiation: A method of heat transfer by short-wavelength energy through air (aka, infrared radiation). Surfaces that absorb radiant heat warm up and radiate additional short-wavelength energy themselves. Radiant heat is what you feel when sitting in front of a fireplace. Radiant heat preheats and dries fuels adjacent to the fire, which initiates combustion by lowering the fuel's ignition temperature. The amount of radiant heat received by fuels increases as the fire front approaches. Radiant heat is a major concern for the safety of wildland firefighters and can ignite homes without direct flame contact.

Rate of spread: The relative activity of a fire in extending its horizontal dimensions. It is expressed as rate of increase of the total perimeter of the fire, as rate of forward spread of the fire front, or as rate of increase in area, depending on the intended use of the information. Rate of spread is usually expressed in chains or acres per hour for a specific period in the fire's history (NWCG 2018b).

Ravine: Topographic features created by streams cutting into unconsolidated materials and that are narrow, steep-sided, and commonly V-shaped. Ravines are steeper than draws (NRCS 2017).

Remote Automatic Weather Stations (RAWS): A weather station that transmits weather observations via satellite to the Wildland Fire Management Information system (NWCG 2018b).

Risk: (1) The chance of fires starting as determined by the presence and activity of causative agents (e.g., lightning), (2) a chance of suffering harm or loss, or (3) a causative agent (NWCG 2018b).

Roadway fuel treatment: A natural or manmade change in fuel characteristics along a roadway which affects fire behavior so that fires burning into them can be more readily controlled, survivable conditions with shorter flame lengths are more likely during a wildfire, and firefighter access is enhanced (NWCG 2018b).

Saddle: A low point on a ridge or interfluve, generally a divide or pass between the heads of streams flowing in opposite directions. The presence of a saddle funnels airflow and increases windspeed, thereby exacerbating fire behavior (NRCS 2017).

Safety zones: An area cleared of flammable materials used by firefighters for escape in the event the line is outflanked or spot fires outside the control line render the line unsafe. In firing operations, crews progress so as to maintain a safety zone close at hand, allowing the fuels inside the control line to be consumed before going ahead. Safety zones may also be constructed as integral parts of fuelbreaks; they are greatly enlarged areas which can be used with relative safety by firefighters without the use of a fire shelter (NWCG 2018b).

Shaded fuelbreak: Fuel treatments in timbered areas where the trees on the break are thinned and pruned to reduce fire potential yet enough trees are retained to make a less favorable microclimate for surface fires (NWCG 2018b).

Slash: Debris resulting from natural events such as wind, fire, or snow breakage or from human activities such as road construction, logging, pruning, thinning, or brush cutting. Slash includes logs, bark, branches, stumps, treetops, and broken understory trees or brush (NWCG 2018b).

Smoldering combustion: The combined processes of dehydration, pyrolysis, solid oxidation, and scattered flaming combustion and glowing combustion, which occur after the flaming combustion phase of a fire; often characterized by large amounts of smoke consisting mainly of tars (NWCG 2018b).

Spot fire: Fire ignited outside the perimeter of the main fire by an ember (NWCG 2018b). Spot fires are particularly concerning because they can form a new flaming front, move in unanticipated directions, trap firefighters between two fires, and require additional firefighting resources to control.

Spotting: Behavior of a fire producing sparks or embers that are carried by the wind and start new fires beyond the zone of direct ignition by the main fire (NWCG 2018b).

Stand: An area of forest that possesses sufficient uniformity in species composition, age, size, structural configuration, and spatial arrangement to be distinguishable from adjacent areas (USFS 2021b).

Structure protection: The protection of homes or other structures from an active wildland fire (NWCG 2018b).

Structure triage: The process of inspecting and classifying structures according to their defensibility or non-defensibility, based on fire behavior, location, construction, and adjacent fuels. Structure triage involves a rapid assessment of a dwelling and its immediate surroundings to determine its potential to escape damage by an approaching wildland fire. Triage factors include the fuels and vegetation in the yard and adjacent to the structure, roof environment, decking and siding materials, prevailing winds, topography, etc. (NWCG 2018b). There are four categories used during structure triage: (1) defensible – prep and hold, (2) defensible – stand alone, (3) non-defensible – prep and leave, and (4) non-defensible – rescue drive-by. The most important feature differentiating defensible and non-defensible structures is the presence of an adequate safety zone for firefighters (NWCG 2018a). Firefighters conduct structure triage and identify defensible homes during wildfire incidents. Categorization of homes are not pre-determined; triage decisions depend on fire behavior and wind speed due to their influence on the size of safety zones needed to keep firefighters safe.

Suppression: The work and activity used to extinguish or limit wildland fire spread (NWCG 2018b).

Surface fire: Fire that burns fuels on the ground, which include dead branches, leaves, and low vegetation (NWCG 2018b).

Surface fuels: Fuels lying on or near the ground, consisting of leaf and needle litter, dead branch material, downed logs, bark, tree cones, and low stature living plants (NWCG 2018b).

Task book: A document listing the performance requirements (competencies and behaviors) for a position in a format that allows for the evaluation of individual (trainee) performance to determine if an individual is qualified in the position. Successful performance of tasks, as observed and recorded by a qualified evaluator, will result in a recommendation to the trainee's home unit that the individual be certified in the position (NWCG 2018b).

Torching: The burning of the foliage of a single tree or a small group of trees from the bottom up. Torching is the type of fire behavior that occurs during passive crown fires and can initiate active crown fires if tree canopies are close to each other (NWCG 2018b).

Values at risk: Aspects of a community or natural area considered valuable by an individual or community that could be negatively impacted by a wildfire or wildfire operations. These values can vary by community and include diverse characteristics such as homes, specific structures, water supply, power grids, natural and cultural resources, community infrastructure, and other economic, environmental, and social values (NWCG 2018b).

Watershed (aka, drainage basin or catchment): An area of land where all precipitation falling in that area drains to the same location in a creek, stream, or river. Smaller watersheds come together to create basins that drain into bays and oceans (National Ocean Service 2021).

Wildfire-resistant building materials: A general term used to describe a material and design feature that can reduce the vulnerability of a building to ignition from wind-blown embers or other wildfire exposures (Quarles 2019; Quarles and Pohl 2018).

Wildland-urban interface (WUI): Any area where the built environment meets wildfire-prone areas—places where wildland fire can move between natural vegetation and the built environment and result in negative impacts on the community (Forge 2018).

7. Index of Figures

8. References

Addington, R.N., Aplet, G.H., Battaglia, M.A., Briggs, J.S., Brown, P.M., 2018. Principles and practices for the restoration of ponderosa pine and dry mixed-conifer forests of the Colorado Front Range (General Technical Report No. RMRS-GTR-373). U.S. Department of Agriculture, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Agee, J.K., 1996a. The influence of forest structure on fire behavior, in: Proceedings of the 17th Annual Forest Vegetation Management Conference. Presented at the 17th Annual Forest Vegetation Management Conference; 16-18 January 1996; Redding, CA, University of California, Agriculture and Natural Resources, Berkely, CA, pp. 52–68.

Agee, J.K., 1996b. Fire Ecology of Pacific Northwest Forests, 2nd ed. Island Press, Washington, DC.

Agee, J.K., Skinner, C.N., 2005. Basic principles of forest fuel reduction treatments. Forest Ecology and Management 211, 83–96.

Avitt, A., 2021. Cameron Peak: Fighting fire together. U.S. Forest Service Feature Stories. https://www.fs.usda.gov/features/cameron-peak-fighting-fire-together

Babrauskas, V., 2018. Firebrands and embers, in: Manzello, S. (Ed.), Encyclopedia of Wildfires and Wildland-Urban Interface (WUI) Fires. Springer, Cham, Switzerland. https://doi.org/10.1007/978-3-319-51727-8_3-1.

Battaglia, M.A., Gannon, B., Brown, P.M., Fornwalt, P.J., Cheng, A.S., Huckaby, L.S., 2018. Changes in forest structure since 1860 in ponderosa pine dominated forests in the Colorado and Wyoming Front Range, USA. Forest Ecology and Management 422, 147–160.

Beloglazov, A., Almashor, M., Abebe, E., Richter, J., Steer, K.C.B., 2016. Simulation of wildfire evacuation with dynamic factors and model composition. Simulation Modelling Practice and Theory 60, 144–159. https://doi.org/10.1016/j.simpat.2015.10.002.

Bennett, M., Fitzgerald, S., Parker, B., Main, M., Perleberg, A., Schnepf, C., Mahoney, R., 2010. Reducing fire risk on your forest property (Pacific Northwest Extension Publication No. PNW 618). Oregon State University, University of Idaho, and Washington State University.

Beverly, J.L., Bothwell, P., Conner, J., Herd, E., 2010. Assessing the exposure of the built environment to potential ignition sources generated from vegetative fuel. International journal of wildland fire 19, 299–313.

Brenkert-Smith, H., Champ, P.A., Telligman, A.L., 2013. Understanding change: Wildfire in Larimer County, Colorado (Research Note No. RMRS-RN-58). U.S. Department of Agriculture, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Brown, K., 1994. Structure triage during wildland/urban interface/intermix fires: Strategic analysis of fire department operations. U.S. Fire Administration, National Fire Academy, Executive Fire Officer Program, Emmitsburg, MD.

CAL FIRE, 2019. Hardening your home [WWW Document]. California Natural Resources Agency, California Department of Forestry and Fire Protection. URL https://www.readyforwildfire.org/prepare-for-wildfire/get-ready/hardening-your-home/

California Fire Safe Council, 2020. Fire safety information for residents [WWW Document]. California Fire Safe Council. URL https://cafiresafecouncil.org/resources/fire-safety-information-for-residents/.

Case, S.R., 1995. The Poudre: A photo history, 1st ed. S.R. Case, Bellvue, CO.

Caton, S.E., Hakes, R.S.P., Gorham, D.J., Zhou, A., Gollner, M.J., 2016. Review of pathways for building fire spread in the wildland urban interface part I: Exposure conditions. Fire Technology 54, 429–473.

CO Department of Public Safety, 2020. Elkhorn Creek Unit #4 prescribed fire review: Executive summary. CO Department of Public Safety, Compliance & Professional Standards Office, Denver, CO.

CSFS, 2021. The home ignition zone: A guide to preparing your home for wildfire and creating defensible space. Colorado State University, Colorado State Forest Service, Fort Collins, CO.

CSFS, 2010. Forestry best management practices to protect water quality in Colorado. Colorado State University, Colorado State Forest Service, Fort Collins, CO.

Decker, K., R. Rondeau, R., Culver, L.D., Malone, D., Gilligan, L., Marshall, S. 2020. Guide to ecological systems of Colorado. Colorado State University, Colorado Natural Heritage Program, Fort Collins, CO.

Dennis, F.C., 2005. Fuelbreak guidelines for forested subdivisions and communities. Colorado State University, Colorado State Forest Service, Fort Collins, CO.

Dennis, F.C., 2003. Creating wildfire-defensible zones (Natural Resources Series No. 6.302). Colorado State University, Cooperative Extension, Fort Collins, CO.

Dether, D.M., 2005. Prescribed fire lessons learned: Escaped prescribed fire reviews and near miss incidents (Report for the Wildland Fire Lessons Learned Center).

Duncan, B.W., Schmalzer, P.A., Breininger, D.R., Stolen, E.D., 2015. Comparing fuels reduction and patch mosaic fire regimes for reducing fire spread potential: A spatial modeling approach. Ecological Modelling 314, 90–99.

Elliot, W.J., Miller, M.E., Enstice, N., 2016. Targeting forest management through fire and erosion modelling. International Journal of Wildland Fire 25, 876–887.

Evans, A.M., Wright, C.S., 2017. Unplanned wildfire in areas with slash piles (Unpublished report for the Joint Fire Science Program No. 11-1-8–4).

Finney, M.A., 2006. An overview of FlamMap fire modeling capabilities, In: Andrews, Patricia L.; Butler, Bret W., Comps. 2006. Fuels Management-How to Measure Success: Conference Proceedings. 28-30 March 2006; Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 213-220.

Forge, P., 2018. Basics of wildland fire behavior & the wildland-urban interface (CPAW Planner Training Materials). Community Planning Assistance for Wildfire, Bozeman and Helena, MT.

Fulé, P.Z., Crouse, J.E., Rouccaforte, J.P., Kalies, E.L., 2012. Do thinning and/or burning treatments in western USA ponderosa or Jeffrey pine-dominated forests help restore natural fire behavior? Forest Ecology and Management 269, 68–81.

Gannon, B.M., Wei, Y., MacDonald, L.H., Kampf, S.K., Jones, K.W., Cannon, J.B., Wolk, B.H., Cheng, A.S., Addington, R.N., Thompson, M.P., 2019. Prioritising fuels reduction for water supply protection. International Journal of Wildland Fire 28, 785–803.

Gropp, C., 2019. Embers cause up to 90% of home & business ignitions during wildfire events (News Release No. 12 March 2019). Insurance Institute for Business & Home Safety, Richburg, SC.

Haas, J.R., Calkin, D.E., Thompson, M.P., 2015. Wildfire risk transmission in the Colorado Front Range, USA. Risk Analysis 35, 226–240.

Hakes, R.S., Caton, S.E., Gorham, D.J., Gollner, M.J., 2017. A review of pathways for building fire spread in the wildland urban interface part II: response of components and systems and mitigation strategies in the United States. Fire technology 53, 475–515.

Hansson, L., Fahrig, L., Merriam, G. (Eds.), 1995. Mosaic Landscapes and Ecological Processes. Springer, Dordrecht, Netherlands.

Harper, J.M., 2011. Benefits of grazing and wildfire risk [WWW Document]. University of California, Agriculture and Natural Resources. URL https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=5463

Hartsough, B.R., Abrams, S., Barbour, R.J., Drews, E.S., McIver, J.D., 2008. The economics of alternative fuel reduction treatments in western United States dry forests: Financial and policy implications from the National Fire and Fire Surrogate Study. Forest Policy & Economics 10, 344–354.

Hegewisch, K.C., Abatzoglou, J.T., Gross, J., 2021. Future Climate Analogs Web Tool, Climate Toolbox.

Hudson, T.R., Bray, R.B., Blunck, D.L., Page, W., Butler, B., 2020. Effects of fuel morphology on ember generation characteristics at the tree scale. International Journal of Wildland Fire 29, 1042–1051.

Hunter, M.E., Shepperd, W.D., Lentile, L.B., Lundquist, J.E., Andreu, M.G., Butler, J.L., Smith, F.W., 2007. A comprehensive guide to fuel treatment practices for ponderosa pine in the Black Hills, Colorado Front Range, and Southwest (General Technical Report No. RMRS-GTR-198). U.S. Department of Agriculture, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

IIBHS, 2019. California Wildfires of 2017 and 2018 [WWW Document]. Insurance Institute for Business & Home Safety. URL https://ibhs.org/wildfire/ibhs-post-event-investigation-california-wildfires-of-2017-2018/

Jain, T., Sikkink, P., Keffe, R., Byrne, J., 2018. To masticate or not: Useful tips for treating forest, woodland, and shrubland vegetation (General Technical Report No. RMRS-GTR-381). U.S. Department of Agriculture, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Jolley, A., 2018. Is investing in defensible space worth it? Six examples point to yes! [WWW Document]. Fire Adapted Communities Learning Network. URL https://fireadaptednetwork.org/is-investing-in-defensible-space-worth-it-six-examples-point-to-yes/

Jones, K.W., Cannon, J.B., Saavedra, F.A., Kampf, S.K., Addington, R.N., 2017. Return on investment form fuel treatments to reduce severe wildfire and erosion in a watershed investment program in Colorado. Journal of Environmental Management 198, 66–77.

Kalies, E.L., Dickson, B.G., Chambers, C.L., Covington, W.W., 2012. Small mammal community occupancy responses to restoration treatments in ponderosa pine forests, northern Arizona, USA. Ecological Applications 22, 204–217.

Keane, R.E., Agee, J., Fulé, P., Keeley, J.E., Key, C., Kitchen, S.G., Miller, R., Schulte, L.A., 2008. Ecological effects of large fires in the United States: Benefit or catastrophe? International Journal of Wildland Fire 17, 696–712.

Kerns, B.K., Buonopane, M., Thies, W.G., Niwa, C., 2011. Reintroducing fire into a ponderosa pine forest with and without cattle grazing: Understory vegetation response. Ecosphere 2, 1–23.

Knapp, E.E., Valachovic, Y.S., Quarles, S.L., Johnson, N.G., 2021. Housing arrangement and vegetation factors associated with single-family home survival in the 2018 Camp Fire, California. Fire Ecology 17, 1–19.

Kreye, J.K., Brewer, N.W., Morgan, P., Varner, J.M., Smith, A.M.S., Hoffman, C.M., Ottmar, R.D., 2014. Fire behavior in masticated fuels: A review. Forest Ecology and Management 314, 193–207.

Loomis, J., Sánchez, J.J., González-Cabán, A., Rideout, D., Reich, R., 2019. Do fuel treatments reduce wildfire suppression costs and property damages? Analysis of suppression costs and property damages in U.S. National Forests, in: Proceedings of the Fifth International Symposium on Fire Economics, Planning, and Policy: Ecosystem Services and Wildfires. General Technical Report PSW-GTR-261. U.S. Department of Agriculture, U.S. Forest Service, Pacific Southwest Research Station, Albany, CA, pp. 70–84.

Maranghides, A., Link, E.D., Hawks, S., McDougald, J., Quarles, S.L., Gorham, D.J., Nazare, S., 2022. WUI structure/parcel/community fire hazard mitigation methodology (NIST Technical Note No. 2205). Department of Commerce, National Institute of Standards and Technology, Washington, DC.

Martinuzzi, S., Stewart, S.I., Helmers, D.P., Mockrin, M.H., Hammer, R.B., Radeloff, V.C., 2015. The 2010 wildland-urban interface of the conterminous United States (Research Map No. NRS-RM-8). U.S. Department of Agriculture, U.S. Forest Service, Northern Research Station, Newtown Square, PA.

Matonis, M.S., Binkley, D., 2018. Not just about the trees: Key role of mosaic-meadows in restoration of ponderosa pine ecosystems. Forest Ecology and Management 411, 120–131.

McIver, J.D., Stephens, S.L., Agee, J.K., Barbour, J., Boerner, R.E.J., Edminster, C.B., Erickson, K.L., Farris, K.L., Fettig, C.J., Fiedler, C.E., Haase, S., Hart, S.C., Keeley, J.E., Knapp, E.E., Lehmkuhl, J.F., Moghaddas, J.J., Otrosina, W., Outcalt, K.W., Schwilk, D.W., Skinner, C.N., Waldrop, T.A., Weatherspoon, C.P., Yaussy, D.A., Youngblood, A., Zack, S., 2013. Ecological effects of alternative fuel-reduction treatments: highlights of the National Fire and Fire Surrogate study (FFS). International Journal of Wildland Fire 22, 63–82.

Mell, W.E., Manzello, S.L., Maranghides, A., Butry, D., Rehm, R.G., 2010. The wildland–urban interface fire problem – current approaches and research needs. International Journal of Wildland Fire 19, 238–251.

Miller, S., 2018. Back to the future: Building resilience in Colorado Front Range forests using research findings and a new guide for restoration of ponderosa and dry-mixed conifer landscapes (Science You Can Use Bulletin No. Issue 28). U.S. Department of Agriculture, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Miller, S., 2015. Slash from the past: Rehabilitating pile burn scars (Science You Can Use Bulletin No. Issue 15). U.S. Department of Agriculture, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Missoula Fire Sciences Laboratory. 2012. Fire regimes of mountain-mahogany communities. In: Fire Effects Information System. U.S. Department of Agriculture, U.S. Forest Service, Missoula Fire Sciences Laboratory, Missoula, MT. URL www.fs.fed.us/database/feis/fire_regimes/Mountainmahogany/all.html

Moriarty, K., Cheng, A.S., Hoffman, C.M., Cottrell, S.P., Alexander, M.E., n.d. Firefighter observations of "surprising" fire behavior in mountain pine beetle-attacked lodgepole pine forests. Fire 2, 34.

National Academies of Sciences, Engineering, and Medicine, 2018. Emergency Alert and Warning Systems: Current Knowledge and Future Research Directions. The National Academies Press, Washington, DC. https://doi.org/10.17226/24935

NOAA, 2021. What is a watershed? [WWW Document]. U.S. Department of Commerce, National Oceanic and Atomspheric Administration, National Ocean Service. URL https://oceanservice.noaa.gov/facts/watershed.html

NRCS, 2017. Glossary of landforms and geologic terms, in: National Soil Survey Handbook. U.S. Department of Agriculture, National Resources Conservation Service, Washington, DC, p. Part 629.

NWCG, 2021. Midflame windspeed. Section 8.2 [WWW Document]. Firefighter Math, National Wildfire Coordinating Group. URL https://www.nwcg.gov/course/ffm/fire-behavior/82-midflame-windspeed

NWCG, 2019. Fire behavior field reference guide (PMS 437). National Wildfire Coordinating Group, Boise, ID.

NWCG, 2018a. Incident Response Pocket Guide (PMS 461 / NFES 001077). National Wildfire Coordinating Group, Boise, ID.

NWCG, 2018b. NWCG glossary of wildland fire (PMS 205). National Wildfire Coordinating Group, Data Management Committee, Data Standards and Terminology Subcommittee, Boise, ID.

NWCG, 2008. S-190: Introduction to wildland fire behavior. National Wildfire Coordinating Group, Training Development Program, Boise, ID.

O'Connor, B., 2021. Fire apparatus access roads [WWW Document]. National Fire Protection Association. URL https://www.nfpa.org/News-and-Research/Publications-and-media/Blogs-Landing-Page/NFPA-Today/Blog-Posts/2021/01/08/Fire-Apparatus-Access-Roads

Parks, S.A., Miller, C., Abatzoglou, J.T., Holsinger, L.M., Parisien, M.A., Dobrowski, S.Z., 2016. How will climate change affect wildland fire severity in the western US? Environmental Research Letters 11, 035002. https://doi.org/10.1088/1748-9326/11/3/03500.

Parsons, R., Jolly, M., Langowski, P., Matonis, M.S., Miller, S., 2014. Post-epidemic fire risk and behavior [Chapter 3], in: Matonis, M.S., Hubbard, R., Gebert, K., Hahn, B., Miller, S., Regan, C. (Eds.), Proceedings RMRS-P-70. Presented at the Future Forests Webinar Series, U.S. Department of Agriculture, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO, pp. 19–28.

Pausas, J.G., Parr, C.L., 2018. Towards an understanding of the evolutionary role of fire in animals. Evolutionary Ecology 32, 113–125.

Paysen, T.E., Ansley, R.J., Brown, J.K., Gotffried, G.J., Haase, S.M., Harrington, M.G., Narog, M.G., Sackett, S.S., Wilson, R.C., 2000. Chapter 6: Fire in western shrubland, woodland, and grassland ecosystems (General Technical Report No. RMRS-GTR-42-vol 2.). U.S. Department of Agriculture, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Pilliod, D.S., Bull, E.L., Hayes, J.L., Wales, B.C., 2006. Wildlife and invertebrate response to fuel reduction treatments in dry coniferous forests of the Western United States: A synthesis (General Technical Report No. RMRS-GTR-173). U.S. Department of Agriculture, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Plucinski, M.P., 2019. Contain and control: Wildfire suppression effectiveness at incidents and across landscapes. Current Forestry Reports 5, 20–40.

Prichard, S.J., Povak, N.A., Kennedy, M.C., Peterson, D.W., 2020. Fuel treatment effectiveness in the context of landform, vegetation, and large, wind-driven wildfires. Ecological Applications 30, e02104.

Quarles, S.L., 2019. Fire ratings for construction materials [WWW Document]. eXtension Foundation. URL https://surviving-wildfire.extension.org/fire-ratings-for-construction-materials/

Quarles, S.L., Pohl, K., 2018. Building a wildfire-resistant home: Codes and costs. Headwaters Economics, Bozeman, MT.

Radeloff, V.C., Helmers, D.P., Kramer, H.A., Mockrin, M.H., Alexandre, P.M., Bar-Massada, A., Butsic, V., Hawbaker, T.J., Martinuzzi, S., Syphard, A.D., others, 2018. Rapid growth of the US wildland-urban interface raises wildfire risk. Proceedings of the National Academy of Sciences 115, 3314–3319.

Reinhardt, E.D., Keane, R.E., Calkin, D.E., Cohen, J.D., 2008. Objectives and considerations for wildland fuel treatments in forested ecosystems of the interior western United States. Forest Ecology and Management 256, 1997–2006.

Romme, W.H., 1982. Fire and landscape diversity in subalpine forests of Yellowstone National Park. Ecological Monographs 52, 199–221.

Scott, J.H., 2006. Comparison of crown fire modeling systems used in three fire management applications (Research Paper No. RMRS-RP-58). U.S. Department of Agriculture, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Scott, J.H., Burgan, R.E., 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. US Department of Agriculture, Forest Service, Rocky Mountain Research Station.

SER, 2004. SER International Primer on Ecological Restoration. Society of Ecological Restoration, Washington, DC.

Shahabi, K., Wilson, J.P., 2014. CASPER: Intelligent capacity-aware evacuation routing. Computers, Environment and Urban Systems 46, 12–24. https://doi.org/10.1016/j.compenvurbsys.2014.03.004.

Sherriff, R.L., Platt, R.V., Veblen, T.T., Schoennagel, T.L., Gartner, M.H., 2014. Historical, observed, and modeled wildfire severity in montane forests of the Colorado Front Range. PLoS One 9, e106971.

Simpkins, K., 2021. Mountain residents underestimate wildfire risk, overestimate preparedness. CU Boulder Today.

Stephens, S.L., Moghaddas, J.J., Edminster, C., Fiedler, C.E., Haase, S., 2009. Fuel treatment effects on vegetation structure, fuels, and potential fire severity in western U.S. forests. Ecological Applications 19, 305–320.

Sullivan, A.L., 2009. Wildland surface fire spread modelling, 1990–2007. 1: Physical and quasi-physical models. International Journal of Wildland Fire 18, 349–368.

Syphard, A.D., Brennan, T.J., Keeley, J.E., 2014. The role of defensible space for residential structure protection during wildfires. International Journal of Wildland Fire 23, 1165–1175.

Syphard, A.D., Keeley, J.E., 2019. Factors associated with structure loss in the 2013-2018 California wildfires. Fire 2, 2030049. https://doi.org/10.3390/fire2030049.

Syphard, A.D., Keeley, J.E., Massada, A.B., Brennan, T.J., J., T., Radeloff, V.C., 2012. Housing arrangement and location determine the likelihood of housing loss due to wildfire. PLoS ONE 7, e33954. https://doi.org/10.1371/journal.pone.0033954.

Tinkham, W.T., Dickinson, Y., Hoffman, C.M., Battaglia, M.A., Ex, S., Underhill, J., 2017. Visualization of heterogenous forest structures following treatment in the Southern Rocky Mountains (General Technical Report No. RMRS-GTR-365). U.S. Department of Agriculture, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Tinkham, W.T., Hoffman, C.M., Ex, S.A., Battaglia, M.A., Saralecos, J.D., 2016. Ponderosa pine forest restoration treatment longevity: Implications of regeneration on fire hazard. Forests 7, 137.

USFS, 2021a. Wildfire risk to communities [WWW Document]. U.S. Department of Agriculture, U.S. Forest Service, Washington, DC. URL https://wildfirerisk.org/

USFS, 2021b. Glossary of forest engineering terms [WWW Document]. U.S. Department of Agriculture, U.S. Forest Service, Southern Research Station, Forest Operations Research. URL https://www.srs.fs.usda.gov/forestops/glossary/

Weir, J.R., Kreuter, U.P., Wonkka, C.L., Twidwell, D., Stroman, D.A., Russell, M., Taylor, C.A., 2019. Liability and prescribed fire: Perception and reality. Rangeland Ecology & Management 72, 533–538.

Wildfire Adapated Partnership, 2018. Fire adapted communities neighborhood ambassador approach: Increasing preparedness through volunteers. Wildfire Adapted Partnership, Durango, CO.

Williams, J., 2013. Exploring the onset of high-impact mega-fires through a forest land management prism. Forest Ecology and Management 294, 4–10.

Wright, C.S., Evans, A.M., Grove, S., Haubensak, K.A., 2019. Pile age and burn season influence fuelbed properties, combustion dynamics, fuel consumption, and charcoal formation when burning hand piles. Forest Ecology and Management 439, 146–158.

Ziegler, J.P., Hoffman, C., Battaglia, M., Mell, W., 2017. Spatially explicit measurements of forest structure and fire behavior following restoration treatments in dry forests. Forest Ecology and Management 386, 1–12.

Appendix A. Community Risk Assessment and Modelling Methodology

Our assessment of wildfire risk is based on fire behavior and evacuation modeling and on-the-ground observations from across the GVFPD. Results from the community risk assessment informed recommendations about priority treatment to protect lives, property, infrastructure, and ecosystems in and around the GVFPD.

A.1. CWPP Plan Units

The goal of delineating plan units is to identify areas with shared fire risk where residents can organize and support each other to effectively mitigate hazardous fuels across the plan unit (**Figure 3.c.1**). To delineate plan units in the GVFPD, we considered clusters of addresses, connectivity of roads, topographic features, land parcels, and local knowledge of community organization. Land ownership also played a role in establishing unit boundaries. Amendments were made to boundaries based on local knowledge from the GVFPD.

A.2. Fire Behavior Analysis

Interpretations and Limitations

Fire behavior models have been rigorously developed and tested based on over 40 years of experimental and observational research (Sullivan 2009). Fire behavior models allow us to identify areas that could experience high-severity wildfires and pose a risk to lives, property, and other values at risk.

> With high-quality input data, fire behavior models can provide reasonable estimates of relative wildfire behavior across a landscape. However, wildfire behavior is complex, and models are a simplification of reality. It is recommended to use fire behavior analyses to assess relative risk across the entire GVFPD. Models cannot produce specific and precise predictions of what will occur in the vicinity of an individual home during a wildfire incident.

We used the fire behavior model FlamMap, which is a fire analysis desktop application that simulates potential fire behavior and spread under constant weather and fuel moisture (Finney 2006). FlamMap is one of the most common models used by land managers to assist with fuel treatment prioritization, and it is often used by fire behavior analysts during wildfire incidents.

Fire behavior analyses are useful for assessing relative risk across the entire GVFPD and are not intended to assess specific fire behavior in the vicinity of individual homes. It is not feasible to predict every combination of fire weather conditions, ignition locations, and suppression activities that might occur during a wildfire. Uncertainty will always remain about where and how a wildfire might behave until a fire is actually occurring, and even then, fire behavior can be erratic and unpredictable.

Fire behavior models like FlamMap do not include structures as a fuel type. Structures like homes, sheds, fences, and other buildings are absolutely a source of fuel during wildland fires and can produce massive amounts of embers that contribute to home-to-home ignitions (Maranghides et al. 2022). However, FlamMap cannot account for fine-scale variation in surface fuel loads, defensible space created by individual homeowners, and the ignitability of building materials, nor are these data available at the scale of individual homes across an entire fire protection district. In the absence of this information and a deeper quantitative understanding of interactions between structures and wildland vegetation during a wildfire, fire behavior cannot be modeled for areas dominated by homes in the same fashion as areas dominated by grassland, shrubland, or forest vegetation. For this reason, we conducted a separate analysis to predict potential exposure of homes to radiant heat and ember cast (see **Appendix A.3**).

Model Specifications and Inputs

We used FlamMap to model flame length, crown fire activity, potential fire sizes, and conditional burn probability. FlamMap requires information on topography and fuel loads across the area of interest (**Figure 8.a.1**). See **Table 9.a.1** and **Table 9.a.2** for details on model inputs and specifications.

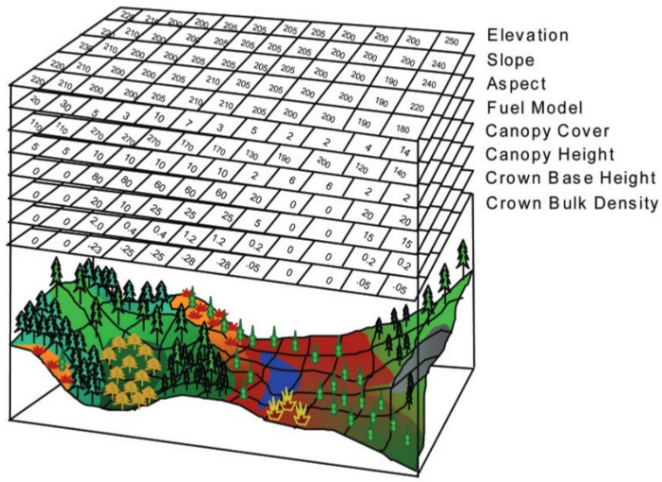


Figure 9.a.1. FlamMap requires a variety of information about topography and fuels. Image from Finney (2006).

We used LANDFIRE data modified by the Colorado Forest Restoration Institute in 2021 as the basis for our modeling. LANDFIRE is a national program spearheaded by the U.S. Department of the Interior and the U.S. Department of Agriculture to provide spatial products characterizing vegetation, fuels, fire regimes, and disturbances across the entire United States. LANDFIRE products serve as standardized inputs for fire behavior modeling. CFRI modified LANDFIRE data by assigning TL5 fire behavior fuel model to lodgepole pine forests and reducing canopy base height by 30% to more closely replicate observed crown fire activity in this forest type. They also modified surface and canopy fuels in areas that experienced fuel treatments and/or wildfires since 2016. We thoroughly quality controlled fuel data and worked with the GVFPD to assess the reasonableness of model predictions.

Figure 9.a.2 depicts the fire behavior fuel models present across the GVFPD. Fuel models are a stylized set of fuel bed characteristics used as input for a variety of wildfire modeling applications to predict fire behavior (Scott and Burgan 2005). Fuels in the and around GVFPD are primarily low- and moderate- grass-shrub and very high load timber-shrub fuels. Our maps of fire behavior predictions include areas indicated as "unburnable / not modeled"—parking lots, roadways, bodies of water, and barren areas are considered unburnable; areas dominated by homes and buildings were classified as "not modeled" because fire behavior models do not include structures as a fuel type (Scott and Burgan 2005).

Fire behavior models require estimates of fire weather conditions, and a common practice is to model fire behavior under hot, dry, and windy conditions for an area—not the average conditions, but extreme conditions. Wildfires that grow to large sizes, exhibit high-severity behavior, and overwhelm suppression capabilities tend to occur under extreme fire weather conditions (Williams 2013).

We modeled potential wildfire behavior under 60th and 90th percentile fire weather conditions. 60th percentile weather condition are average fire weather conditions. 660th percentile conditions are like a normal summer day, whereas 90th percentile conditions are extremely hot, dry days—days that would qualify for red flag warnings and result in large-fire growth, such as conditions in early September 2020 during the Cameron Peak fire. These two benchmarks allow us to analyze where an average fire in the district may burn so the GVFPD can prioritize outreach and treatment under regular circumstances, as well as what can be expected under more extreme circumstances, as was seen in 2020.

Weather parameters for our analysis came from data collected at the Red Feather RAWS and fuel moisture conditions from FireFamilyPlus. Under 90th percentile weather conditions in the GVFPD, relative humidity is 13%, temperature is 80°F, 1-hour fuel moisture is 5%, and 10-hour fuel moisture is 8%, and 100-hour fuel moisture is 11% (**Table 9.a.2**).

Winds across the Front Range of Colorado are unpredictable and can be extremely gusty in mountainous areas. We modeled 20-foot windspeeds of 15 mph for 60th percentile fire weather conditions and 25 mph for 90th percentile fire weather conditions. Wind speeds of 25 mph qualify as red flag warnings when occurring with low relative humidity and dry fuels (**Table 1.c.1**). We modeled potential fire spread under winds blowing out of the east southeast (113°) and out of the west northwest (293°) based on observations from the Red Feather RAWS and observations of local firefighters. We modeled flame length and crown fire activity based on winds out of the west northwest, and we modeled burn probability based on both these prevailing winds.

FlamMap offers two methods for calculating crown fire initiation and spread: the Scott and Reinhardt method and the Finney method. We used the Scott and Reinhardt method as this method resulted in predictions of crown fire occurrence more consistent with expectations and has been found more reliable than the Finney method (Scott 2006).

Fire spread was modeled with FlamMap's "minimum travel time" algorithm to predict fire growth between cells and account for fire spread through spotting. We modeled fire growth under 10,000 random ignitions across the landscape, and we allowed fires to grow for 4 hours in the absence of firefighter suppression and control measures. We modeled fire behavior in an area 15 times larger than the GVFPD and centered on the GVFPD to capture the landscape-scale movement of fire. Conditional burn probability is calculated as the percentage of simulated fires that burn each 30-meter by 30-meter (0.2 acre) area under specified fire weather conditions, wind directions, and wind speeds.

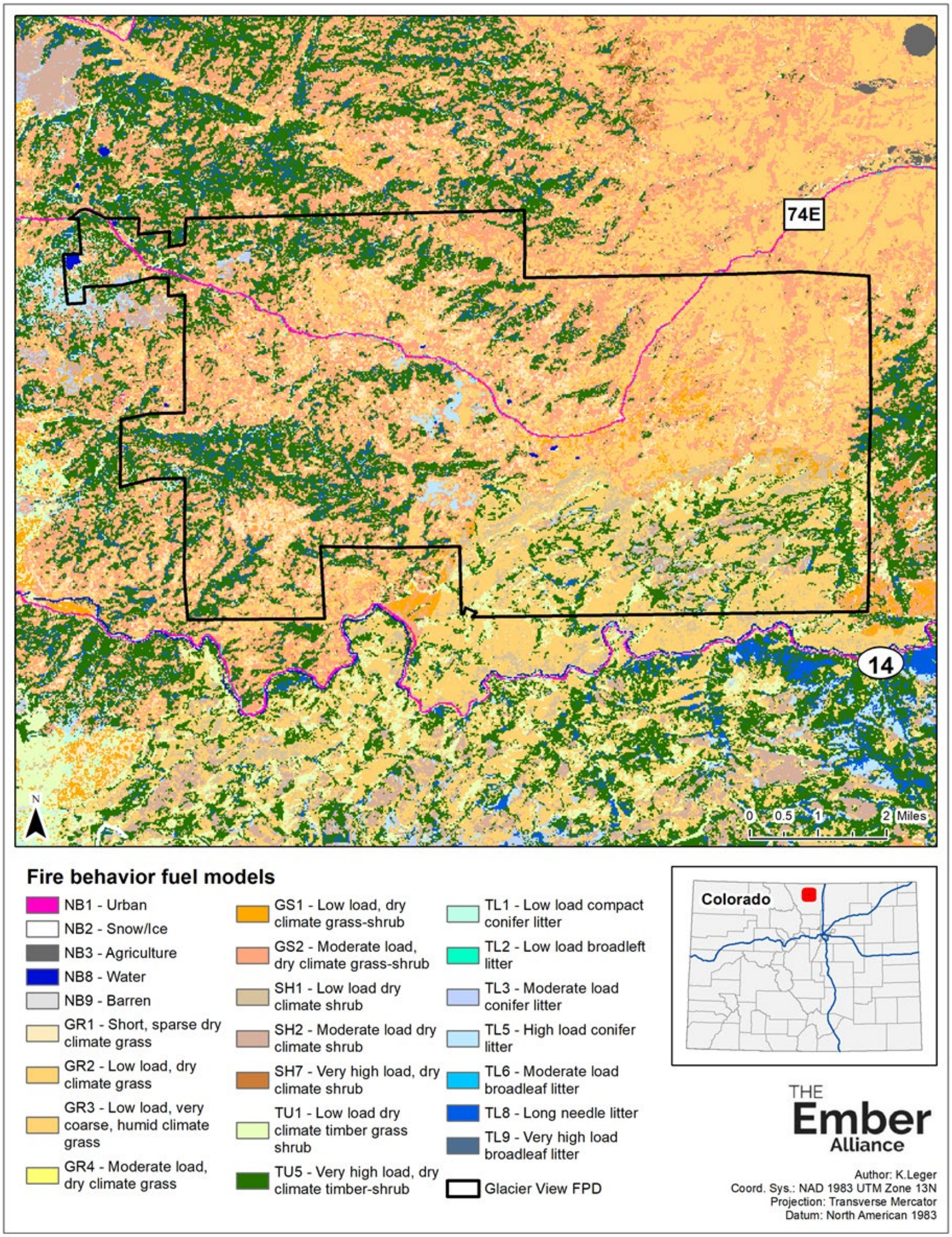


Figure 9.a.2. Fuels in and around GVFPD are primarily low- and moderate- grass-shrub and very high load timber-shrub fuels. See Scott and Burgan (2005) for a description of each fuel model. (Source: LANDFIRE with modifications by the Colorado Forest Restoration Institute). An interactive map with fire behavior fuel models is available online at https://experience.arcgis.com/experience/225f72cc029c4e37a2acbdefc60b2140/page/Fire-Behavior/.

Table 9.a.1. Model specifications used for fire behavior analyses with FlamMap for the 2022 GVFPD CWPP.

Model specification	Value
Crown fire calculation method	Scott/Reinhardt (2001)
Wind options	Gridded winds
Wind grid resolution	60 meters
Number of random ignitions	10,000*
Resolution of calculations	30 meters
Maximum simulation time	240 minutes
Minimum travel paths	500 meters
Spot probability	0.7
Spotting delay	15 minutes
Lateral search depth	6 meters
Vertical search depth	4 meters

*We used the same random ignition locations for fire spread analysis under 60th and 90th fire weather conditions.

Table 9.a.2. Fire weather conditions utilized for fire behavior modeling are based on weather observations from the Red Feather Remote Automatic Weather Station between June 15 and October 15, 2014-2021 and fuel moisture predictions from FireFamilyPlus. Weather conditions on September 6, 2020 during the Cameron Peak Fire are presented for comparison.

Variable	60th percentile	90th percentile	Cameron Peak Fire (for comparison)
Temperature	73° Fahrenheit	80° Fahrenheit	83° Fahrenheit
Relative humidity	23%	13%	9%
Wind direction	East southeast (113°) and west northwest (293°)	East southeast (113°) and west northwest (293°)	194° South-Southwest
20-foot wind speed[1]	15 mph	25 mph	13 mph, gusting up to 35 mph
Fuel moisture[2]			
1-hour	6%	5%	3%
10-hour	11%	8%	6%
100-hour	13%	11%	10%
1000-hour[3]	20%	13%	12%
Live woody	90%	75%	---
Live herbaceous	50%	30%	---
Crown foliage	100%	80%	---

[1]20-foot wind speeds are approximately 5 times larger than winds at ground level in fully sheltered fuels; vegetation and friction slow down windspeeds closer to ground level (NWCG 2021).

[2]One-hour fuels are dead vegetation less than 0.25 inch in diameter (e.g., dead grass), ten-hour fuels are dead vegetation 0.25 inch to 1 inch in diameter (e.g., leaf litter and pine needles), one hundred-hour fuels are dead vegetation 1 inch to 3 inches in diameter (e.g., fine branches), and one thousand-hour fuels are dead vegetation 3 inches to 8 inches in diameter (e.g., large branches). Fuels with larger diameters have a smaller surface area to volume ratio and take more time to dry out or to become wetter as relative humidity in the air changes.

[3]1000-hour fuel is moisture not used by FlamMap for predicting fire behavior but is included here to provide additional context.

Predicted Flame Lengths

Flame length is the distance measured from the average flame tip to the middle of the flaming zone at the base of the fire. Flame length is measured on an angle when the flames are tilted due to effects of wind and slope (see image at right). Flame length is an indicator of fireline intensity, and it is utilized by firefighters to guide tactical decisions following the Haul Chart (**Table 9.a.3**).

Under 60th percentile weather conditions, 15% of the GVFPD an experience very high to extreme fire behavior with flame lengths over 11 feet. Under 90th percentile weather conditions, 32% can experience very high to extreme fire behavior with flame lengths over 11 feet (**Figure 9.a.3**; **Table 9.a.4**). Higher flame lengths are predicted for areas with dense ponderosa pine forests, particularly on steep, north-facing slopes, and flame lengths are lower in the eastern portions of the FPD that are primarily dominated by shrublands and grasslands. The highest average flame lengths are predicted for the areas in and around the Lady Moon, North Rim, Red Feather Highlands CWPP plan units (**Table 9.a.4**).

Table 9.a.3. Description of fire behavior and tactical interpretations for firefighters from the Haul Chart (NWCG 2019).

Fire behavior class	Flame length (feet)	Rate of spread (chains*/hour)	Tactical interpretation
Very Low	0-1	0-2	Direct attack with handcrews
Low	1-4	2-5	Direct attack with handcrews
Moderate	4-8	5-20	Direct attack with equipment
High	8-11	20-50	Indirect attack
Very High	11-25	50-150	Indirect attack
Extreme	25+	150+	Indirect attack

****Note:*** 1 chain = 66 feet. Chains are commonly used in forestry and fire management as a measure of distance. Chains were used for measurements in the initial public land survey of the U.S. in the mid-1800s. 1 chain / hour = 1.1 feet / minute.

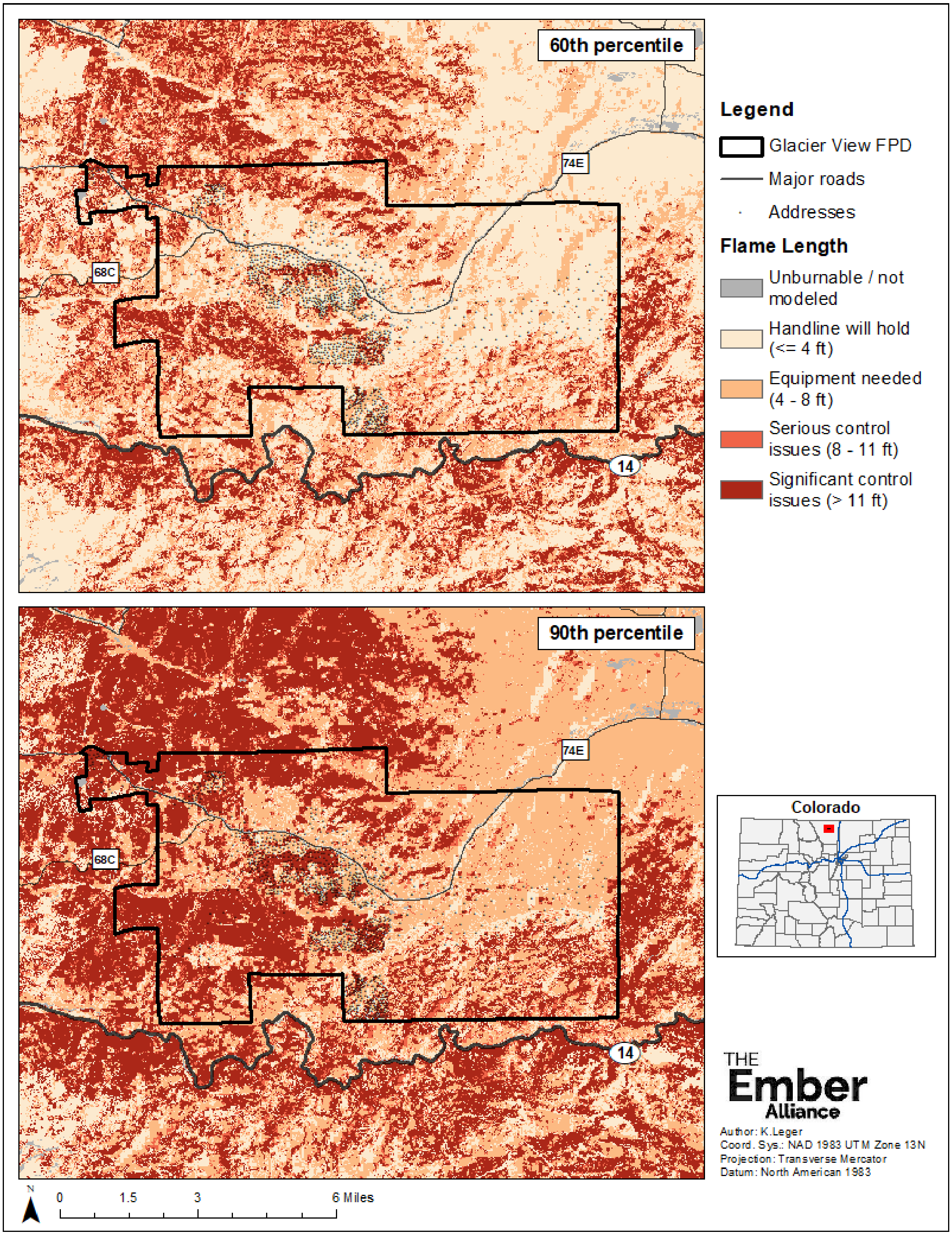


Figure 9.a.3. Flame lengths in GVFPD under 60th and 90th percentile fire weather conditions, categorized by the Haul Chart (**Table 9.a.3**). An interactive map with predicted flame lengths is available online at https://experience.arcgis.com/experience/225f72cc029c4e37a2acbdefc60b2140/page/Fire-Behavior/.

Table 9.a.4. Average flame length across the entire GVFPD and in each CWPP plan unit. Potentially non-survivable flame lengths start at 8 feet according to the Haul Chart (**Table 9.a.3**). Flame lengths are summarized for the plan unit and adjacent topographic areas that could contribute to fire behavior within the plan unit. Colors correspond with the legend in **Figure 9.a.3**.

	60th Percentile		90th Percentile	
	Average Flame Length (feet)	Maximum Flame Length (feet)	Average Flame Length (feet)	Maximum Flame Length (feet)
Entire GVFPD	**7.3**	**134.8**	**16.5**	**174.1**
Deer Meadows	4.7	134.8	9.4	168.9
Glacier View Meadows 1	6.2	60.5	14.3	106.9
Glacier View Meadows 2	6.6	69.6	15.0	114.4
Glacier View Meadows 3	4.8	84.5	10.4	136.2
Green Mountain Meadows	7.0	106.4	14.6	159.2
Lady Moon	9.0	97.0	24.5	146.6
North Rim	9.6	96.8	24.0	153.5
Red Feather Highlands	8.8	97.0	23.1	146.6

Predicted Crown Fire Activity

FlamMap models three types of fire activity: surface fires, passive crown fires, and active crown fires. See a discussion about fire behavior in **Section 1.c. Introduction to Wildfire Behavior and Terminology**. Both passive and active crown fires pose a significant risk to the safety of firefighters and residents and can destroy homes through radiant and convective heating and ember production.

Under 60th percentile weather conditions, 42% of the GVFPD can experience passive crown fire, and less than 1% can experience extreme fire behavior with active crown fire. Under 90th percentile weather conditions, 41% can experience passive crown fire, and 5% of the district is subject to extreme fire behavior with active crown fire (**Figure 9.a.4**; **Table 9.a.5**). Steep slopes with dense forests are more likely to experience active crown fires. There are fewer contiguous forest areas predicted for passive or active crown fires in the area burned by the 2012 High Park Fire due to mortality of large patches of dense forest from that fire. The areas in and around Lady Moon, North Rim, Red Feather Highlands CWPP plan units have the highest susceptibility to passive and active crown fires due to the prevalence of dense forests and steep slopes (**Table 9.a.5**).

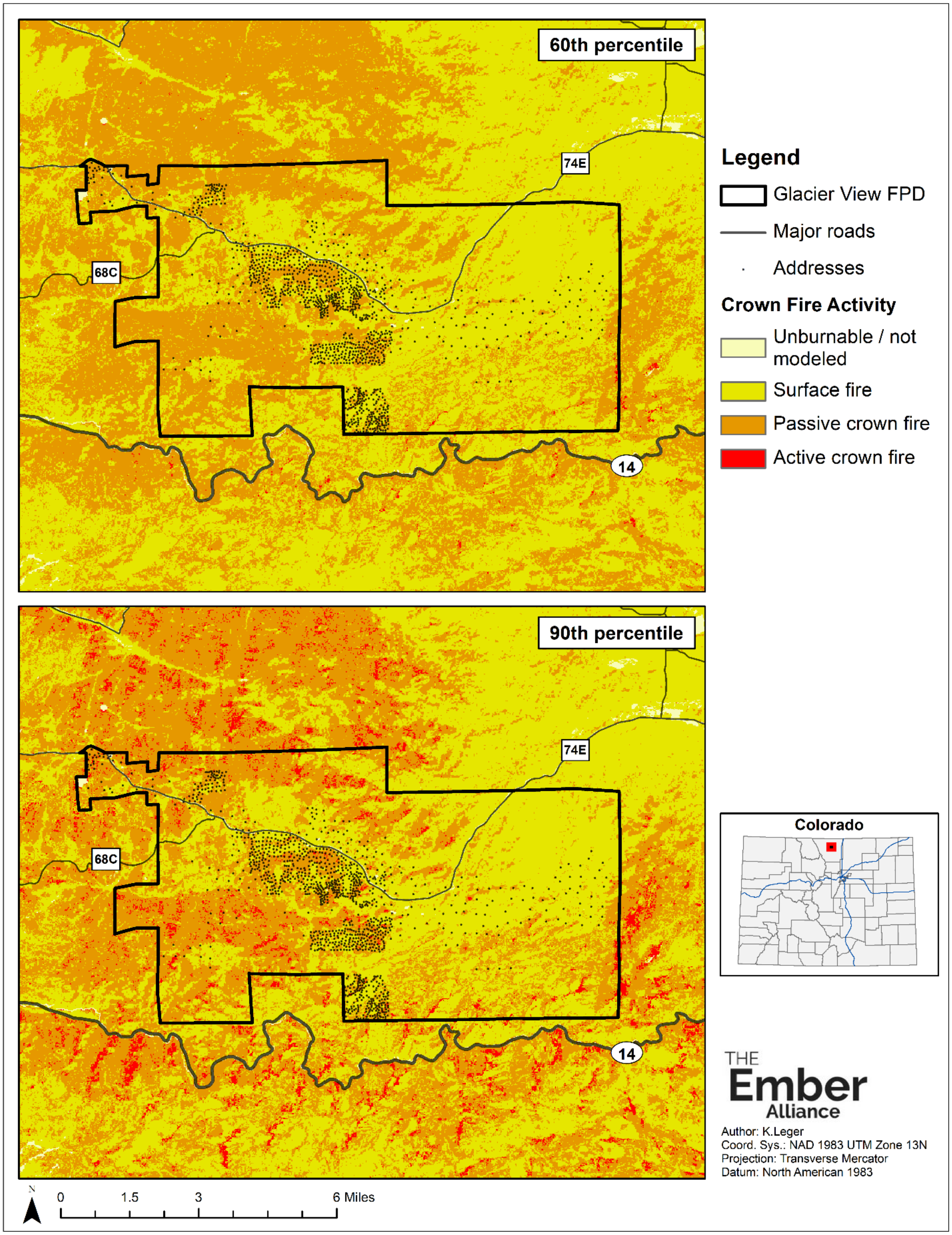


Figure 9.a.4. Crown fire activity under 60th and 90th percentile fire weather conditions in GVFPD. An interactive map with predicted crown fire activity is available online at https://experience.arcgis.com/experience/225f72cc029c4e37a2acbdefc60b2140/page/Fire-Behavior/.

Table 9.a.5. Percent of the entire GVFPD and each CWPP plan unit predicted to experience each category of fire activity. Crown fire activity is summarized for the plan unit and adjacent topographic areas that could contribute to fire behavior within the plan unit. Colors correspond with the legend in **Figure 9.a.4**.

	60th Percentile				90th Percentile			
	Active Crown Fire	Passive Crown Fire	Surface Fire	Un-burnable	Active Crown Fire	Passive Crown Fire	Surface Fire	Un-burnable
Entire GVFPD	**0.4%**	**41.7%**	**57.0%**	**0.9%**	**5.2%**	**41.1%**	**52.8%**	**0.9%**
Deer Meadows	0.4%	20.3%	78.9%	0.4%	2.4%	22.1%	75.2%	0.4%
Glacier View Meadows 1	0.0%	40.0%	58.1%	1.8%	2.8%	42.4%	52.9%	1.8%
Glacier View Meadows 2	0.1%	39.7%	59.8%	0.3%	3.8%	41.1%	54.7%	0.3%
Glacier View Meadows 3	0.7%	28.6%	70.1%	0.6%	2.8%	31.5%	65.1%	0.6%
Green Mountain Meadows	0.4%	36.7%	61.9%	1.1%	4.9%	34.9%	59.1%	1.1%
Lady Moon	0.2%	64.0%	33.6%	2.2%	7.1%	66.5%	24.2%	2.2%
North Rim	0.1%	66.3%	33.5%	0.1%	7.0%	64.5%	28.4%	0.1%
Red Feather Highlands	0.2%	64.5%	33.2%	2.1%	5.7%	66.7%	25.5%	2.1%

Predicted Conditional Burn Probability and Fire Sizes

Conditional burn probability indicates how likely an area is to burn during a wildfire. Wind direction strongly affects burn probability, carrying fires quickly up slopes facing toward the incoming winds (**Figure 9.a.5**; **Figure 9.a.6**). Topography, non-burnable barriers such as wide rivers, interstates, and highways, and fuel loads also influence conditional burn probability by dictating how fire spreads across the landscape.

Short-range transport of embers can cause spot fires to ignite even across unburnable barriers such as the County Road 74E (Red Feather Lakes Road), particularly when the head of the fire is being pushed by wind directly at the road. Fires that spread slower towards roads on their flanks are less likely to cross roads, as depicted from some of the simulated fire perimeters in **Figure 9.a.6**. Rapid fire growth and spotting across roadways is more likely under higher windspeeds and with drier fuel conditions.

Conditional burn probability is relatively high in the eastern portion of the GVFPD due to the abundance of grasslands and shrublands that can promote rapid rates of spread (**Figure 9.a.5**). Dense forest conditions and steep slopes in the Green Mountain Meadows, Lady Moon, North Rim, and Red Feather Highlands CWPP plan units result in higher burn probabilities relative to other portions of the GVFPD (**Table 9.a.6**).

Unpredictable wind conditions along the Colorado Front Range make it difficult to predict potential fire spread, making it imperative for residents across the GVFPD to take measures to mitigate their home ignition zone (see **Section 3.a Individual Recommendations**).

There is a real potential for wildfires to spread across large swaths of GVFPD District given uncontrollable fire behavior and extreme fire weather conditions, such as those experienced across the Colorado Front Range in 2020. **During red flag warnings, all residents need to be prepared for evacuations in the case of a wildfire, just as the fire department will be preparing for wildfire response.**

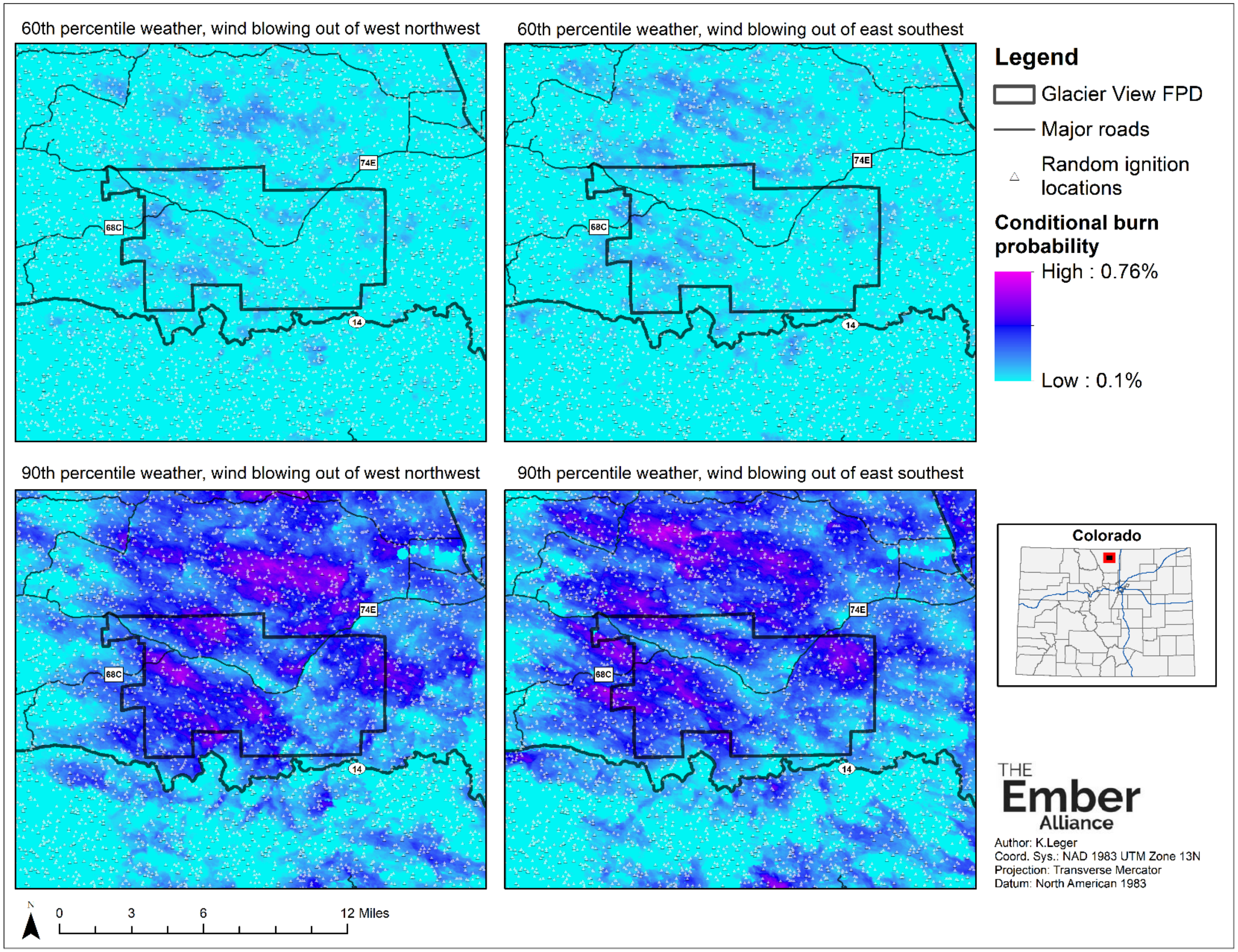


Figure 9.a.5. Conditional burn probability under 60th and 90th percentile fire weather conditions under winds blowing out of the west northwest and out of the east southeast. Wildfire spread was simulated for 4-hours without suppression activities from 10,000 random ignition locations across an area 15 times larger than and centered on GVFPD. An interactive map with conditional burn probability is available online at https://experience.arcgis.com/experience/225f72cc029c4e37a2acbdefc60b2140/page/Fire-Behavior/.

Table 9.a.6. Conditional burn probability for the entire GVFPD and each CWPP plan unit. Burn probabilities were averaged for winds blowing out of the west northwest and out of the east southeast. Conditional burn probability is summarized for the plan unit and adjacent topographic areas that could contribute to fire behavior within the plan unit. Colors correspond with the legend in **Figure 9.a.5**.

	60th Percentile		90th Percentile	
	Average Burn Probability	**Maximum Burn Probability**	**Average Burn Probability**	**Maximum Burn Probability**
Entire GVFPD	**0.166%**	**0.510%**	**0.249%**	**0.620%**
Deer Meadows	0.114%	0.300%	0.182%	0.410%
Glacier View Meadows 1	0.171%	0.340%	0.255%	0.440%
Glacier View Meadows 2	0.145%	0.380%	0.225%	0.490%
Glacier View Meadows 3	0.085%	0.270%	0.140%	0.360%
Green Mountain Meadows	0.169%	0.450%	0.250%	0.530%
Lady Moon	0.161%	0.400%	0.259%	0.530%
North Rim	0.250%	0.400%	0.362%	0.520%
Red Feather Highlands	0.173%	0.400%	0.273%	0.530%

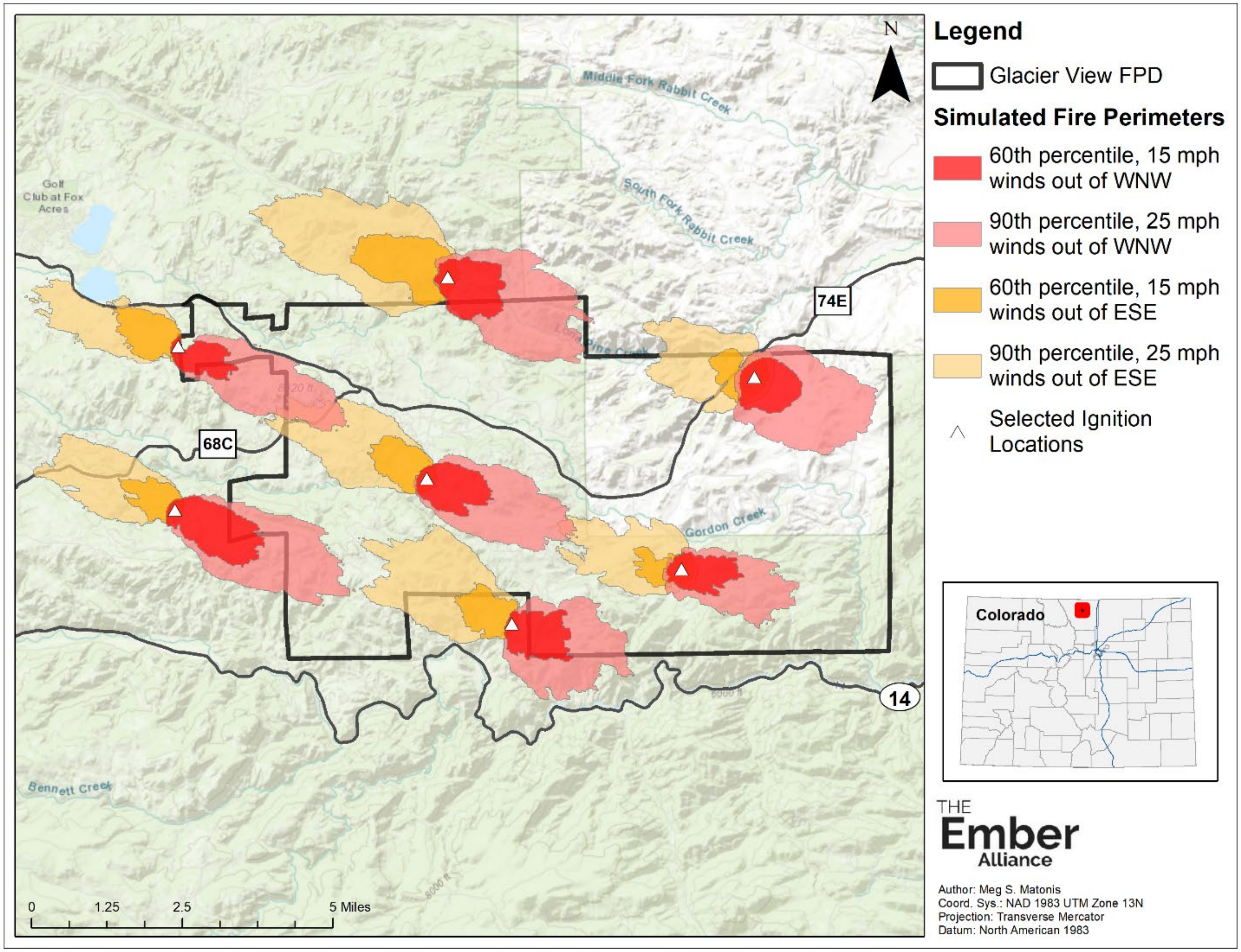


Figure 9.a.6. Simulated fire perimeters after 4-hours of fire growth without suppression activities originating from 7 of the 10,000 randomly generated ignition locations across GVFPD. We modeled fire growth using FlamMap's minimum travel time algorithm and 60th and 90th percentile fire weather conditions under prevailing winds out of the west-northwest and east-southeast. Each fire perimeter is a unique run from an ignition, and multiple fire perimeters are shown to demonstrate a variety of potential fire sizes, shapes, and travel paths.

A.3. Predicted Radiant Heat and Ember Cast Exposure

We assessed the risk that radiant heat and short-range and long-range ember cast pose to structures. See **Section 1.c. Introduction to Wildfire Behavior and Terminology** for a description of how wildfires can ignite homes. Ember production and transport and their ability to ignite recipient fuels are guided by complex processes, so we utilized the simplified approach of Beverly et al. (2010) to assess home exposure to radiant heating and short-and long-range ember cast (**Figure 8.a.7**). Exposure is based on distance from long flame lengths and potential active crown fire assuming:

- Radiant heat can ignite homes when extreme fire behavior (flame lengths > 16 feet) occurs within 33 yards (30 meters) of structures.
- Short-range embers can reach homes within 0.06 miles (100 meters) of active crown fires.
- Long-range embers can reach homes within 0.3 miles (500 meters) of active crown fires.

Embers can ignite homes even when the flaming front of a wildfire is far away. See **Mitigate the Home Ignition Zone** for tangible and relatively simple steps you can take to harden your home against embers. Mitigation practices, such as removing pine needles from gutters and installing covers over vents, can make ignition less likely and make it easier for firefighters to defend your property.

Distance thresholds used by Beverly et al. (2010) are based on observations from actual wildfires, but their estimates are lower than those from some researchers. Studies on wildfires burning eucalyptus forests in Australia and wildfires burning chaparral in California demonstrated that embers can travel 12 to 15 miles from the flaming front and ignite spot fires (Caton et al. 2016), but these fuel types are very different from conifer forests in Colorado. Embers from ponderosa pine trees tend to ignite fuels at a much lower rate than embers from other tree species (Hudson et al. 2020). In addition, the number of embers reaching an area decreases exponentially with distance traveled, and the likelihood of structure ignition increases with the number of embers landing on the structure (Caton et al. 2016). Therefore, using conservative estimates of distance allows us to identify areas with the greatest risk of ignition from short- and long-range embers.

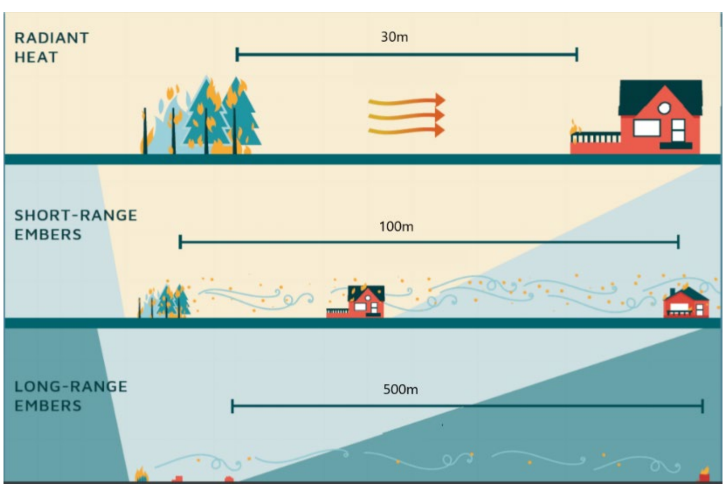


Figure 9.a.7. Research by Beverly and others (2010) suggest that homes are exposed to radiant heat, short-range embers, and long-range embers depending on their distance from the flaming front.

We determined whether exposure to radiant heat and short- and long-range ember cast from active crown fires was possible within the home ignition zone (HIZ; 100-feet radius) of each structure in GVFPD[4].

Homes in the northeastern part of GVFPD have less exposure to radiant heat and short-and long-rang ember cast because of the abundance of grassy and shrubby fuel types (**Figure 9.a.8**). Almost 95% of the homes in GVFPD are at risk of long-range ember cast from nearby burning vegetation under 90% percentile weather conditions, and about 25% of homes are at risk of short-range ember cast and 40% to radiant heat as well (**Figure 9.a.9**). CWPP plan units with the greatest percentage of homes exposed to radiant heat and short- and long-range ember cast are Glacier View Meadows 3, Lady Moon, and Red Feather Highlands (**Table 9.a.7**).

Almost 60% of homes within GVFPD could be exposed to short-range ember cast from at least one other home (**Figure 9.a.10**). Homes within about 330 feet of each other have a greater risk of home-to-home ignition from radiant heat and short-range embers (Syphard et al. 2012). Fuel treatments within HIZs and surrounding undeveloped areas could help reduce the exposure of homes to radiant heat and short-range ember cast.

Potential exposure to radiant heating and long- and short-range ember cast is widespread across GVFPD, and this awareness should encourage residents and business owners to complete home hardening practices to reduce the risk of ignition.

[4] It is recommended to use this analysis to assess relative risk across the entire GVFPD and not to evaluate absolute risk to individual homes. FlamMap and the approach of Beverly and others (2010) cannot account for defensible space, the fire resistance of materials used in home construction, and other fine-scale variation in fuel loads that contribute to the ignition potential of individual homes.

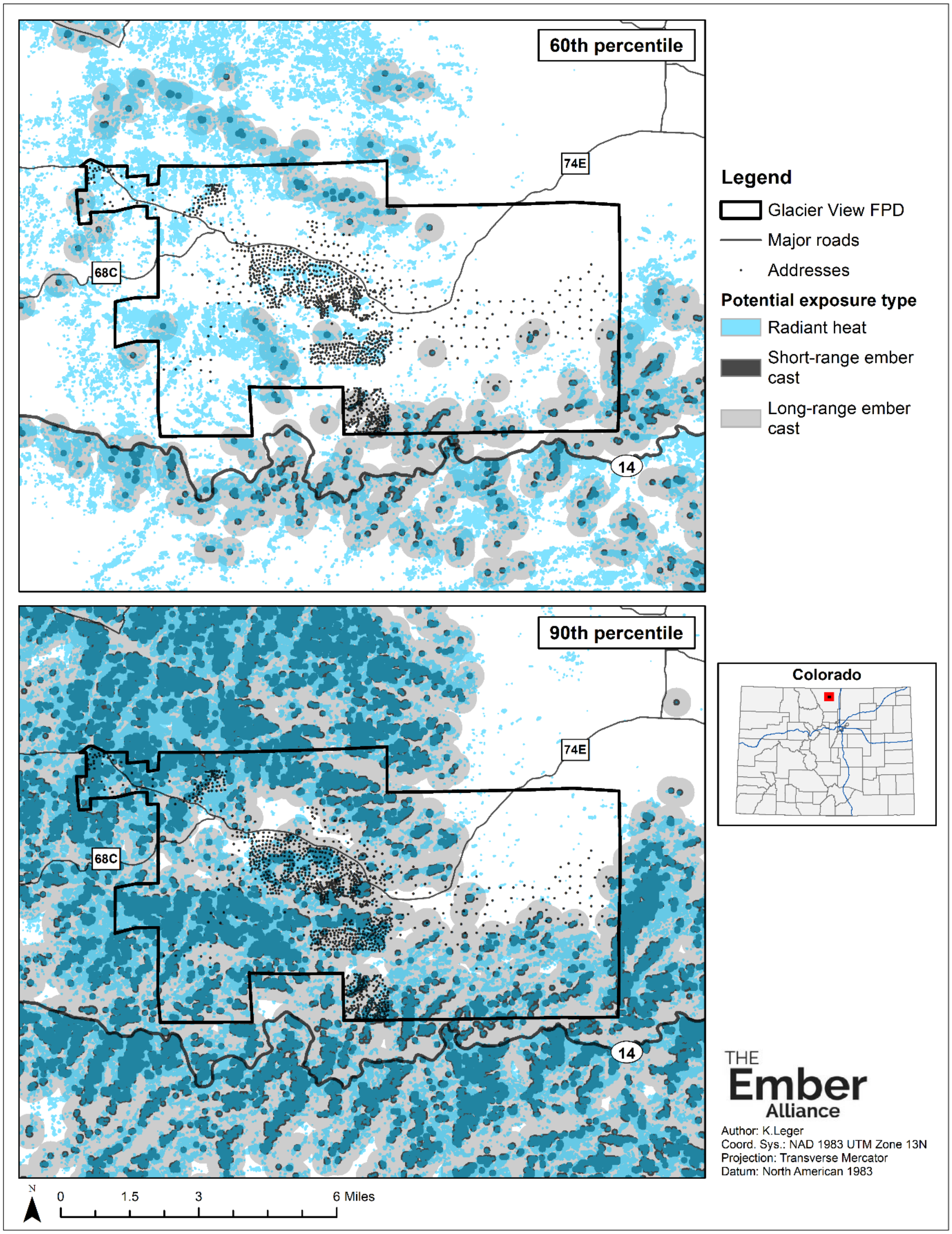


Figure 9.a.8. Predicted exposure to radiant heat and short-and long-range ember cast under 60th and 90th percentile fire weather conditions in GVFPD.

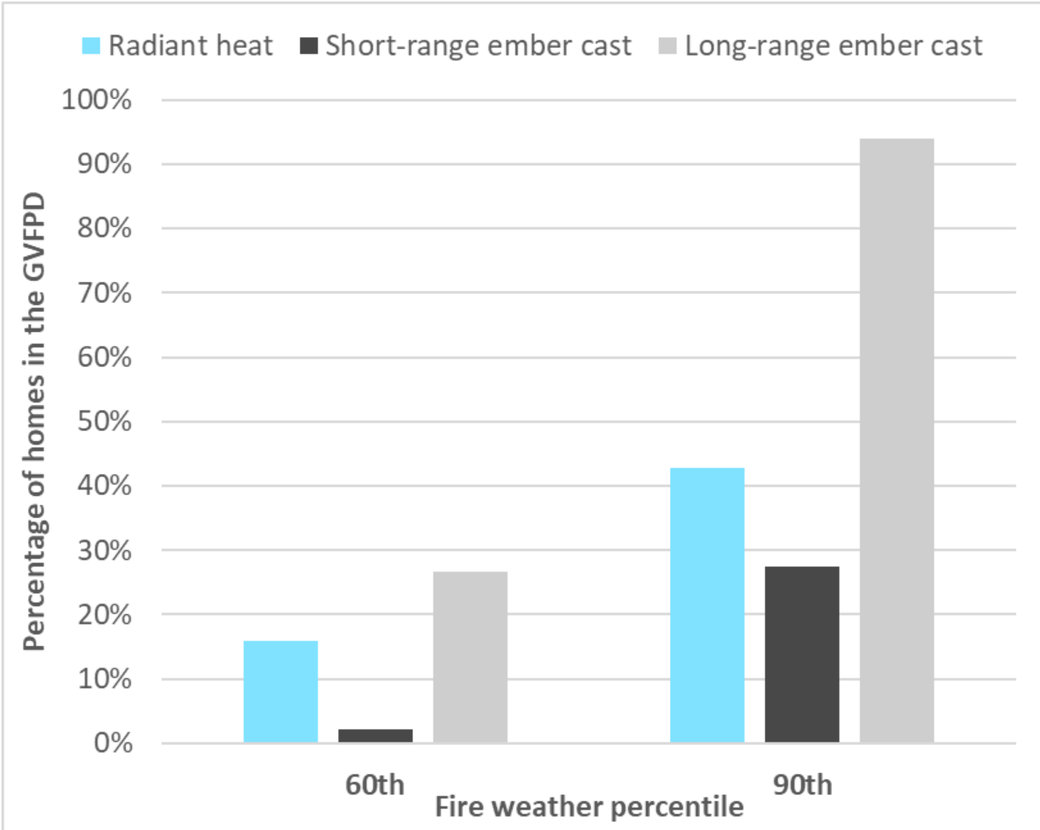


Figure 9.a.9. Percentage of homes potentially exposed to radiant heat and short-and long-range ember cast under 60th and 90th percentile fire weather conditions in GVFPD. Colors correspond to the legend in **Figure 9.a.8**.

Table 9.a.7. Percentage of structures in the entire GVFPD and each CWPP plan unit at risk of exposure to radiant heat, short-range ember cast, and/or long-range ember cast.

	60th Percentile Weather			**90th Percentile Weather**		
	Radiant Heat	Short-Range Ember Cast	Long-Range Ember Cast	Radiant Heat	Short-Range Ember Cast	Long-Range Ember Cast
Entire GVFPD	**16%**	**2%**	**27%**	**43%**	**27%**	**94%**
Deer Meadows	0%	1%	27%	8%	9%	57%
Glacier View Meadows 1	15%	0%	21%	39%	27%	97%
Glacier View Meadows 2	13%	0%	19%	45%	26%	100%
Glacier View Meadows 3	32%	16%	84%	61%	42%	98%
Green Mountain Meadows	2%	0%	2%	11%	12%	82%
Lady Moon	54%	0%	42%	92%	67%	100%
North Rim	15%	0%	25%	55%	35%	100%
Red Feather Highlands	25%	0%	10%	79%	29%	100%

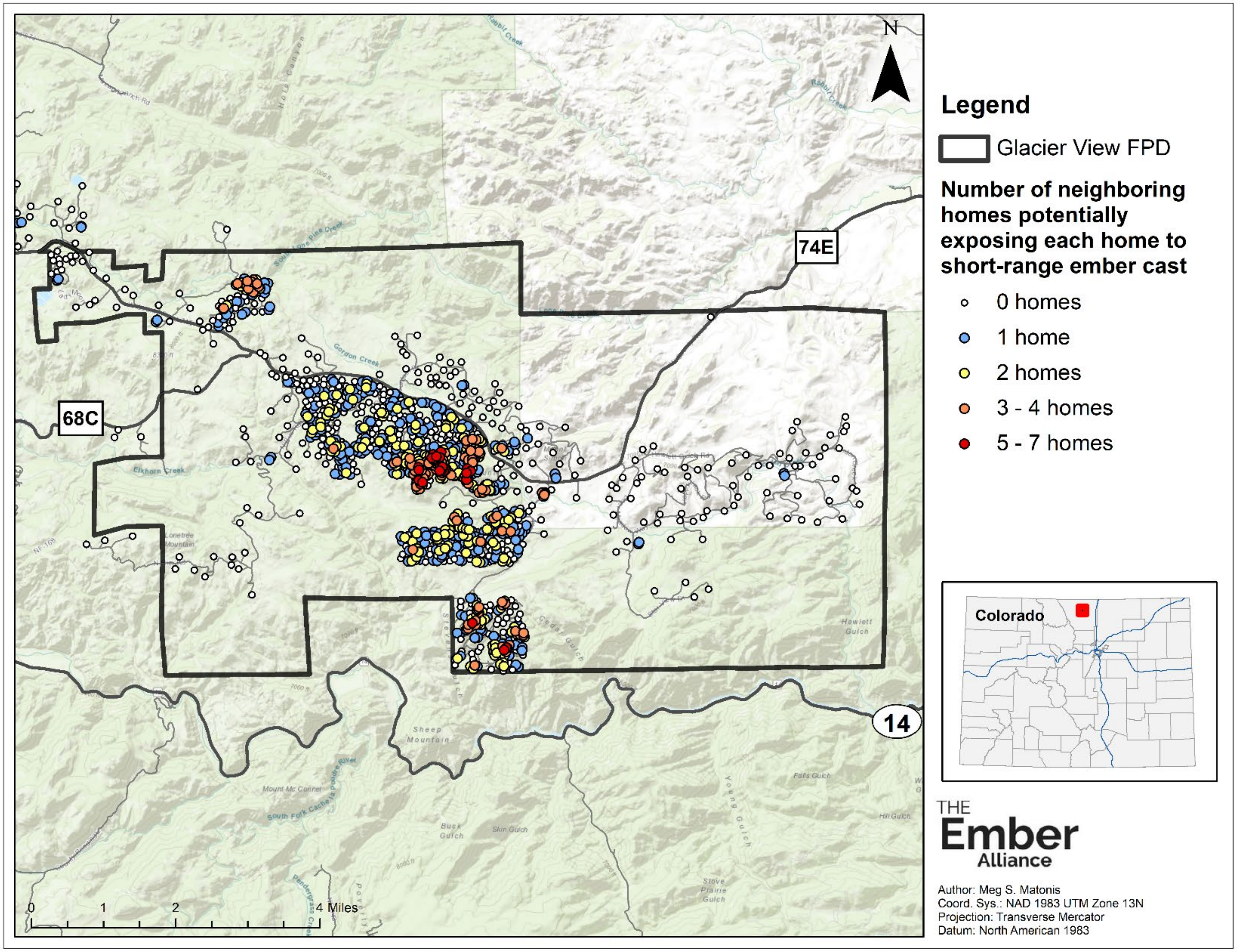


Figure 9.a.10. About 60% of homes in GVFPD could be exposed to short-range ember cast from at least one neighboring home. Homes within 100-meters of other homes are at greater risk of home-to-home ignitions from short-range ember cast (Syphard et al. 2012).

A.4. Evacuation

Evacuation concerns can weigh heavily on the minds of many residents in GVFPD. The death of 86 people in Paradise, California during the 2018 Camp Fire, many of whom were stranded on roadways during evacuation, underscores the importance of evacuation preparedness and fuel mitigation along evacuation routes.

Evacuation Modeling and Scenarios

> **Keep in mind:** Simulation models cannot account for all variables present during an evacuation, so these results are useful as a guide for strategic planning rather than a depiction of what will occur in any specific evacuation event.

We modeled evacuation time and roadway congestion using ArcCASPER (Shahabi and Wilson 2014). The ArcCASPER model considers roadway capacity, road speed, number of cars evacuating per address, and the relationship between roadway congestion and reduction in travel speed. The model assumes simultaneous departure of vehicles, but it starts by determining evacuation routes for vehicles with the longest distance to travel. The purpose of the model is to minimize evacuation time for the entire district, not to minimize the evacuation time for each individual resident.

The model's algorithm starts with the evacuee farthest from predefined evacuation destinations and finds that evacuee's shortest path to a predefined safe evacuation location. It iteratively continues this process until there are no more evacuees left. During the analysis, ArcCASPER dynamically updates how long it takes to traverse each road segment based on the number of evacuees using that route and the relationship between traffic and travel speeds. The model adjusts evacuation routes until it minimizes the global evacuation time (i.e., the time it takes for all evacuees to reach a safe evacuation location).

For our analysis, we used an exponential traffic model with a critical density of 10 and saturation density of 100. The critical density is the maximum number of cars that can be on a road with two lanes (one lane in each direction) without a reduction in travel speed, and saturation density is the number of cars on the road at which the traversal speed reduces to half the original speed.

ArcCASPER does not account for unpredictable events, such as roadway blockage from accidents or reduced visibility from smoke. It also does not consider emergency vehicles traveling the opposite direction of evacuation traffic.

Based on research by Beloglazov et al. (2016), we assumed that it takes 30 minutes for individuals to mobilize and depart their homes after receiving a mandatory evacuation order. We conducted analyses with four different scenarios for evacuation directions: (1) directing residents to a location west of GVFPD on County Road 74E (Red Feather Lakes Road), (2) directing residents to a location northeast of GVFPD on County Road 74E, (3) direction residents to a location west of GVFP on County Road 68C, and (4) directing residents to any of the three previously mentioned locations. We used roadway data from OpenStreetMap and the Colorado Department of Transportation, with modifications to the road network based on local expertise.

For each evacuation scenario, we evacuated all 1,046 developed residencies within the GVFPD plus 25 residencies immediately adjacent to GVFPD that would likely evacuate simultaneously with those inside the GVFPD boundary. We modeled two vehicles leaving each residential. We did not include additional traffic that might be on the road from visitors, recreationists, and commuters not residing in or immediately adjacent to GVFPD. It is impossible to know exact numbers of additional evacuation traffic that could be present during a wildfire evacuation because numbers of additional vehicles fluctuate throughout the day, week, and year. In total, our evacuation scenarios included 2,145 evacuating vehicles.

The intent of running the evacuation model for all of GVFPD at once was to assess an extreme scenario when the most cars would be on the road at the same time. This allowed us to identify areas of major congestion during a large-scale evacuation. Even if evacuation orders are staggered for different portions of GVFPD, it is unlikely that all residents in an evacuation unit would evacuate before the next unit begins evacuating. It is more likely that evacuation orders would be staggered but overlap in time.

Estimates from ArcCASPER are useful for determining relative evacuation capacity and congestion across GVFPD and are not intended to predict household-specific evacuation times. Law enforcement personnel will direct traffic during a wildfire event, so our evacuation modeling is not meant to suggest alternate routes for individual residents. **Residents need to follow guidance from law enforcement personnel during evacuation events, practice safe driving, and practice good evacuation etiquette (e.g., allowing cars to merge and not texting or stopping to take photographs).**

Evacuation Congestion

It is important for law enforcement personnel to plan for areas of high congestion when making decisions about how to conduct actual evacuations in GVFPD. Roads were categorized by how much congestion may occur, and how much longer it may take to evacuate compared to everyday scenarios without evacuation traffic. We assessed evacuation congestion under four scenarios with different evacuation destinations because the direction that residents could be routed during a wildfire emergency is dependent on the location of the wildfire and wildfire behavior.

Depending on the evacuation destination, portions of County Road 74E and County Road 68C could experience extreme congestion, which means travel times were predicted to take at least 4 times longer with evacuation traffic than without evacuation traffic (**Figure 9.a.11**). High evacuation congestion could also be experienced along Mount Champion Drive, Cucharas Mountain Drive, Lizard Head Mountain Drive, Mount Harvard Road, Mount Moriah Road, and Eiger Road in the central portion of GVFPD south of County Road 74E.

The road networks in Deer Meadows in the eastern part of GVFPD and Green Mountain Meadows in the central part of GVFPD appear capable of handling evacuation traffic, with predictions not exceeding low congestion (travel times taking 1.1-2 times longer with evacuation traffic), with the exception of Deer Meadow Way in Deer Meadows and Mount Simon Drive in Green Mountain Meadows that could experience moderate congestion (travel times taking 2.1-3 times longer).

It is important to reiterate that congestion modeling does not account for unexpected barriers such as cars breaking down, car accidents, road closures, etc. It also does not take into consideration additional traffic aside from individual evacuation groups; if an evacuation were ordered over a weekend, these congestion indices would increase dramatically. However, this analysis does show areas that are prone to traffic build up even under the best-case scenario.

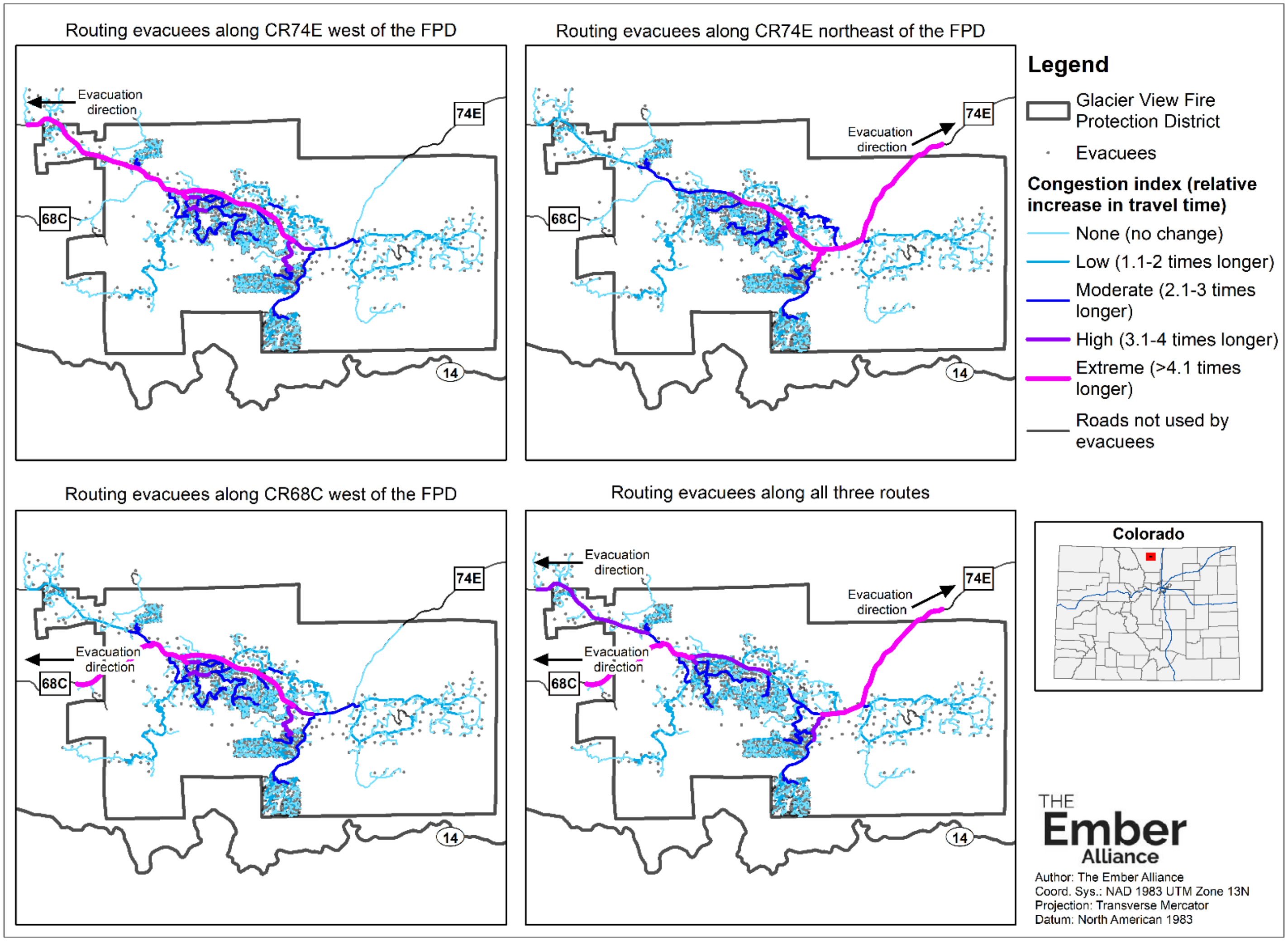


Figure 9.a.11. Predicted congestion across GVFPD under a simultaneous district-wide evacuation order. Congestion categories (none, low, moderate, high, extreme) are based on the ratio between the time required to traverse a segment of road with congestion vs. without congestion. Evacuation congestion was simulated for two vehicles leaving each residency. Evacuation scenarios were conducted for directing residents to (1) a location west of GVFPD on County Road 74E (Red Feather Lakes Road), (2) a location northeast of GVFPD on County Road 74E, (3) a location west of GVFP on County Road 68C, and (4) any of the three previously mentioned locations. An interactive map with predicted evacuation congestion is available online at https://experience.arcgis.com/experience/225f72cc029c4e37a2acbdefc60b2140/page/Treatments/.

Evacuation Time

Evacuation time indicates how long it might take for a vehicle to receive an evacuation order, depart from an address, and reach an evacuation site. Estimates of evacuation time can serve as a benchmark for emergency pre-planning and strategic decision making.

> The actual time it would take to evacuate during a specific incident is influenced by a variety of factors not considered in this modeling effort, such as the staggering of evacuation orders, the nature of evacuation orders (i.e., voluntary versus mandatory), traffic accidents, delays from people stopping to take photographs, reduced visibility from smoke, etc.

Predicted evacuation times are highly dependent on the evacuation destination. Evacuation times were longest across GVFPD if everyone were routed northeast of GVFPD on County Road 74E, and evacuation times were shortest if residents are routed to any of the three destinations (west of GVFPD on County Road 74E, northeast of GVFPD on County Road 74E, or west of GVFP on County Road 68C) rather than directing all residents to one destination (**Figure 9.a.12**; **Figure 9.a.13**). However, routing residents in all three directions might not be possible depending on wildfire location and wildfire behavior.

Residents in the Lady Moon and Red Feather Highlands CWPP plan units had the shortest evacuation times for the three scenarios with egress to the west of GVFPD due to their proximity to Country Road 74E and County Road 68C. Long evacuation times were consistently observed for residents in Glacier View Meadows 3 and Glacier View Meadows 2 due to high density of homes, fewer major egress points, and a greater distance from County Road 74E. Residents in Deer Meadows could experience long evacuation times if residents were routed to the west of GVFPD because evacuation traffic would already start backing up on Country Road 74E as they approached the western boundary of GVFPD.

These model results should be interpreted as relative ratings showing which neighborhoods may take longer than others to evacuate. It is important to note that these times are given under the best-case scenario in which residents are safely and efficiently evacuating, there are no accidents blocking the roads, there is no smoke hindering visibility, and evacuation groups are departing individually. It is important for residents to be prepared so they can leave promptly in the case of an evacuation order.

> **How realistic are estimated evacuation times from ArcCASPER?**
>
> The estimates we present make assumptions about the number of vehicles leaving each residency and the time it takes for residents to mobilize and depart after receiving an evacuation order. We could not account for unpredictable events in this modeling effort, such as roadway blockage from accidents or reduced visibility from smoke. It is impossible to know what actual evacuation times might be during a wildfire incident. There has never been an actual district-wide evacuation, and law enforcement personnel make evacuation decisions based on specific fire behavior during an incident.

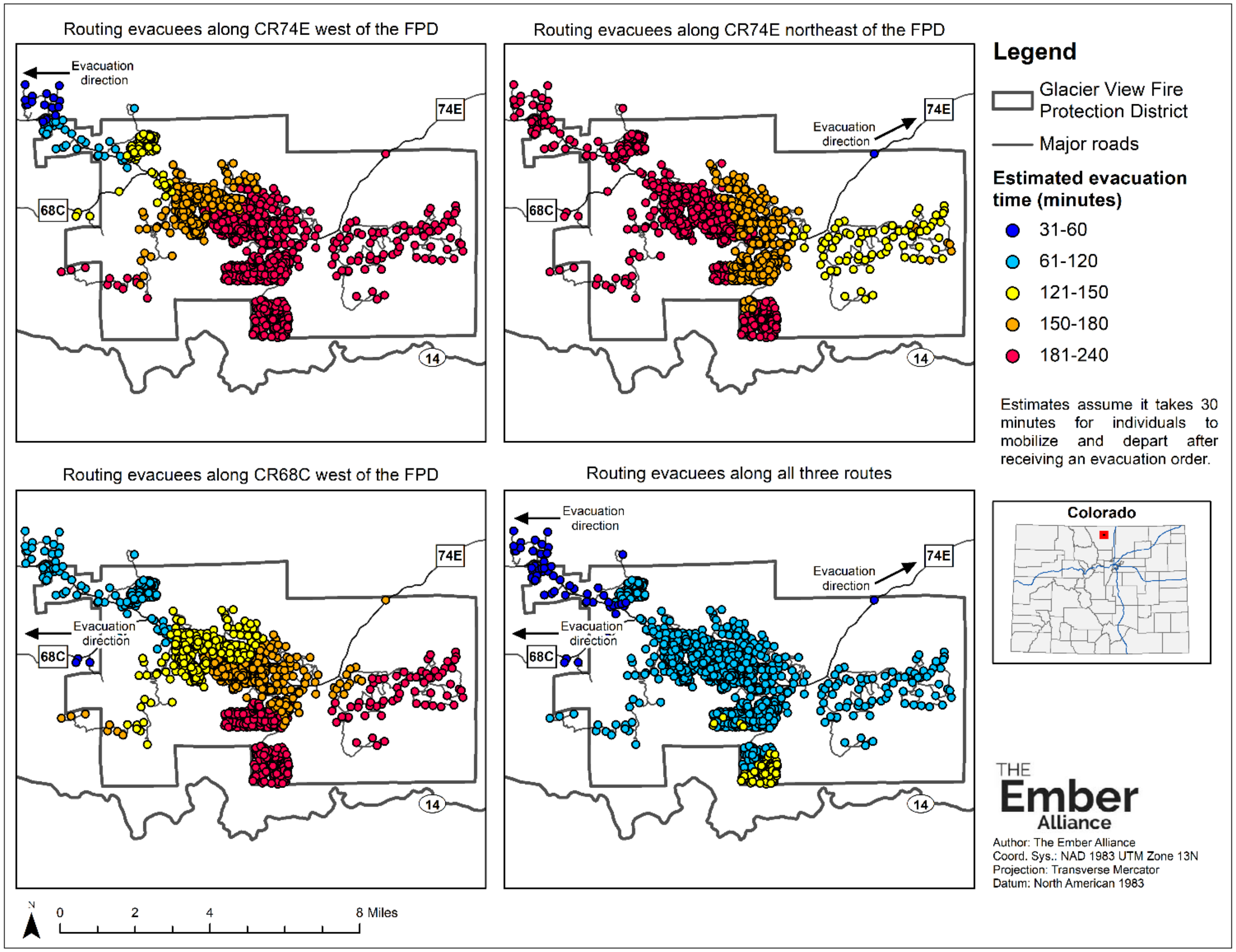


Figure 9.a.12. Predicted evacuation times across GVFPD under a simultaneous district-wide evacuation order. Evacuation time is how long it takes for a resident to receive an evacuation order, prepare their belongings, depart, and reach a safe evacuation route. We assumed that it takes 30 minutes for individuals to mobilize and depart after receiving an evacuation order. Evacuation times were simulated for two vehicles leaving each residency. Evacuation scenarios were conducted for directing residents to (1) a location west of GVFPD on County Road 74E (Red Feather Lakes Road), (2) a location northeast of GVFPD on County Road 74E, (3) a location west of GVFP on County Road 68C, and (4) any of the three previously mentioned locations.

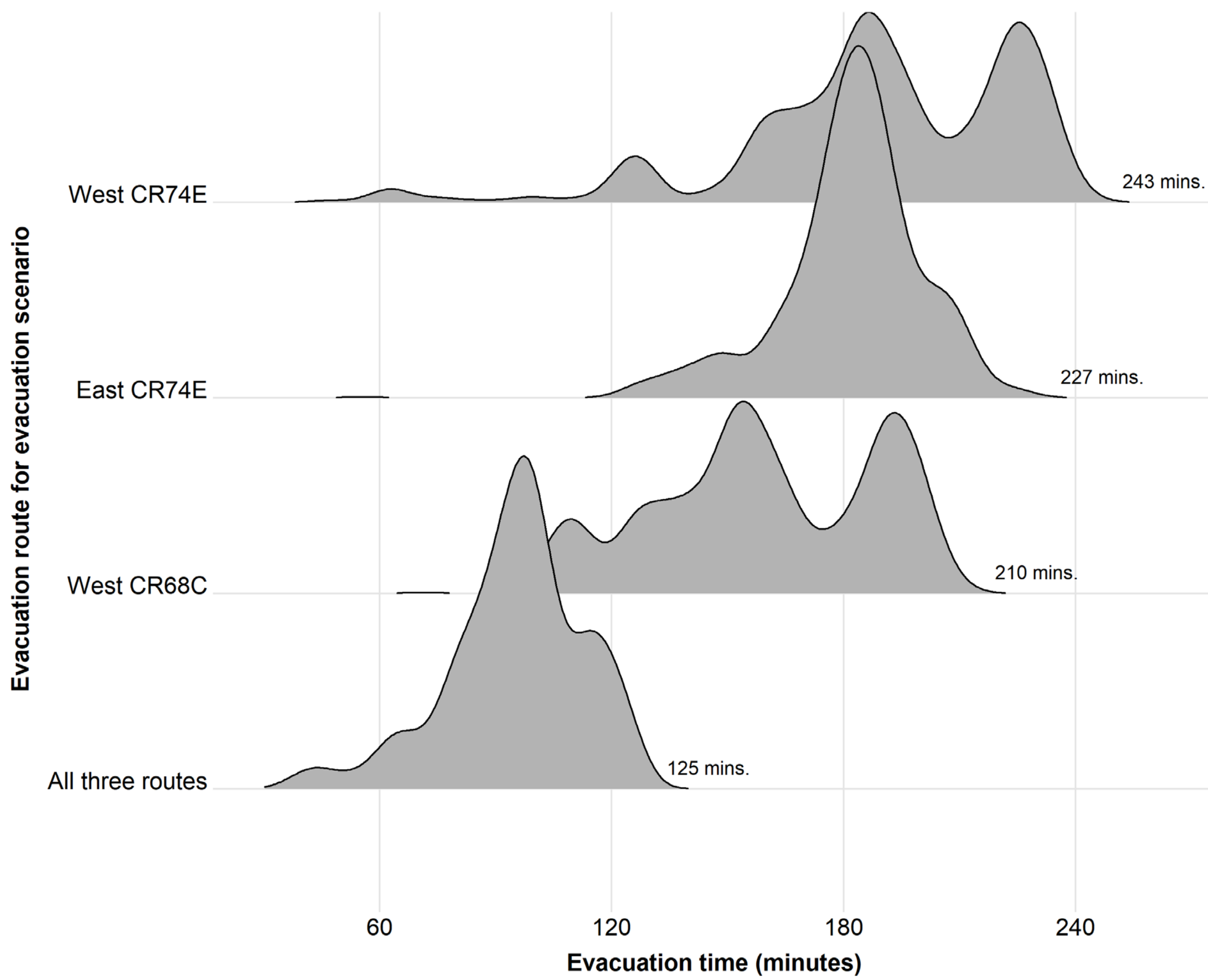


Figure 9.a.13. Distribution of predicted evacuation times under a simultaneous district-wide evacuation order for GVFPD. Minutes displayed to the right of distributions indicate the total time it took to evacuate all vehicles out of GVFPD. We assumed that it takes 30 minutes for individuals to mobilize and depart after receiving an evacuation order. Evacuation times were simulated for two vehicles leaving each residency. Evacuation scenarios were conducted for directing residents to (1) a location west of GVFPD on County Road 74E (Red Feather Lakes Road), (2) a location northeast of GVFPD on County Road 74E, (3) a location west of GVFP on County Road 68C, and (4) any of the three previously mentioned locations.

A.5. Roadway Survivability

Tragedies have occurred when flames from fast-moving wildfires burn over roads while residents are evacuating. Residents can perish in their vehicles trapped on the road, and egress routes can become blocked from flames. **Mitigation actions along sections of road with high risk for non-survivable conditions during a wildfire can increase the chances of survival for residents stranded in their vehicles during a wildfire and decrease the chance that roadways become impassable due to flames.**

We utilized fire behavior predictions to identify road segments that could experience non-survivable conditions during a wildfire. We used roadway data from OpenStreetMap and the Colorado Department of Transportation, with modifications to the road network based on local expertise. We identified "non-survivable roadways" as portions of roads adjacent to areas with predicted flame lengths greater than 8 feet. Drivers stopped or trapped on these roadways could have a low chance of survival due to radiant heat emitted from fires of this intensity. This assumption is based on the Haul Chart, which is a standard tool used by firefighters to relate flame lengths to tactical decisions (**Table 9.a.2**) (NWCG 2019). Direct attack of a flaming front is no longer feasible once flame lengths exceed about 8 feet due to the intensity of heat output. Flames greater than 8 feet could also make roads impassable and cut residents off from egress routes. Non-survivable conditions are more common along roads lined by thick forests with abundant ladder fuels, such as trees with low limbs and saplings and tall shrubs beneath overstory tress (**Figure 9.a.14**).

Under moderate 60th percentile fire weather, 7% of the roads in GVFPD could experience non-survivable conditions, and this percentage rises to 28% under extreme 90th percentile fire weather (**Figure 9.a.15**; **Table 9.a.8**). The highest percentage of potentially non-survivable roads is in the Lady Moon CWPP plan unit, and the greatest mileage of potentially non-survivable roads is in the Glacier View Meadows 1 plan unit. Under 90th percentile fire weather conditions, at least a third of roads are potentially non-survivable in 6 of 8 CWPP plan units (**Table 9.a.8**).

Some non-survivable road segments are part of key evacuation routes and a high priority for mitigation to reduce fuels and potential flame lengths, including portions of County Road 74E and County Road 68C. We identified these areas as evacuation pinch points and incorporated them into recommendations for roadway fuel treatments across the GVFPD (see **Section 4.c. Roadway Fuel Treatment Recommendations**).

Survivable Roadways	Potentially Non-Survivable Roadways
	
	

Figure 9.a.14. Some roads and driveways in GVFPD have been well mitigated by removing tall trees and saplings, removing limbs on the remaining trees, and keeping grass mowed (left images). Other roads could experience potentially non-survivable conditions because they are lined by thick forests that have an abundance of ladder fuels (right images). Photo credits: The Ember Alliance.

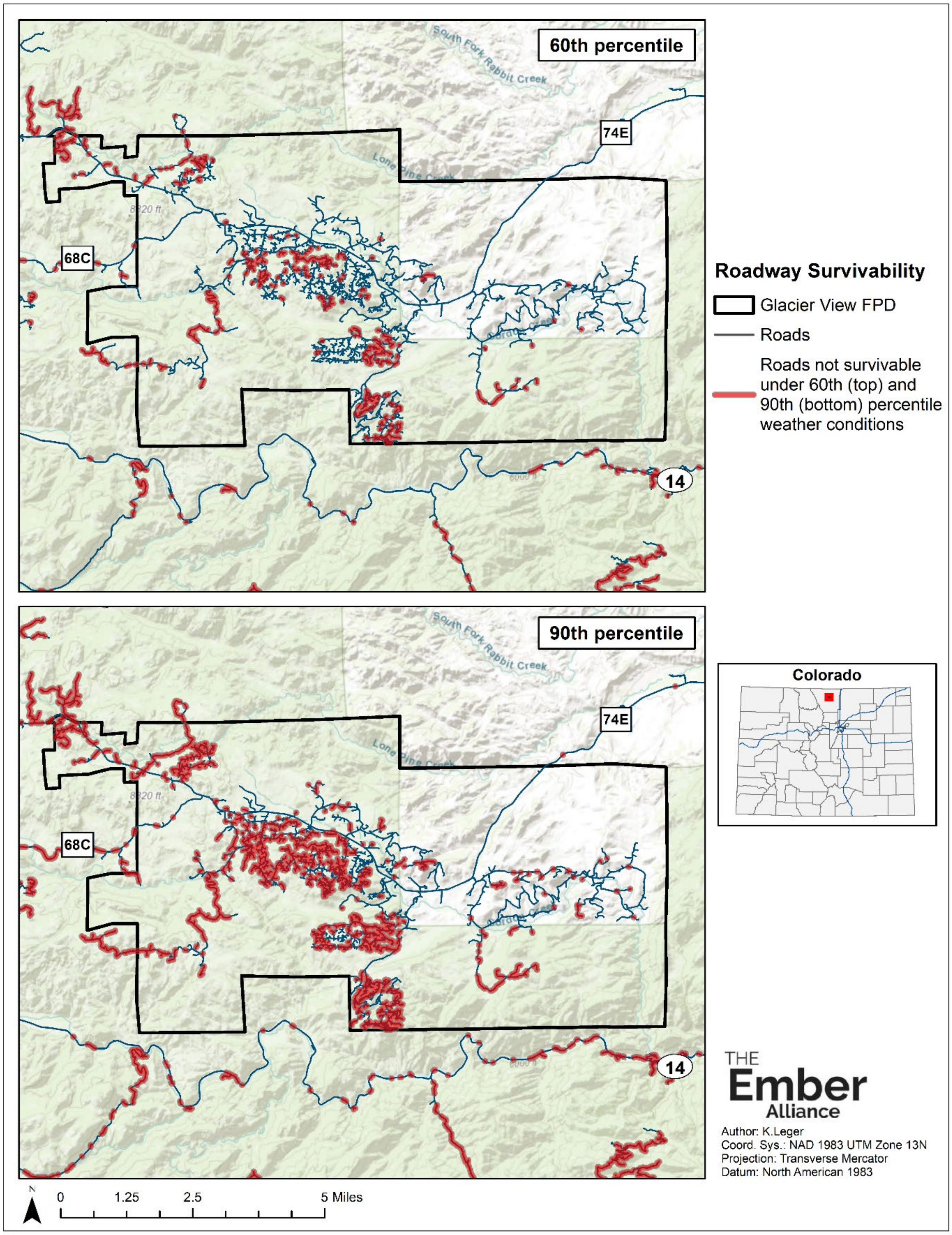


Figure 9.a.15. Under 60th percentile fire weather conditions, 7% of roads and driveways in GVFPD could potentially experience non-survivable conditions during wildfires (i.e., flame lengths over 8 feet). This percentage rises to 28% under 90th percentile fire weather conditions.

Table 9.a.8. Percentage of potentially non-survivable roads across the entire GVFPD and in each CWPP plan unit. Darker colors indicate plan units with higher percentages of non-survivable roads.

	60th Percentile		90th Percentile	
	Miles of Roads	Percent of Roads	Miles of Roads	Percent of Roads
Entire GVFPD	**11.6**	**7%**	**45.3**	**28%**
Deer Meadows	0.5	2%	2.4	9%
Glacier View Meadows 1	3.8	7%	18.0	33%
Glacier View Meadows 2	1.0	6%	6.0	33%
Glacier View Meadows 3	2.0	13%	5.7	38%
Green Mountain Meadows	0.4	2%	1.4	8%
Lady Moon	1.5	30%	2.7	54%
North Rim	1.4	17%	3.8	46%
Red Feather Highlands	1.0	12%	4.2	51%

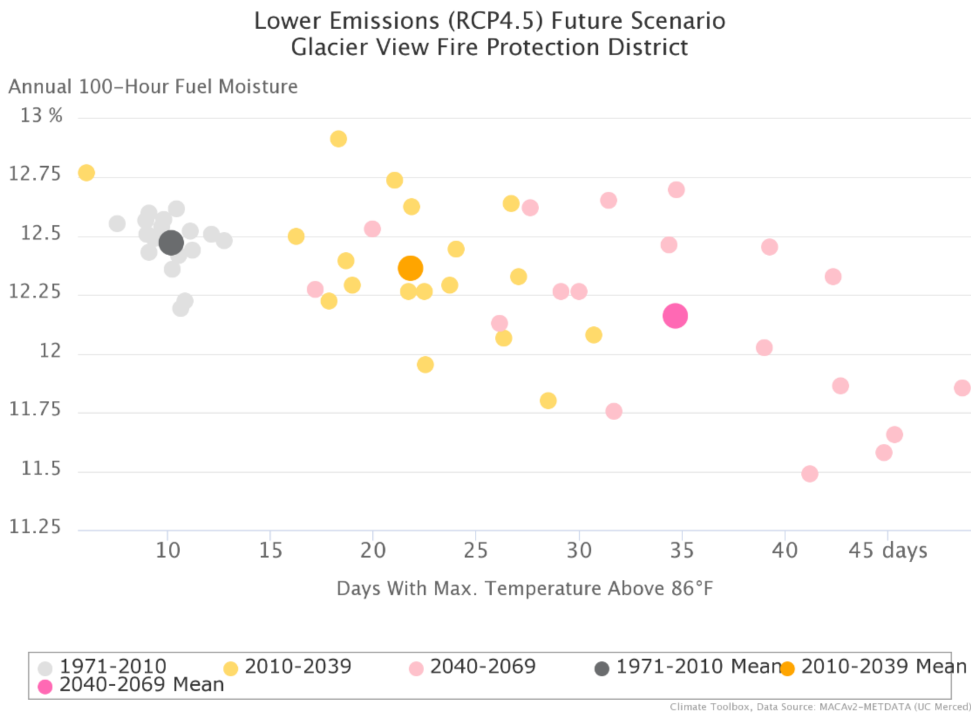
A.6. Climate Change Assessment

Climate change has a measurable impact on fire intensity and frequency, and this is likely to continue given current trajectories. To assess how different climate scenarios might affect the fire district, we used the Climate Toolbox's Future Climate Scatter to project future weather scenarios for GVFPD. This tool models climate scenarios for the next fifty years using the Representative Concentration Pathways 4.5 and 8.5. These two models forecast future climate scenarios based on different levels of global greenhouse gas emissions. We analyzed four variables: expected maximum temperature each year and the number of days expected to be "high fire danger" days, and annual 100-hour fuel moisture levels and days with a heat index over 90° Fahrenheit.

The models predict that under moderate or intense greenhouse gas concentrations, GVFPD will experience hotter summer temperatures and an increased number of days considered to be high fire danger. In the next 50 years, it would be reasonable to expect maximum summer temperatures to increase by 5-7° Fahrenheit, and **the number of high fire danger days is likely to increase by 13-17 more days per year (Figure 9.a.16, Figure 9.a.17)**.

Fire behavior models from **Section A.2** account for RAWS weather inputs from 2014-2020. They do not include future weather predictions. These predictions are presented to add a layer of depth regarding the future of fire danger in GVFPD but are not used in conjunction with other models. Fire behavior has the potential to be extreme based on the weather from the past twenty years, and it may be even more extreme and frequent under the future conditions presented here. This behavior could include longer flame lengths, faster rates of spread, higher fire severity, and more crown fire activity. More extreme fire behavior increases danger to the life safety of residents, as well as to their homes, businesses, and community resiliency.

Figure 9.a.16. Potential future weather conditions in GVFPD modelled with the Climate Toolbox Future Climate Scatter (Hegewisch et al. 2021). The top graph is modelled under the RCP 4.5 scenario, where greenhouse gas emissions stabilize before the year 2100, peaking around 2040. The bottom graph is modelled under the RCP 8.5 scenario, where greenhouse gas emissions are not curtailed by 2100.



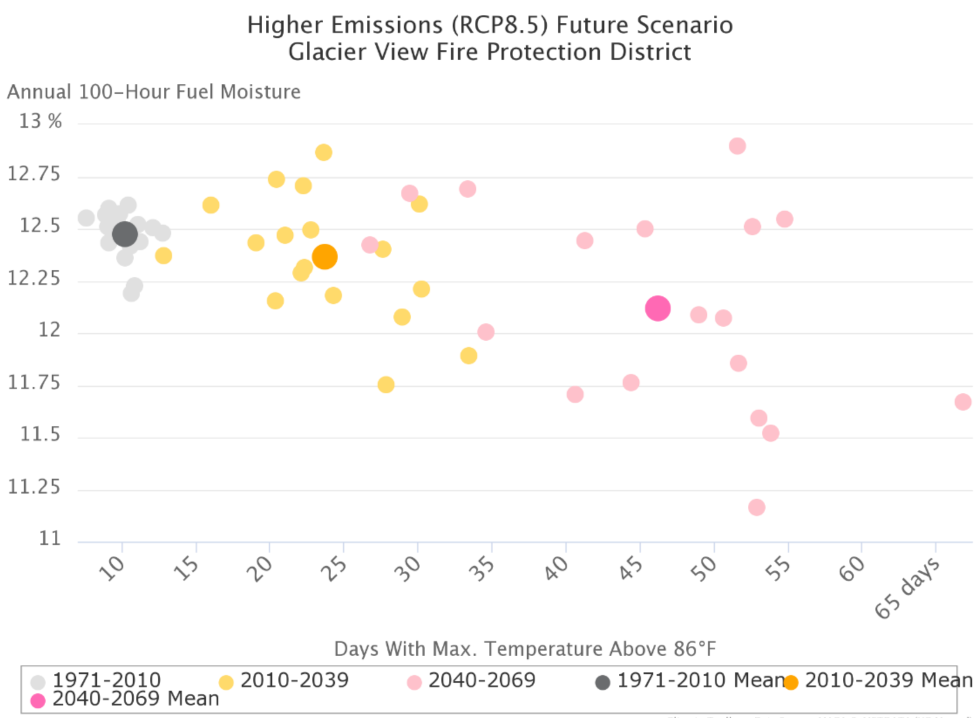


Figure 9.a.17. Potential future conditions that impact fire behavior and suppression activities in GVFPD modelled with the Climate Toolbox Future Climate Scatter (Hegewisch et al. 2021). The top graph is modelled under the RCP 4.5 scenario, where greenhouse gas emissions stabilize before the year 2100, peaking around 2040. The bottom graph is modelled under the RCP 8.5 scenario, where greenhouse gas emissions are not curtailed by 2100.

Appendix B. Treatment Prioritization Methodology

B.1. Plan Unit Hazard Assessment

We compared the **relative** risk that wildfires pose to life and property in eight plan units across GVFPD (**Figure 3.c.2**). Homes across GVFPD have risk from wildfire damage, but to help prioritize hazard mitigation, we developed a rating of ***relative risk***. A plan unit receiving a relative rating of "moderate risk" has risk factors that are lower than risk factors in other plan units, but it is still an area with wildfire hazards. We assessed hazards in four categories: fire risk, fire suppression challenges (e.g., limited hydrant availability and engine access), evacuation hazards, and home ignition zone hazards. We developed the ratings of relative risk specifically for GVFPD, so the assessment is not suitable for comparing GVFPD to other communities.

Our assessment was based on predictions of fire behavior, potential exposure to radiant heat and ember cast, roadway survivability, and evacuation time, as well as an on-the-ground assessment of each plan unit. In summer of 2021, The Ember Alliance drove around the GVFPD and used a modified version of the NFPA Wildfire Hazard Severity Form Checklist (NFPA 299 / 1144) to rate home ignition zone hazards within each plan unit.

Hazard Rating Scale

A rating scale was developed specifically for GVFPD based on the range of values observed across the community (Table 9.b.1). The purpose of the assessment is to compare relative hazards within the community and is not suitable for comparing GVFPD to other communities.

Table 9.b.1. Relative hazard rating matrix for GVFPD.

	Points		**Relative hazard rating**		
Hazard category	Max. possible	Range of values observed GVFPD plan units	Moderate	High	Extreme
A. Fire risk	55	7 – 55	<20	20-44	≥45
B. Fire suppression challenges	45	13 – 28	<20	20-24	≥25
C. Evacuation hazards	40	10 – 35	<20	20-24	≥25
D. Home ignition zone hazards	53	12 – 31	<15	15-19	≥20
Overall risk	193	62 – 130	<80	80-99	≥100

Relative Risk Rating Form

A. Fire Risk	Points
1. Average flame length[1]	
<11 feet	0
11-15 feet	6
>15 feet	12
2. Crown fire activity (percent area predicted for active crown fire)[1]	
<3%	0
3-5%	6
>5%	12
3. Exposure to extreme radiant heat from grass/shrub and shrub fuel types (percent area with flame lengths > 8 feet)[1]	
<10%	0
10-25%	6
>25%	12
4. Conditional burn probability[1]	
<0.20%	0
0.20-0.25%	3
>0.25%	6
4. Additional risk factors	
Mid-slope homes	2
Homes on ridge tops	2
Saddles / ravines / chimneys	4
Utilities (gas / electric) placement	
All underground	0
Infrequent overhead powerlines	3
Frequent overhead powerlines	5
A. Total points possible	**55**

[1]Predictions from FlamMap under 90th percentile fire weather conditions for plan unit and adjacent watersheds.

B. Fire Suppression Challenges	Points
1. Average response time[2]	
<8 minutes	0
8-15 minutes	3
>15 minutes	5
2. Percentage of homes near hydrants	
>75%	0
25-75%	5
<25%	10
3. Presence of dip / draft sites	
Not necessary due to hydrant availability	0
At least one dip / draft site	0
No dip / draft site	5
4. Road/driveway accessibility for Type 3 engines (percent of roads/driveways)	
>90%	0
75-90%	5
50-75%	10
<50%	15
5. Presence of legible and reflective signs (percent of roads and homes)	
>90%	0
75-90%	3
<75%	5
6. Presence / absence of HazMat	
Absent	0
Present	5
B. Total points possible	**45**

[2] Response time estimated using Service Area analysis in ArcMap.

C. Evacuation Hazards	Points
1. Number of lanes in each direction	
At least 1 lane on >75% of roads	0
At least 1 lane on >50-75% of roads	5
Less than 1 lane on >50% of roads	10
2. Number of major egress directions from plan unit	
≥3	0
2	5
1	10
3. Mean household evacuation time[3]	
<60 minutes	0
60-95 minutes	5
>95 minutes	10
4. Percentage of road with non-survivable conditions under 90th percentile fire weather	
<10%	0
10-40%	5
>40%	10
C. Total points possible	**40**

[3]Estimates from ArcCASPER (see **Appendix A.4 Evacuation Modeling and Scenarios** for methodology and assumptions).

D. Home Ignition Zone Hazards	Points
1. Roof construction material	
Class B or C on <10% of homes	0
Class B or C on 10-15% of homes	5
Class B or C on >25% of homes	10
Class C on >50% of homes	15
2. Percent of homes with combustible siding / decking	
<10%	0
10-50%	5
>50%	10
3. Percent of homes with wooden fences within defensible space zone 1	
<10%	0
10-25%	1
>25%	2
4. Percent of homes with adequate mitigation of ladder and canopy fuels in defensible space zones 1 and 2	
>90%	0
75-90%	3
50-75%	6
<50%	10
5. Percent of homes with adequate maintenance of defensible space	
>90%	0
75-90%	1
50-75%	3
<50%	5
6. Percent of homes with additional hazards in zones 1 and 2 (e.g., wood piles, flammable lawn furniture)	
<10%	0
10-25%	1
25-50%	3
>50%	5
7. Average number of homes potentially exposed to short-range ember cast from other homes	
0 homes	0
1 home	3
>1 home	6
D. Total points possible	**53**

B.2. Fuel Treatment Prioritization Methodology

Foresters often conduct fuels treatments across forest stands—areas with similar tree sizes, species compositions, topography, and soils types. To create stand boundaries for our fuel treatment prioritization, we delineated small watersheds (i.e., an area of land where all precipitation falling in that area drains to the same location) and subdivided these into three hillslopes—one on each side of a stream or river and one above the headwaters of the watershed (**Figure 8.b.2**). We delineated hillslopes in ArcGIS using a modified version of the WEPP Hillslope Toolbox, which is based on TOPAZ (Topographic Parameterization Software) from the USDA Agricultural Research Service.

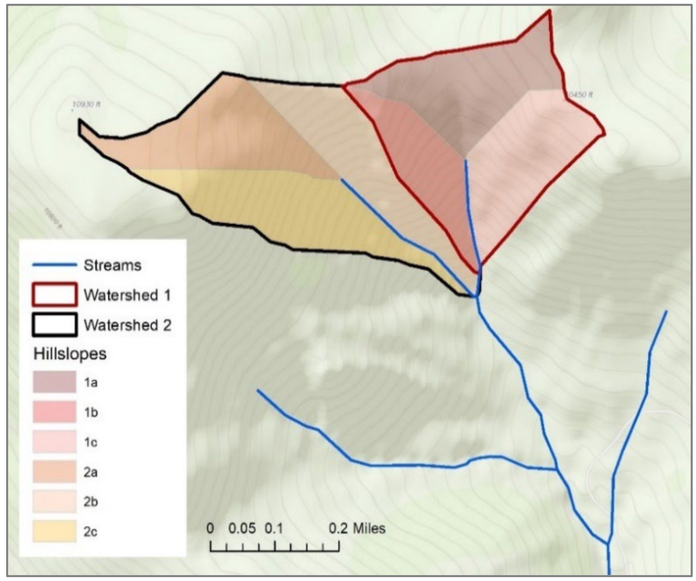


Figure 9.b.1. Depiction of small watersheds and their subdivided hillslopes.

We used 30 m resolution digital elevation models from the U.S. Geological Service, and delineated hillslopes with a critical source area of 60 hectares (about 150 acres) and a minimum source channel length of 330 feet (100 meters). Critical source area is the minimum allowable area above the head of a first-order channel, and minimum source channel length is the minimum length of a channel used to delineate watersheds.

We split hillslopes by major roads (Highway 14 and Red Feather Lakes Road) and only considered hillslopes north of Highway 14. We merged hillslopes <10 acres with larger, adjacent hillslopes. We delineated a total of 858 hillslopes in and around GVFPD averaging 135 acres in size and ranging from 10 to 750 acres—reasonable sizes for forest management projects in the WUI.

We developed a prioritization scheme to weight potential treatment units based on predicted fire behavior under 60th and 90th percentile fire weather conditions, homes potentially exposed to short-range ember cast and radiant heat from the unit, presence of priority roadway treatments, and percent slope within the unit (**Table 9.b.2**). We used a combination of 60th and 90th percentile weather conditions based on the range of conditions across GVFPD; the goal was to identify areas of greater risk, and variation was low for some fire behavior predictions under 90th percentile conditions, making it hard to set priorities. According to Hunter et al. (2007), use of mechanical equipment is generally infeasible on slopes greater than 35%. We assumed that handcrews can thin forests on slopes up to 50%. Since it is less feasible to treat steep areas, we lowered the priority of stands that had high percentages of inoperable slopes.

We prioritized roadside treatments based on non-survivable conditions (predicted flame lengths >8 feet) under 90th percentile fire weather conditions and the degree of potential congestion during an evacuation (**Table 9.b.3**.)

Table 9.b.2. Prioritization scheme for ranking potential treatment units to mitigate fire hazards within and adjacent to GVFPD.

Prioritization category	Maximum weight		First priority	Second priority	Third priority
Number of homes exposed to short-range ember cast from crown fire in the unit (**90th percentile fire weather**) and/or radiant heat from flame lengths > 8 feet (**60th percentile fire weather**)	30%	Cutoff	≥5 homes	1-4 homes	0 homes
		Weight	30	15	0
Contains priority roadways (non-survivable evacuation pinch point)	20%	Cutoff	At least one 1st priority roadway	At least one 2nd or 3rd priority roadway	No priority roadways
		Weight	20	10	0
Percent active crown fire (**90th percentile fire weather**)	15%	Cutoff	≥15%	5 - <15%	<5%
		Weight	15	8	0
Percent area with flame lengths > 8 feet (**60th percentile fire weather**)	15%	Cutoff	≥50%	25 - <50%	<25%
		Weight	15	8	0
Average conditional burn probability (**60th percentile fire weather**, average BP of 15 mph ESE winds and 15 mph WNW winds)	15%	Cutoff	≥0.3%	0.15 - <0.3%	<0.15%
		Weight	15	8	0
Percent of area with operable (slopes <50%)	5%	Cutoff	≥67%	50-66%	<50%
		Weight	5	3	0
Overall priority			**First priority**	**Second priority**	**Third priority**
		Cutoff	≥51	31 – 50	16 - 30

Table 9.b.3. Prioritization scheme for ranking potential roadside treatments to mitigate fire hazards along roadways in GVFPD.

Prioritization category	Conditions
First	• Non-survivable conditions (flame lengths >8 feet) under 90th percentile fire weather conditions • Major evacuation pinch points (congestion ratio ≥2.5) • Non-survivable portions of Red Feather Lakes Road and CR68C under 90th percentile fire weather conditions
Second	• Non-survivable conditions (flame lengths >8 feet) under 90th percentile fire weather conditions • Moderate evacuation pinch points (congestion ratio ≥1.5 to <2.5)
Third	• Non-survivable conditions (flame lengths >8 feet) under 90th percentile fire weather conditions • Minor evacuation pinch points (congestion ratio ≥1.0 to <1.5)