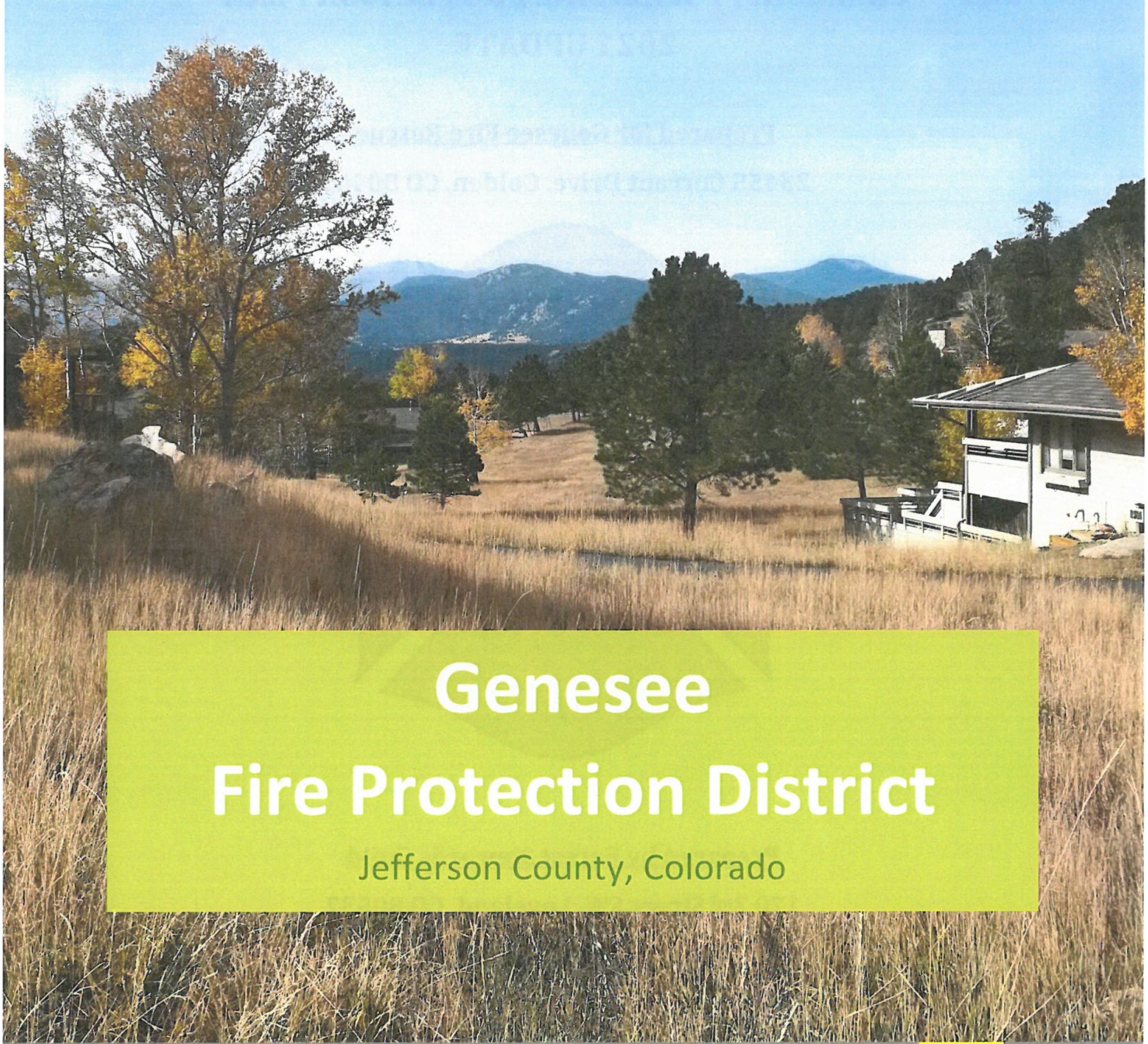
Forest Stewards Guild

2021



Genesee Fire Protection District

Jefferson County, Colorado

Community Wildfire Protection Plan

GENESEE FIRE PROTECTION DISTRICT
COMMUNITY WILDFIRE PROTECTION PLAN
2021 UPDATE

Prepared for Genesee Fire Rescue

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ACRONYMS

CSFS	Colorado State Forest Service
CWPP	Community Wildfire Protection Plan
DFPC	Division of Fire Prevention and Control
ERC	Energy Release Component
EVT	Existing Vegetation Type
FAC	Fire Adapted Community
GFPD	Genesee Fire Protection District
GFR	Genesee Fire Rescue
HIZ	Home Ignition Zone
HOA	Homeowner's Association
IIBHS	Insurance Institute for Business & Home Safety
IRPG	Incident Response Pocket Guide
ISO	Insurance Services Office
JCOS	Jefferson County Open Space
JCSO	Jefferson County Sherriff's Office
JeffCom	Jefferson County Communications Center Authority
NFPA	National Fire Protection Association
NWCG	National Wildfire Coordinating Group
RAWS	Remote Automatic Weather Stations
USFS	U.S. Forest Service
WUI	Wildland-Urban Interface

1. Introduction

1a. 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. 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 assist with funding gaps for fuel mitigation projects since many grants require an approved CWPP.

Elements of a holistic and actionable CWPP.

The 2021 CWPP for the Genesee Fire Protection District (GFPD) is a complete update of the 2008 plan, addressing a changing landscape and taking advantage of advances in fire science. It includes a wildfire risk analysis, prioritization of mitigation activities, and implementation recommendations. This document is a tool for Genesee Fire Rescue (GFR), land managers, residents, and homeowner's associations (HOAs) to begin prioritizing projects that make GFPD a safer and more resilient community to wildfire. Specific objectives of this project were as follows:

- Produce an actionable CWPP based on robust analyses of fuel hazards, burn probability, evacuation routes, and community values across the GFPD.
- 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.

In addition, this project involved creating strategic and tactical maps and evacuation pre-plans for GFR to increase community preparedness and safety of firefighters and residents. Maps and pre-plans were based on technical analyses and discussions with GFR, law-enforcement officers, and other partners. The Forest Stewards Guild—a national non-profit dedicated to sustainable forest management—worked with GFR to conduct fire behavior analyses and prepare the CWPP. The Guild and representatives from GFR 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. GFPD shares some risk factors common to past catastrophic wildfires across the country. The 2021 CWPP provides an assessment of wildfire risk in the GFPD and includes suggestions for residents, community leaders, and emergency responders to mitigate risk and enhance community safety.

Headquarters for Genesee Fire Rescue—the local fire department that protects the Genesee Fire Protection District. Photo from the Forest Stewards Guild.

1b. Stakeholder Engagement

Community engagement is a vital aspect of CWPP development and implementation. We released a 9-minute introductory CWPP video on YouTube in June 2020 to inform residents about the purpose and intent of the 2021 CWPP. The video was watched over 350 times—a testament to the community's high level of interest and engagement in issues around wildfires. We also posted information about the CWPP on the website for GFR.

Due to the outbreak of COVID-19, we were unable to hold in-person meetings with residents, so we conducted electronic surveys to provide opportunities for community involvement. In summer 2020, we surveyed HOA community managers, HOA board presidents, business property managers, and other community leaders for their perspectives on how best to interact with residents in the GFPD and for their sense of the community's current awareness, understanding, and commitment to wildfire preparedness. In August and September 2020, we surveyed Genesee residents to gauge their knowledge of wildfire and assess their concerns. Questions developed by the Wildfire Research group (WiRē) were instrumental in conducting the survey. Feedback from the community surveys informed the development of recommendations and priorities for the 2021 CWPP.

In early 2020, we contacted agencies and organizations with a shared interest in mitigation of wildfire hazards across the GFPD. Partners like Xcel Energy, Genesee Water and Sanitation District, and Jefferson County Road and Bridge Division have valuable assets within and adjacent to the community, and agencies like Denver Mountain Parks and Jefferson County Open Space manage land surrounding the GFPD. We are grateful to Xcel Energy and Genesee Water and Sanitation District for sharing geospatial data about their infrastructure across the GFPD.

We reached out to state-level agencies that facilitate fuel treatments, wildfire suppression, and prescribed burning, including the Colorado Division of Fire Prevention and Control (DFPC) and the Colorado State Forest Service (CSFS). We hosted a meeting with land managers from the Colorado State Forest Service, Denver Mountain Parks, Jefferson Conservation District, Jefferson County Open Space (JCOS), and the Genesee Foundation in January 2021, to discuss the findings of our fire behavior analyses and learn about their organization's fuel treatment priorities. We also met with representatives from the Jefferson County Sherriff's Office, including their Director of Emergency Management, in January 2021 to discuss evacuation concerns, methods to improve coordination among agencies, and approaches to evacuation pre-planning.

1c. Introduction to Wildfire Behavior and Terminology

Here we provide a summary of wildfire behavior concepts to help residents as they contemplate the findings of the 2021 CWPP and begin to implement recommendations. See the glossary at the end of the CWPP for the definition of key terms.

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 1c.1), and they are the variables that wildland firefighters pay attention to when assessing potential wildfire behavior during an incident (NWCG 2019).

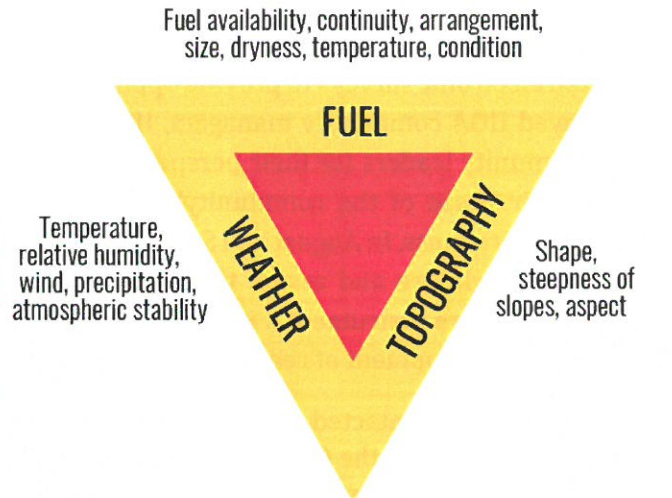


Figure 1c.1. Interactions between fuels, weather, and topography dictate fire behavior (source: California State University).

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. If you think of a campfire, flashy fuels are the kindling that you use to start the fire. Flashy fuels dry out faster than other fuel types when relative humidity drops or when exposed to radiant and convective heat[1]. Fires in grassy fuel types can be more predictable and easier for firefighters to control, but grassland fires can quickly spread across large areas.

Shrubs, small trees, and downed branches 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.

Large living trees, 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 and others 2019; Parsons and others 2014).

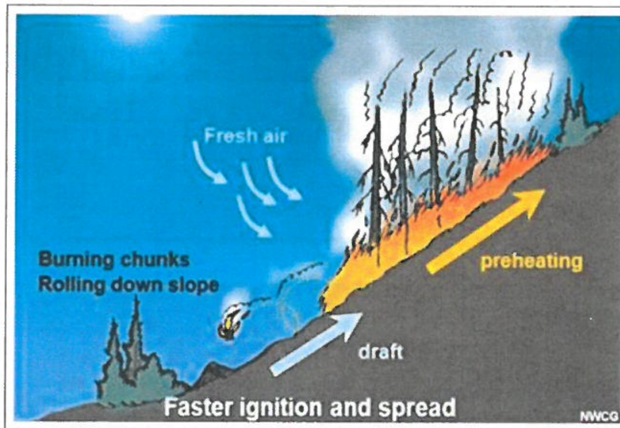
[1]See the glossary at the end of the CWPP for definitions of heat transfer methods.

Topography

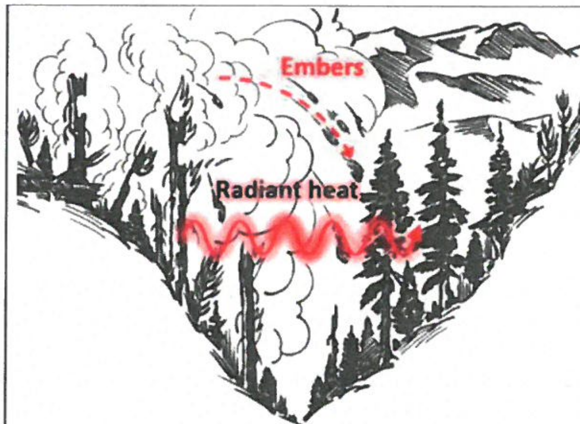
Topography (slope and aspect) influences fire intensity, speed, and spread. In the northern hemisphere, north-facing slopes experience less sun exposure during the day, resulting in higher fuel moistures. Tree density is often higher on north-facing slopes due to higher soil moisture. South-facing slopes 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 1c.2).

Narrow canyons and gorges[2] 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 1c.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 1c.2. Steep slopes and topographic features such as narrow canyons exacerbate fire behavior and fire effects.

[2] Canyons are long, deep, and very steep-sided topographic features primarily cut into bedrock and often containing a perennial stream at the bottom. A gorge is a narrow, deep valley with nearly vertical and rocky walls, being smaller than a canyon and more steep-sided than a ravine. There are no canyons or gorges within the GFPD, but there are draws and ravines that have relatively steep slopes and can increase fire spread through radiant and convective heating. Draws and ravines are created when a watercourse cuts into unconsolidated materials. Draws generally have a broader floor and more gently sloping sides than a ravine (NRCS 2017).

Weather

Weather conditions that impact fire behavior include temperature, relative humidity, precipitation, lightning activity, and wind speed and direction. 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 1c.1).

Direct sunlight and hot temperatures can preheat fuels and bring 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 1c.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	

Strong, gusty wind contributed to rapid growth of the 2020 East Troublesome Fire in Colorado (photo by Jessy Ellenberger, Associated Press).

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 1c.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 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 and others 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 and others 2018).

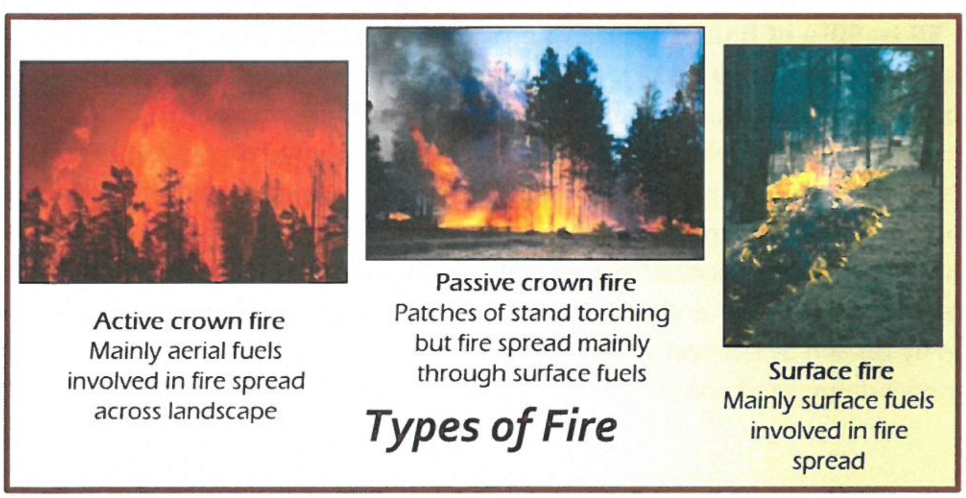


Figure 1c.3. Active crown fire, passive crown fire, and surface fire are common types of fire behavior.

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 and others 2016). The WUI is defined as the area where structures and development meet with wildland fuels and vegetation. WUI is subdivided into intermix, areas where housing and wildland vegetation intermingle, and interface, areas where housing is in the vicinity of larger areas of dense wildland vegetation (Martinuzzi and others 2015).

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 (e.g., wood, metal, or brick siding), the temperature of the flame, the ambient air temperature, and distance from the flame (Caton and others 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). Some housing materials can burn hotter than the surrounding vegetation, thereby exacerbating wildfire intensity and initiating home-to-home ignition (Mell and others 2010).

Homes build mid-slope and at the top of steep slopes and within ravines and draws across the GFPD are at greater risk of convective heat from wildfires. A wildfire could rapidly spread up this steep, grassy slope and threaten the home above.

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. 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 and others 2016; Syphard and Keeley 2019). Embers can also penetrate homes if windows are destroyed by radiant or convective heat. See Section 4b (Mitigating the Home Ignition Zone) for specific 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, and more importantly, to protect the lives of firefighters (NWCG 2018a).** 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 (NWCG 2018a). Homes that are defensible have adequate safety zones where firefighters could survive if encroached upon by flames without needing to deploy their fire shelters. Homes that are less ignitable, surrounded by defensible space, and safely accessible are more likely to receive the protection of firefighters and fire engines; such homes have a greater chance of being successfully defended and pose fewer hazards to the lives of firefighters.

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. Section 4b (Mitigating 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. Genesee Fire Protection District: Background

2a. General Description

The GFPD is located in Jefferson County in the foothills west of Denver, Colorado. This community sits south of I-70 and north of Highway 74 and encompasses 4 square miles. Genesee Fire Rescue is responsible for protecting the fire protection district, which includes about 1,500 homes, 28 commercial buildings, and 3,600 residents. Residents are predominantly full-time occupants who own single-family homes, and many residents commute to Denver for work. The median age of residents in the Genesee census-designated place, which overlaps with much of the GFPD, is 51 years and 17% of residents are over 65 years old, meaning that the population is generally older than most communities in Jefferson County (U.S. Census Bureau 2012).

The GFPD abuts Evergreen and Foothills Fire Protection Districts. Most of the GFPD is private land, bordered by Lair o' the Bear Park managed by Jefferson County Open Space and Genesee Park, Katherine Craig Park, and Corwina Park managed by Denver Mountain Parks.

Elevation in the GFPD ranges from 6,600 to 8,040 feet above sea level. The entire district falls within the Bear Creek Watershed, and part of the GFPD drains southwards into Bear Creek and the other part drains northward toward Mt. Vernon Canyon. The area is primarily covered by ponderosa pine and mixed-conifer forests, with interspersed grasslands and shrublands (Figure 2a.1). Black bear, elk, mountain lion, mule deer, and golden eagles are some of the large wildlife found in the GFPD.

Fuel loads are variable across the GFPD (Figure 2a.2). 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 and could experience active crown fires that would be difficult if not impossible for firefighters to contain. Grassy areas are interspersed across the GFPD and 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.

Values at risk to wildfire in the GFPD include private homes, commercial buildings, Flatirons Church, the GFR fire station, water treatment infrastructure maintained by the Genesee Water and Sanitation District, three communications towers, and two reservoirs (Figure 2a.3). Values at risk surrounding the GFPD include Rockland Community Church, Ralston Elementary School, additional communication towers, recreational areas maintained by Denver Mountain Parks, and about 12 miles of overhead powerlines. A gas transmission pipeline runs through the GFPD—the pipeline is buried deep and would not be threatened by wildfires, but it is important for firefighters to be aware of underground energy infrastructure when digging firelines with heavy equipment.

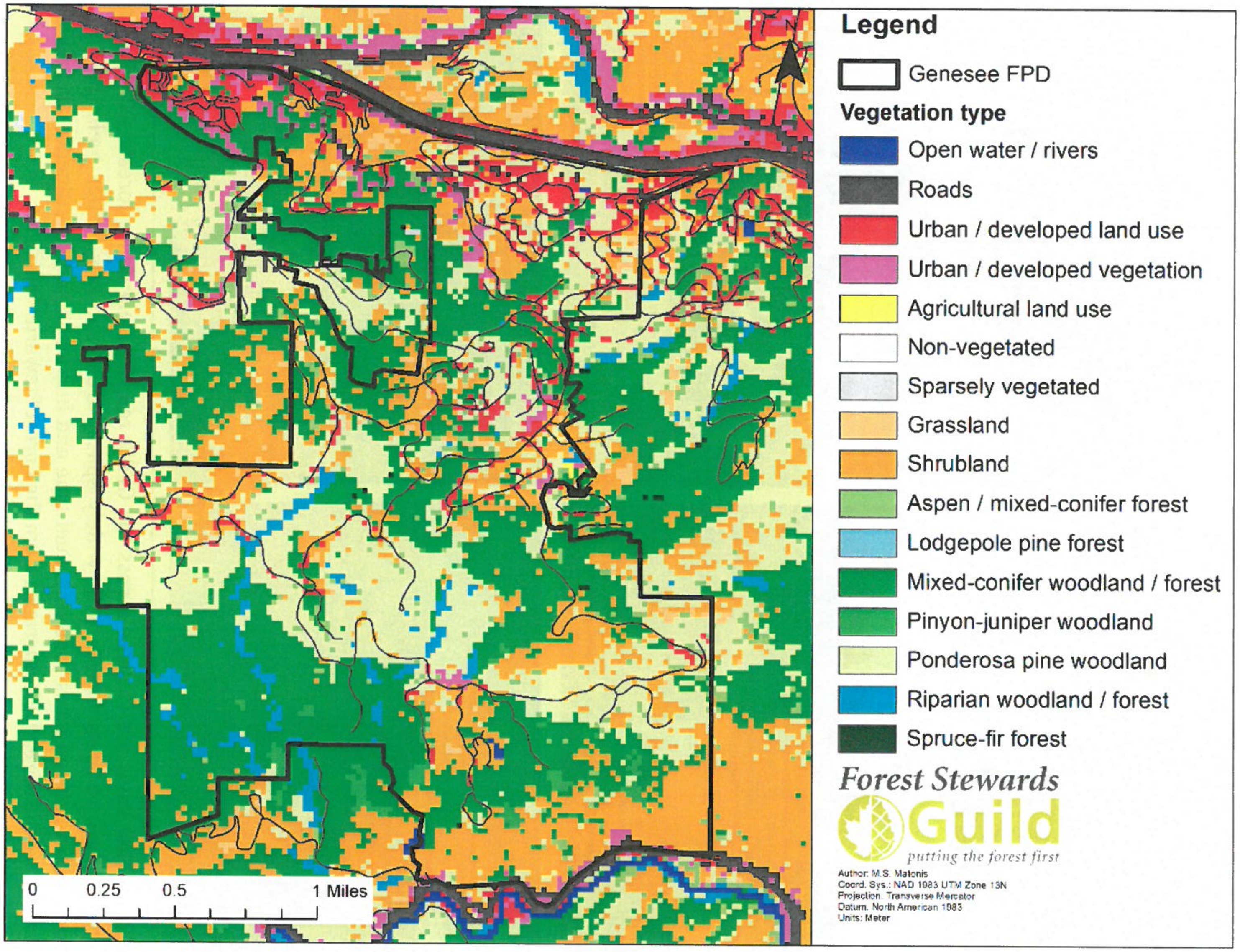


Figure 2a.1. Vegetation in the GFPD is primarily ponderosa pine and mixed-conifer forests with interspersed grasslands and shrublands (source: 2016 LANDFIRE re-map with modifications by the Forest Stewards Guild to increase accuracy).

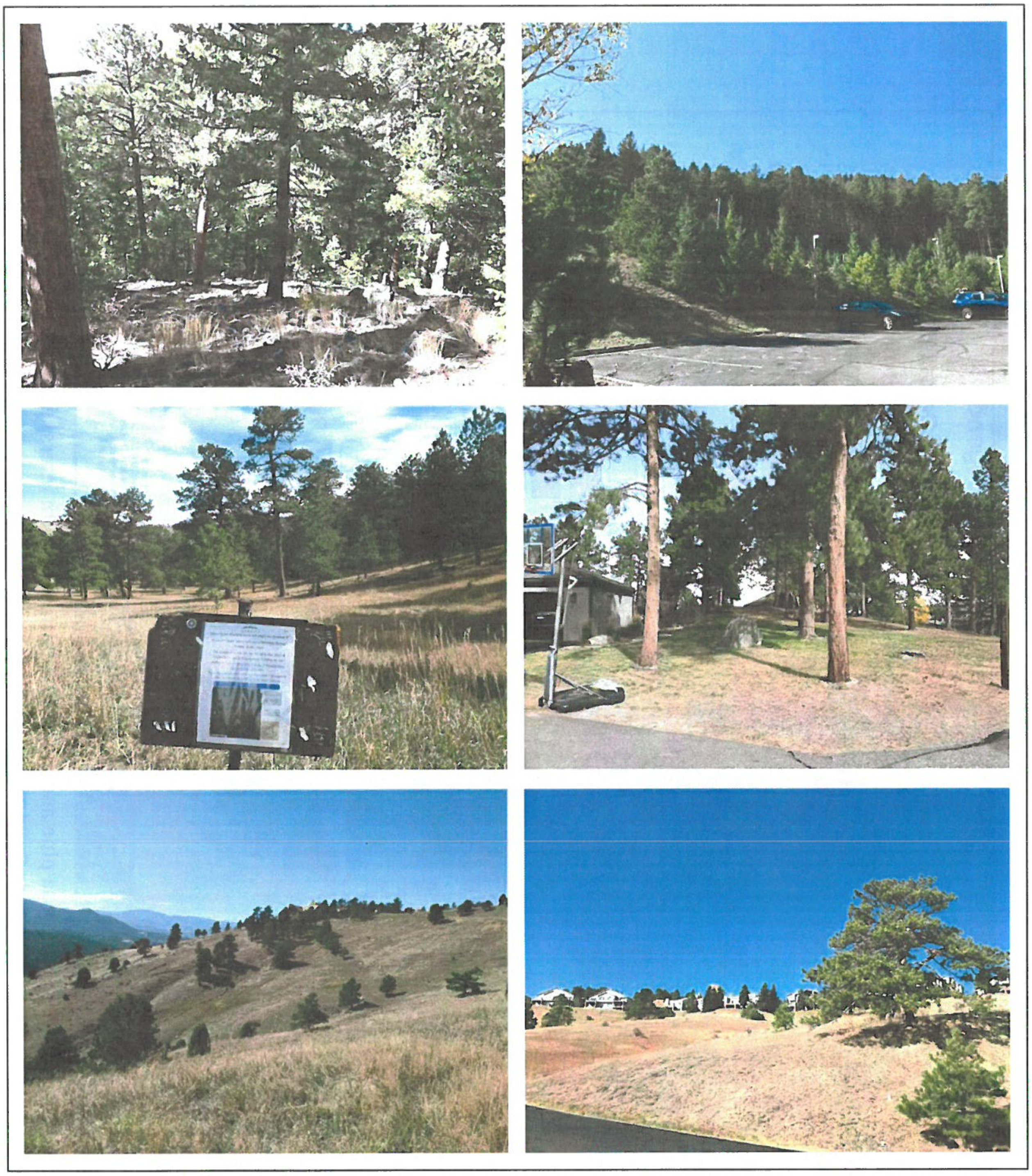


Figure 2a.2. Fuel loads are variable across the GFPD, ranging from dense forests with abundant ladder fuels (top), to open forests with widely spaced trees and few ladder fuels (middle), to grasslands with scattered trees (bottom). Fuel type and fuel loads greatly influence fire behavior, intensity, and rate of spread. Photographs from the Forest Stewards Guild.

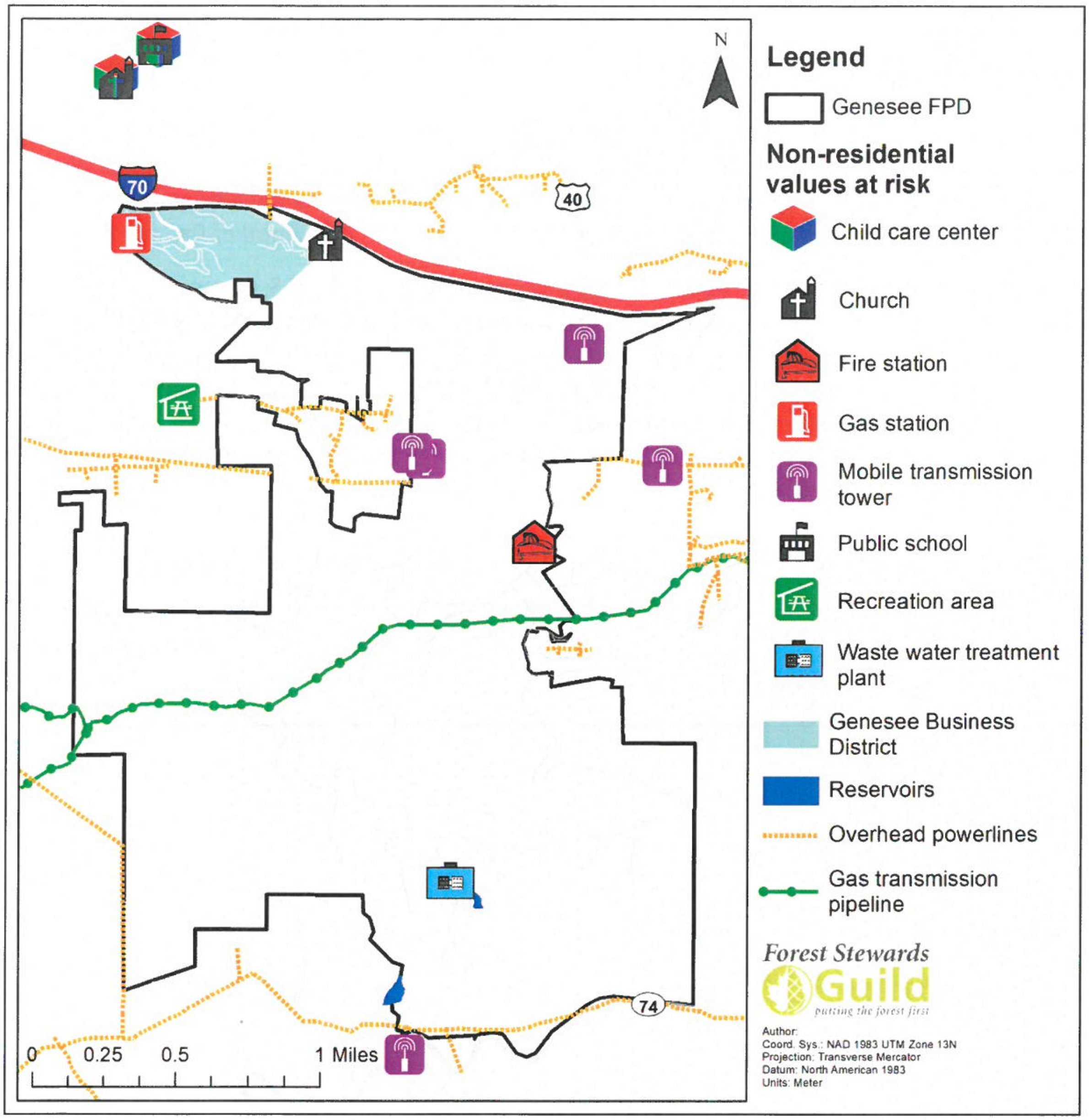


Figure 2a.3. Non-residential values at risk to wildfire within and around the GFPD.

2b. Wildland-Urban Interface

All residents of the GFPD live in the WUI (Figure 2b.1). Over the past 50 years, immigration to the mountains west of Denver has increased the number of occupied structures within this historically forested 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 U.S. Forest Service, populated areas in GFPD have greater risk than 97% of communities in Colorado in terms of potential damage from wildfires (Figure 2b.2; USFS 2020). High fire risk is common to many WUI communities along the Colorado Front Range (Radeloff and others 2018). Damages from wildfires in the Colorado's WUI can be extensive, as demonstrated by the 2012 Waldo Canyon Fire that destroyed 346 buildings, the 2013 Black Forest Fire that destroyed 511 buildings, and the 2020 East Troublesome Fire that destroyed at least 366 buildings.

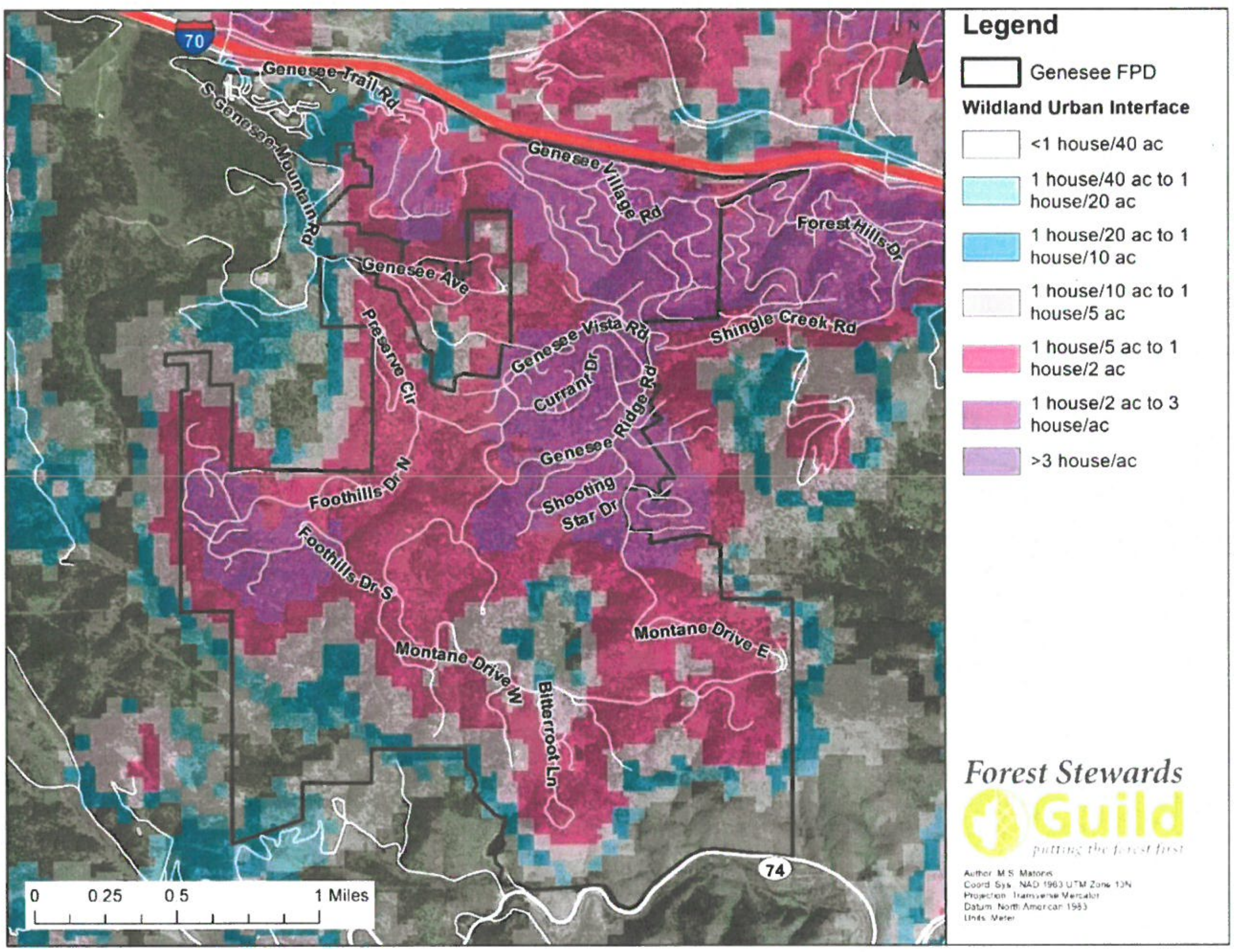


Figure 2b.1. Wildland-Urban Interface and Intermix in the Genesee Fire Protection District displayed by housing density per acre from the lowest density of 1 house per 40 acres to the highest density of 3 houses per acre.

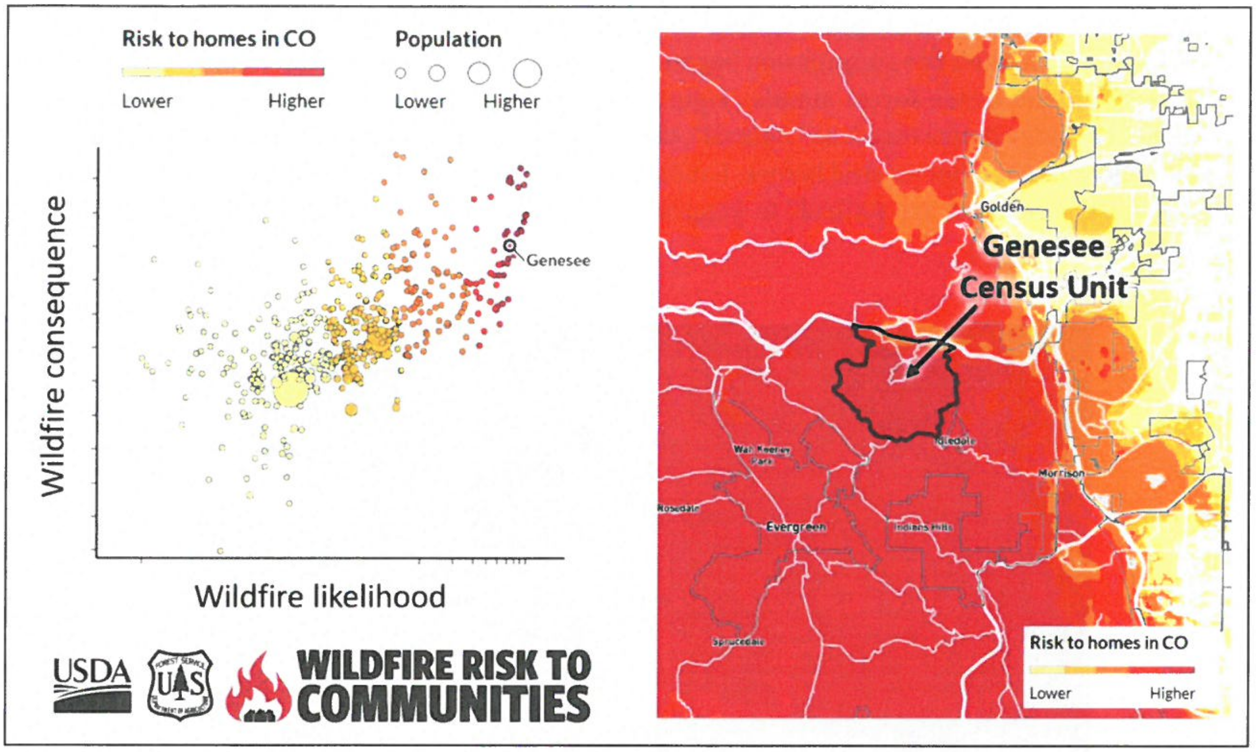


Figure 2b.2. According to the 2020 Wildfire Risk to Communities analysis by the U.S. Forest Service, GFPD has extremely high risk in terms of potential damage from wildfires. High fire risk is common to many WUI communities along the Colorado Front Range (Source: https://wildfirerisk.org).

2c. 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 and Ute First Nations. These indigenous groups utilized fire as a land management tool. Lightning ignited fires were common before European settlement in the 1850's, with low- to mixed-severity fires occurring every 7 to 50 years and occasional severe, stand-replacing fires. Fire behavior resulted in 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 and others 2018).

Ponderosa pine and mixed-conifer forests were fire-adapted ecosystems and very resilient to wildfires. 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 (Figure 2c.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 and others 2012; Pilliod and others 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 2c.2; Addington and others 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 (Hass 2014).

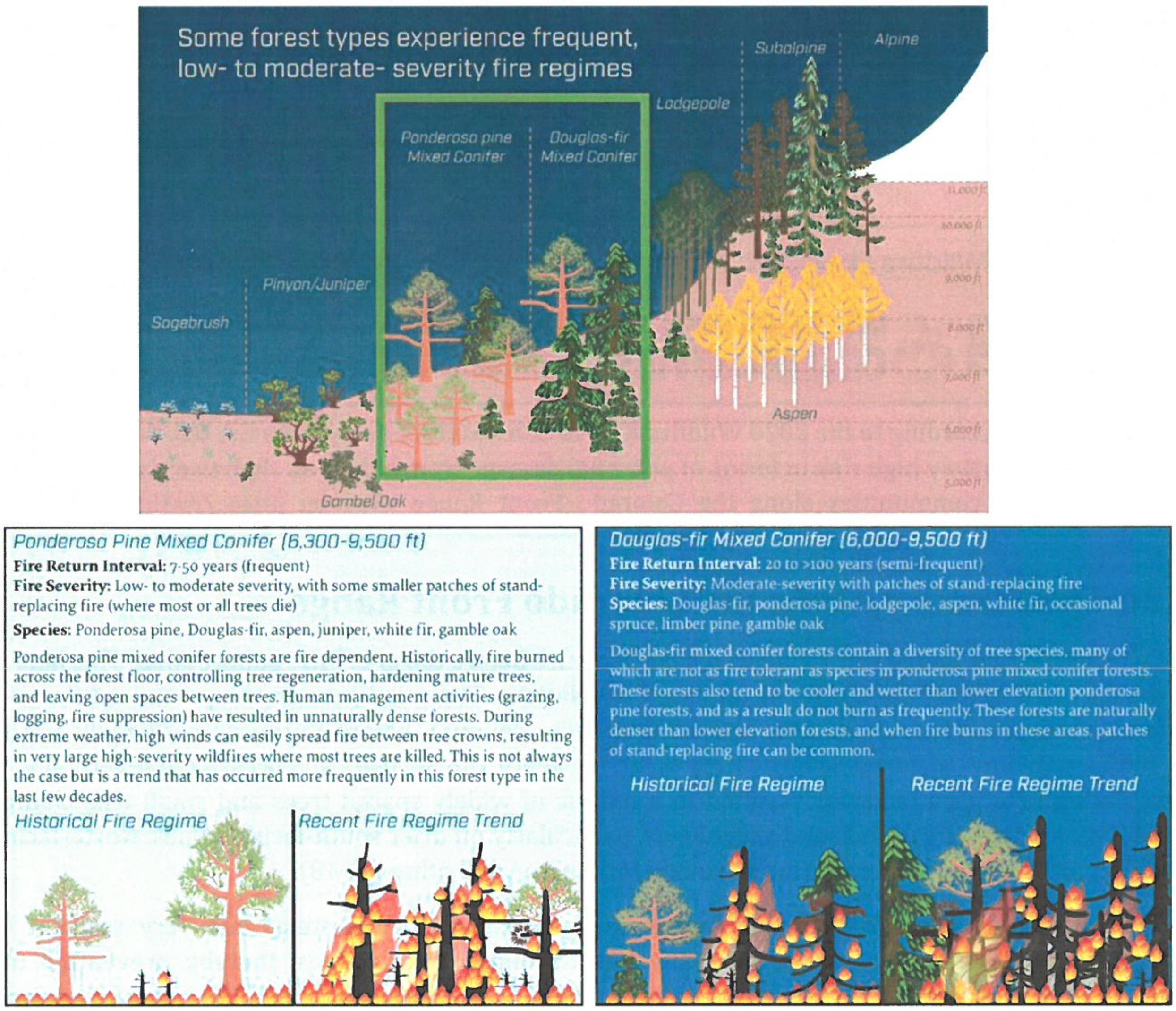


Figure 2c.1. Ponderosa pine forests along the Colorado Front Range historically experience frequent fires every 7-50 years and mixed-conifer forests experienced semi-frequent fires every 20 to >100 years, resulting in less dense forest conditions than we see today. Infographics from the Colorado Forest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

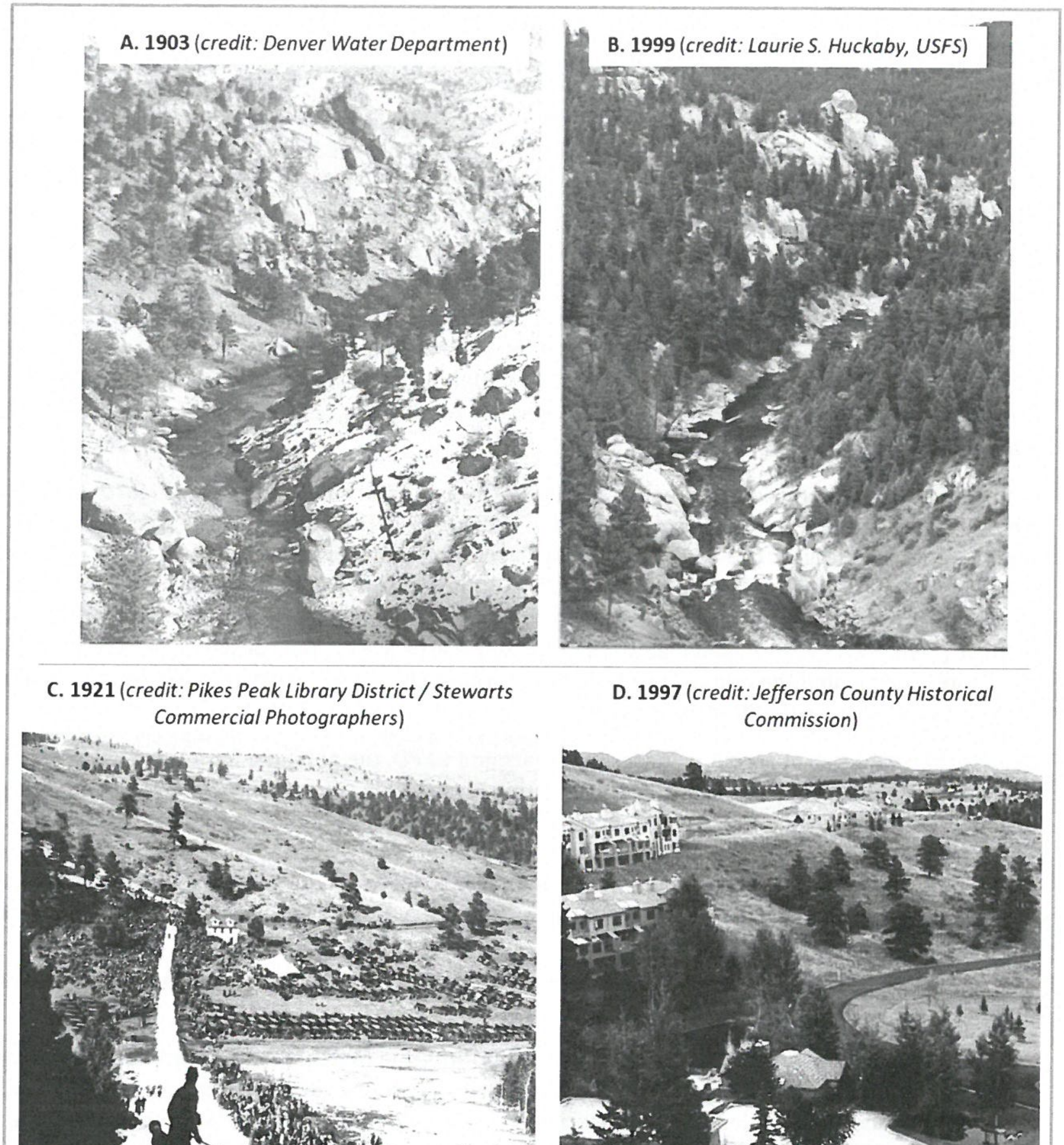


Figure 2c.2. Tree densities in many ponderosa pine and mixed-conifer forests are higher today than they were historically in part due to fire suppression, as demonstrated by these paired photographs along the South Platte River on the Pike National Forest, Colorado (top images) and in the area that was once the Genesee Mountain Ski Jump and is now the Chimney Creek HOAs (bottom images). The area in the foreground of image (d) still resembles open ponderosa pine forests, but the hills in the background support very dense forests that are dissimilar to conditions in the mid-1800s and early 1900s. Images are borrowed from Battaglia and others (2018), Ski Jumping Hill Archive (Weeger 2021), and the Jefferson County Historical Commission (1997).

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 (Parks and others 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 (Hass and others 2015).

Days with red flag warnings indicate severe fire weather and require extra vigilance by fire departments and residents (see Table 1c.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. The fire weather zone that includes GFPD experienced between 0 and 17 red flag warnings per year from 2006 to 2020, with 5 red flag warnings in 2019 and 16 red flag warnings in 2020 (Figure 2c.3). Red flag conditions are most common in March, April, June, and October.

From 2003-2017, there were a total of 36 fire starts in and around the GFPD (Figure 2c.4). All ignitions were contained within a day or two, and about 85% of these fires were kept to less than 0.2 acres in size. The largest fire was the Sawmill Gulch Fire, which burned about 40 acres near the Lookout Mountain exit on March 3, 2012. Fire ignitions in and around the GFPD occurred at all months of the year except for December, with the most ignitions recorded in July, September, and October (Figure 2c.3). Since many ignitions in the GFPD area are human caused, their occurrence is distributed throughout the year more than lightning-caused ignitions—a pattern observed across the United States (Balch and others 2017).

Despite the small size of recent wildfires in and around GFPD, the potential for a large wildfire that exceeds the suppression capacity of local firefighting resources is great. In July 2020, the fast-moving Elephant Butte Fire prompted the evacuation of about 1,000 homes in the Evergreen Fire Protection District and grew to a size of 50 acres. During development of the Genesee Fire Protection CWPP, the three largest wildfires in Colorado history, the Cameron Peak Fire, East Troublesome Fire, and Pine Gulch Fire, started and burned over 540,000 acres (Figure 2c.5). The size of these wildfires dwarfed the size of the GFPD.

Take Away Message

The GFPD is at high risk for large, high-severity wildfires due to dense forest conditions, dry and hot weather, and strong, gusty winds. Increasing drought and warming temperatures exacerbate wildfire risk in the area. Genesee Fire Rescue and residents in the GFPD must prepare for large wildfire events. Proactive work is imperative.

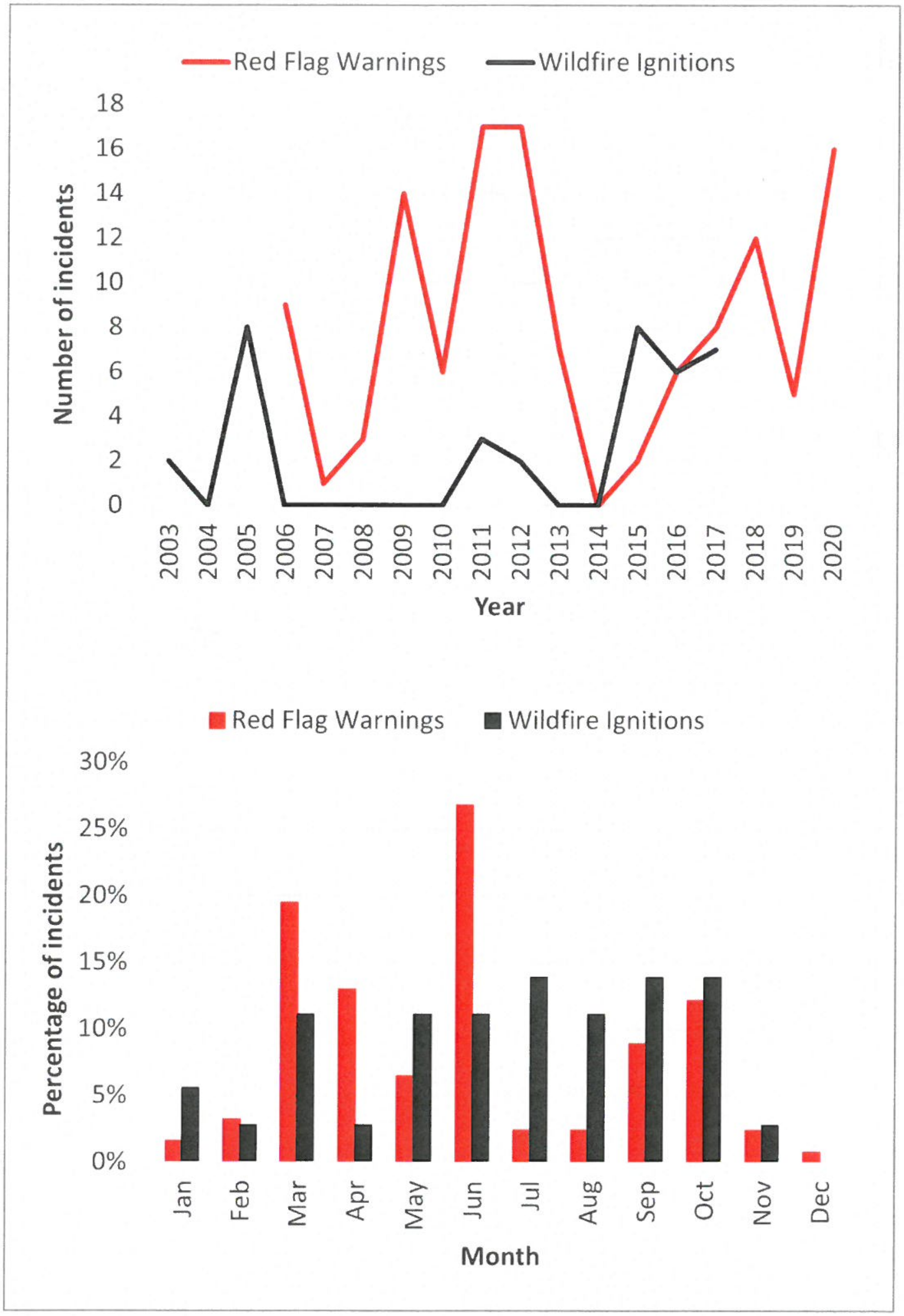


Figure 2c.3. Number of red flag warnings and wildfire ignitions by year (top) and percentage of red flag warnings and wildfire ignitions by month (bottom) in and around the GFPD. Data on historical red flag warnings were available for 2006 to 2020 and data on fire ignitions were available for 2003 to 2017 (sources: archived NWS watch/warnings from Iowa State University, Iowa Environmental Mesonet; historic ignitions from the Colorado State Forest Service, Colorado Forest Atlas).

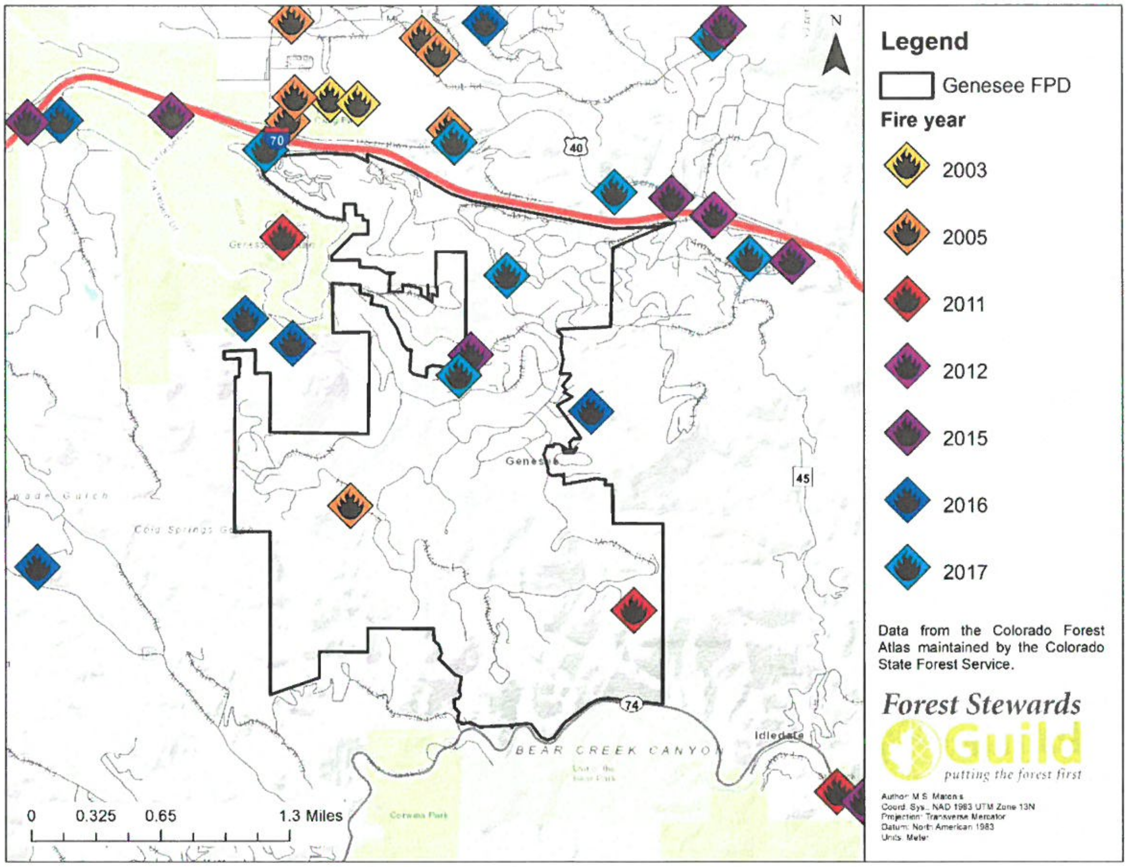


Figure 2c.4. Fire starts in and around Genesee from 2003-2017 (source: Colorado State Forest Service, [Colorado Forest Atlas]).

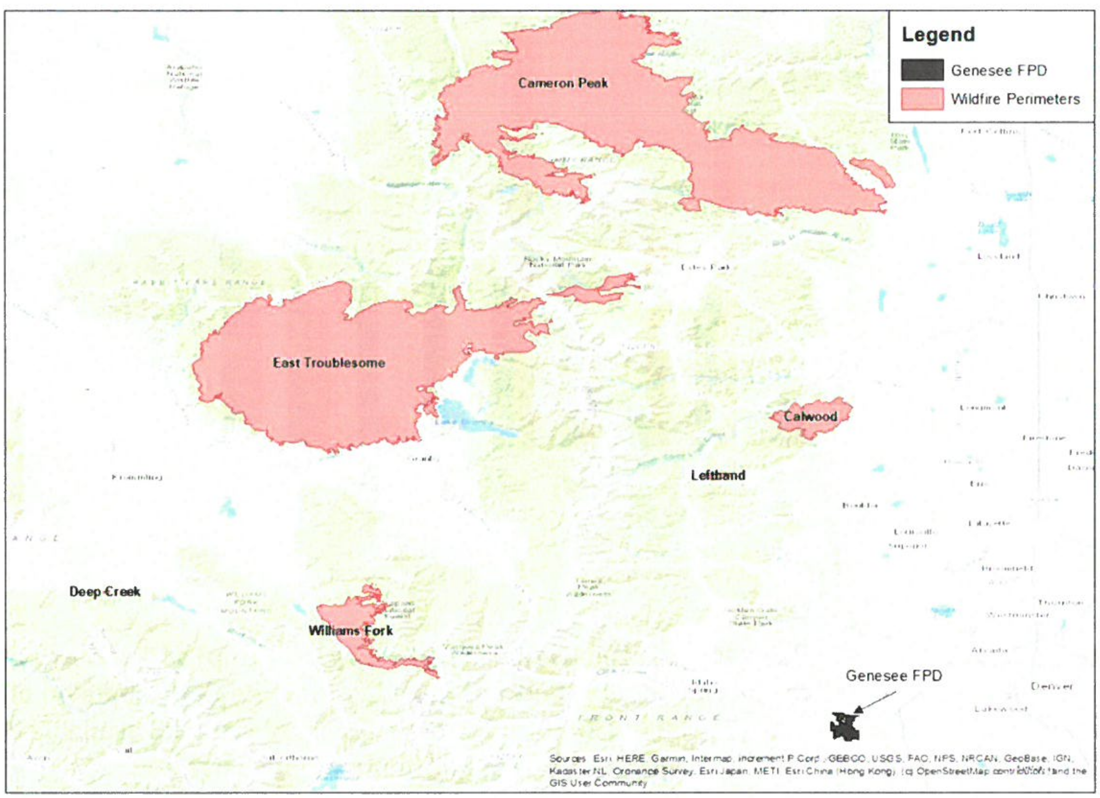


Figure 2c.5. Extent of 2020 wildfires along the Colorado Front Range.

2d. Accomplishments Since the 2008 CWPP

GFR and other organizations have accomplished significant wildfire mitigation work and fire department upgrades since the initial CWPP in 2008. Residents and first responders have hardened homes, created defensible space, and enhanced emergency preparedness. This 2021 CWPP demonstrates a commitment to expand upon previous work.

Genesee Fire Rescue

- The Jefferson County Sheriff's Office, GFR, Colorado State Patrol, Foothills Fire Department, and the Highland Rescue Team conducted an evacuation drill on April 13, 2013 with residents and emergency responders to practice wildland fire evacuations. The drill covered the Genesee Foundation, Genesee Village HOA, Riva Chase HOA, and Chimney Creek HOAs—an area with more than 1,500 homes. About 400 residents and 50 first responders participated. Residents were sent text and email notifications about when to evacuate and where to go.

- GFR hired a full-time Training Chief in 2017 and developed a formal training plan for volunteer firefighters, which includes annual wildland refreshers and monthly trainings. GFR partners with adjacent districts to expand training opportunities for volunteers. GFR occasionally sends wildland crews to wildfire incidents across the Colorado Front Range, including the 2020 Cameron Peak Fire, to provide invaluable experience for volunteer firefighters.

Genesee Fire Rescue sent wildland firefighters and a brush truck to assist with the 2020 Cameron Peak Fire.

- GFR holds an annual open house to bring the public and fire department together to discuss wildfire preparedness. GFR conducted targeted wildfire outreach after major Colorado wildfire events, like the 2013 Black Forest Fire, and held seminars about defensible space and home hardening. Attendance at outreach events tends to be smaller during less-severe wildfire seasons.

- GFR updated their website in 2020 to provide resources on emergency preparedness and wildfire risk mitigation to all residents. GFR also invested in a new full-time position with responsibility for public education related to wildfire risks, mitigation, and evacuation.

- GFR and partners applied for grants to purchase wildland fire supplies and make shared communications improvements. Expanding and maintaining equipment and personal protective equipment are a consistent part of the department's efforts.

Mutual Aid

- The Jefferson County Communications Center Authority (Jeffcom) has made improvements to the mutual aid infrastructure through the Mountain Agency Dispatch. Wildfire pre-plans produced by the Forest Stewards Guild for GFR will be available to all responders on First Due, which will enhance the ability of outside resources to assist with wildfires in the GFPD.

Genesee Water and Sanitation District

- Genesee Water and Sanitation District built a reservoir along Highway 74. The dam provides drought protection to GFPD residents and improves wildfire response in the area by serving as a location for helicopters to pick up water (aka, dip site).

Residents and Homeowners' Associations

- Many residents of the GFPD have mitigated risks on their property since 2008. A grant from the Department of Natural Resources enabled some of this work through cost-sharing for defensible space. Mitigation efforts have been led by HOAs and motivated residents.
- Genesee Foundation—the largest HOA in the district—has been a FireWise community since 2002 and invested more than $1 million in forest management and fire mitigation activities. Genesee Foundation has held annual or semiannual curbside chipping program and pine needle pickup for almost 20 years.
- Genesee Foundation went through a community planning effort in 2012 that identified wildfire risk as one of five priority areas, and as a result, established the Genesee Fire & Safety Committee. In 2014, this committee received a $99,100 grant under the Wildfire Risk Reduction Grant Program to provide a 50-50 cost share for residents who implemented a certified defensible space plan. Over the 3-year course of the grant, 46 defensible space plans were completed for a total of 73 acres. Based on the success of this program, the Genesee Foundation's Open Space Manager began including private property defensible space funds in grant applications for open space management. A total of 61 properties have completed grant-supported defensible space projects. An unknown number of additional properties have also done defensible space work.

Call to Action

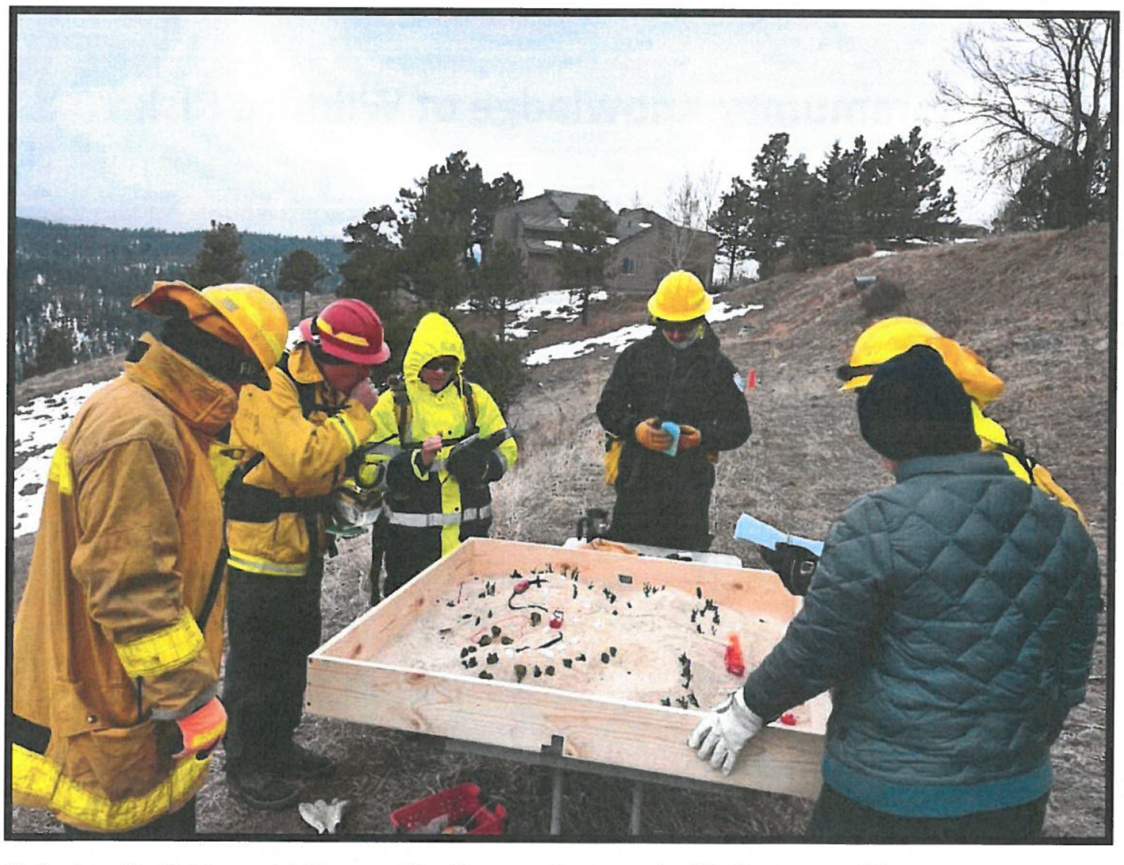
As awareness about wildfire risk continues to grow in the GFPD, it is of utmost importance that residents and HOAs help reduce shared risk. Action and community-building centered around mitigation have reduced wildfire risk and increased community resilience across the mountain west. Mitigation work by residents can spur mitigation by their neighbors (Brenkert-Smith and others 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).

2e. District Capacity

Genesee Fire Rescue is a combination paid and volunteer fire organization. GFR has 3 full-time staff—a Fire Chief, Training Chief, and Wildland Specialist—and 32 volunteers. GFR is staffed 24/7 with volunteer support and provides fire and medical services to approximately 1,500 homes, 28 commercial buildings, and 1,200 acres of open space owned by HOAs. GFR has highly qualified staff and volunteers, and they are committed to constantly improving interagency communication, training, and pre-planning.

All operations and equipment are based out of the GFR Station in the northeastern portion of the GFPD. Fire response equipment includes a command vehicle, utility vehicle, type 6 brush truck, type 3 engine, type 1 engine, and 75-foot ladder truck. GFR utilizes about 250 hydrants that are maintained by Genesee Water & Sanitation. Due to the adequate capacity of GFR's staffing, coverage, emergency communication system, water supply, and outreach efforts, all homes protected by GFR are assigned an ISO (Insurance Services Office) rating of 3 out of 10 (1 is the best rating).

Since 2008, GFR has received several grants to improve their capacity to respond to wildland fire. In 2013 and 2015, they received grants to improve communication with very-high frequency (VHF) units for apparatus and handheld radios and to create a shared communication network among mountain fire agencies. In 2019, GFR received a Volunteer Fire Assistance Grant from the Colorado Division of Fire Prevention and Control to update their wildland fire equipment. These efforts have improved GFR's ability to respond to interagency fire events.



Volunteer firefighters with Genesee Fire Rescue using a sand table during a wildfire training exercise.

2f. Resident Preparedness for Wildfire

The Forest Stewards Guild and GFR administered an online survey as part of the CWPP process; over 300 residents (10% of all residents) in the GFPD participated (see Appendix A for a complete summary of survey results). Most residents feel they understand the level of wildfire risk in the GFPD and understand factors that impact fire behavior (Figure 2f.1). About 70% of residents think there is at least a 50% chance that their home would be destroyed or severely damaged if a wildfire starts or spreads to their property.

Many residents have undertaken actions to lessen the risk of wildfire around their homes (Figure 2f.2), and additional information and guidance on mitigation measures could spur even more risk reduction (Figure 2f.3). However, the desire to keep trees near homes for aesthetic reasons, shading, or privacy screening are a major barrier to the creation of more intensive defensible space around many homes.

Many residents in GFPD feel underprepared to evacuate during a wildfire event. A third of residents do not have an evacuation plan for their family and three-fourth of residents do not have go-bags packed and ready to go. According to the Jefferson County Communications Center Authority (JeffCom), a large portion of residents (80%) are opted into CodeRED, but over half of residents are moderately to very concerned that they would not receive timely information about the need to evacuate. Over 65% of residents are concerned that their community does not have enough roads to handle evacuation traffic.

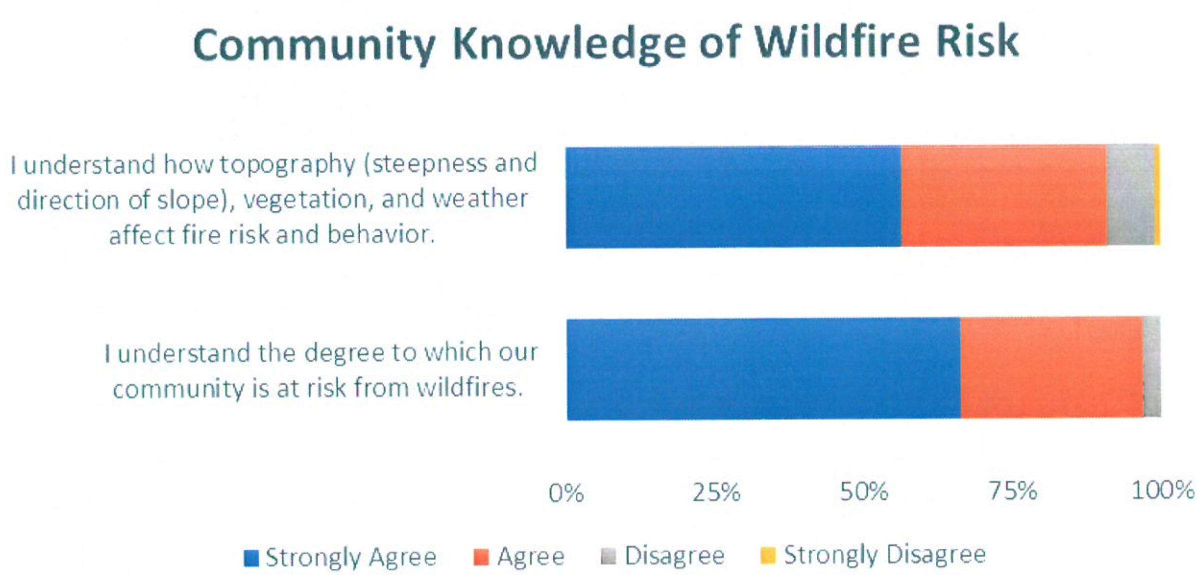


Figure 2f.1. Residents in the Genesee Fire Protection District generally feel familiar with the wildfire risk in their community and factors influencing fire behavior.

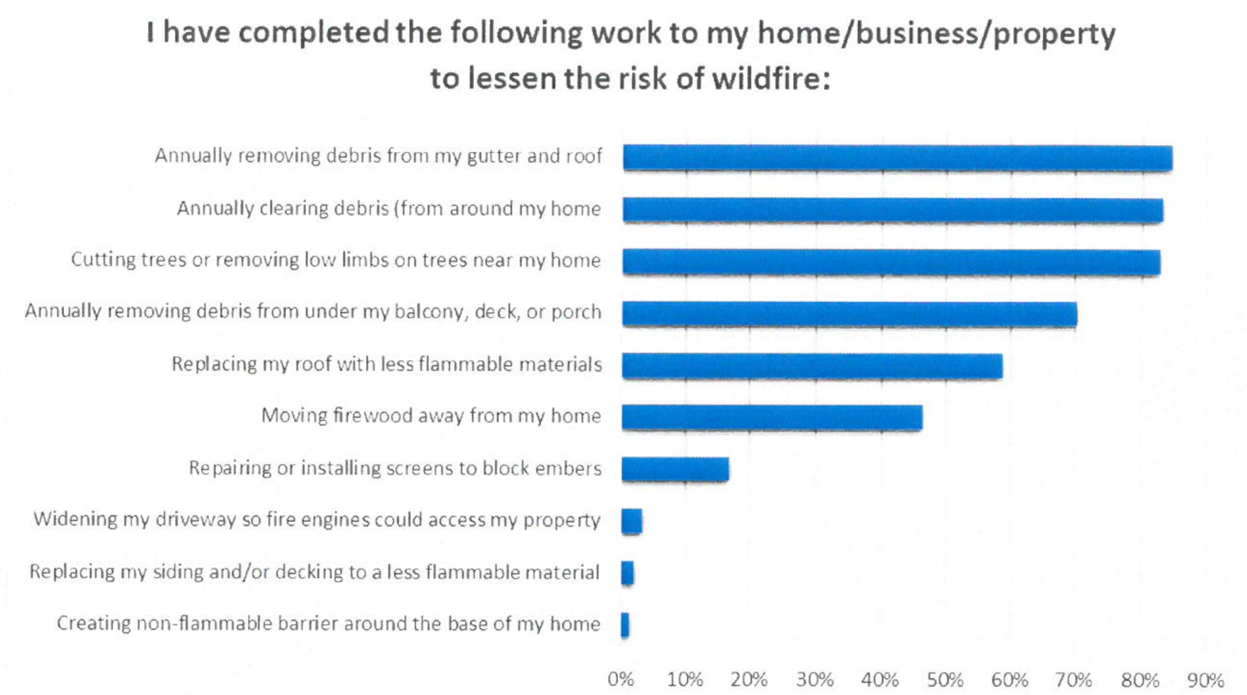


Figure 2f.2. Many residents in the Genesee Fire Protection District have undertaken efforts to mitigate wildfire risk around their homes.

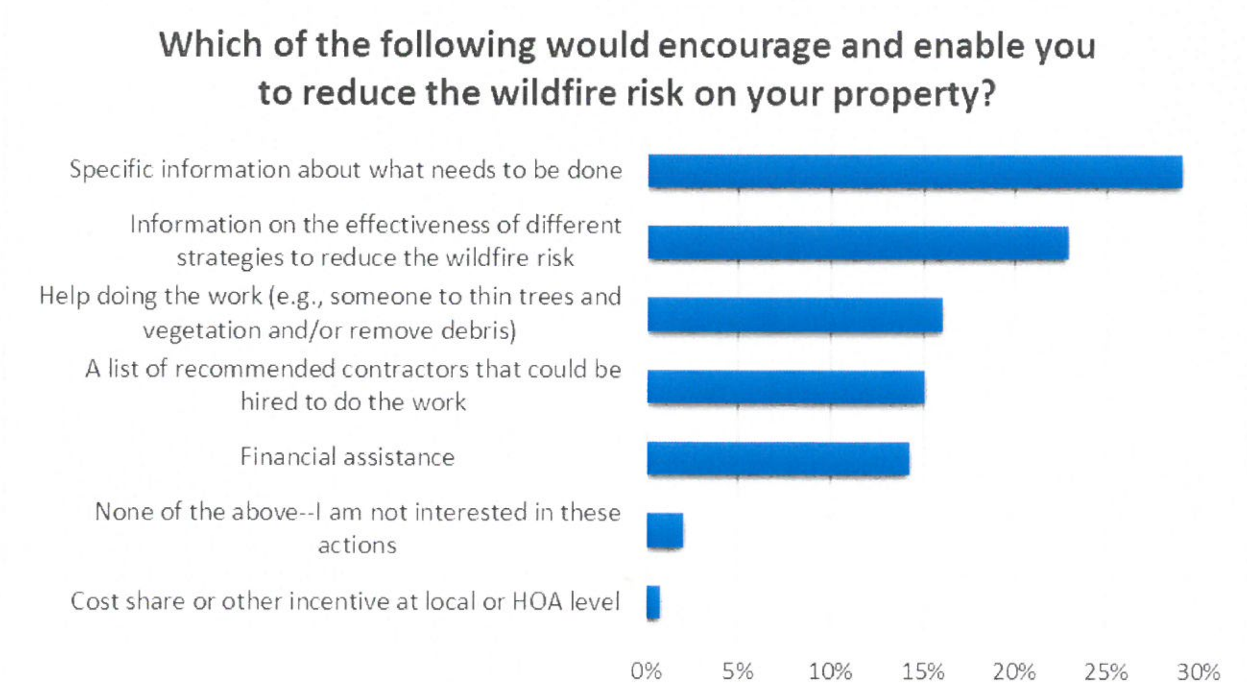


Figure 2f.3. Information about mitigation measures would encourage and enable residents in the Genesee Fire Protection District to reduce wildfire risk on their property.

3. Community Risk Assessment

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

3a. CWPP Plan Units

We divided the GFPD into 16 plan units as part of the 2021 CWPP to assess relative risk across the community (Figure 3a.1). Plan units were delineated along HOA boundaries and property boundaries with considerations of roadways and topographic features. Portions of the Genesee Estates plan unit are in the Evergreen Fire Protection District, but we included them in the Genesee Fire Protection District CWPP because GFR is the nearest emergency responder to residents in that area.

The hope is that residents in the same CWPP plan unit will discuss joint risk and organize 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.

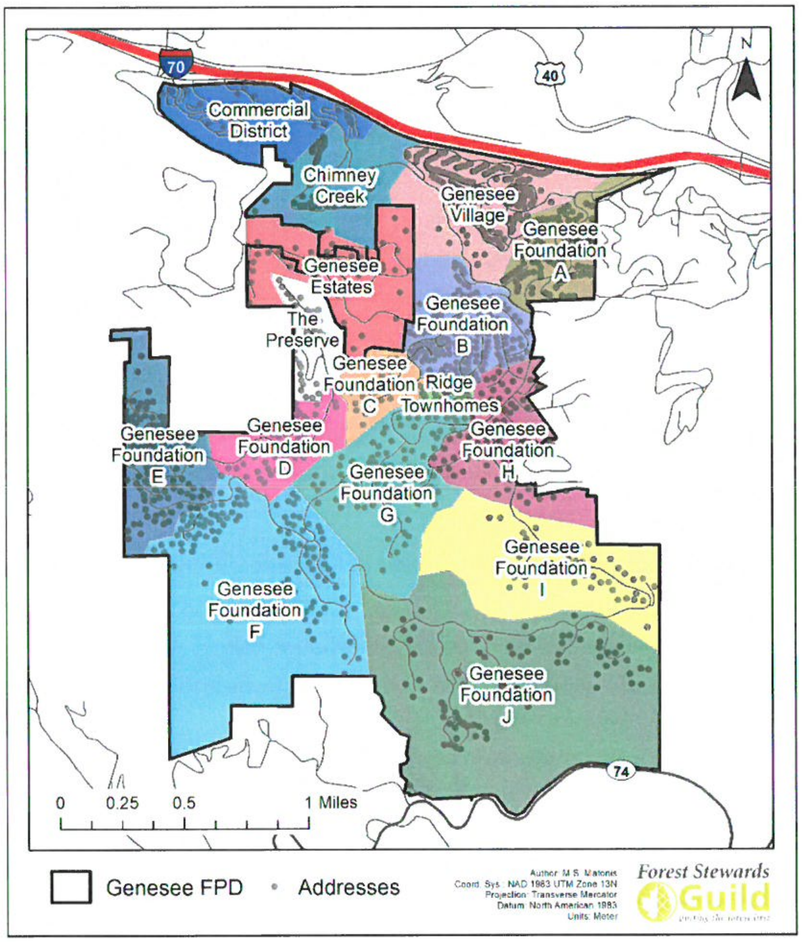


Figure 3a.1. We assessed relative risk among CWPP plan units and made strategic recommendations to address wildfire risk across the Genesee Fire Protection District.

3b. Fire Behavior Analysis

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 GFPD. 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.

It is important to understand limitations and appropriate use of fire behavior models. We cannot 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 burn and behave until a fire is actually occurring, and even then, fire behavior can be erratic and unpredictable.

It is recommended to use fire behavior analyses to assess relative risk across the entire GFPD and not to assess specific fire behavior in the vicinity of individual homes. **FlamMap cannot account for fine-scale variation in surface fuel loads, defensible space created by individual homeowners, or the ignitability of building materials.**

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 3b.1). See Appendix B for details on model inputs and specifications.

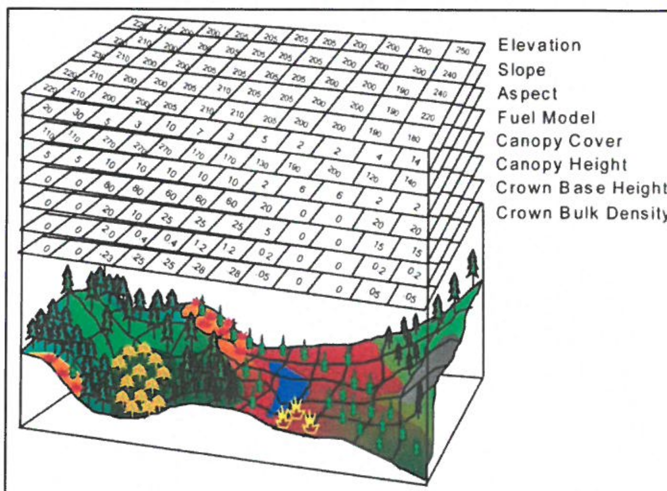


Figure 3b.1. FlamMap requires a variety of information about topography and fuels. Image from Finney (2006).

We thoroughly quality controlled fuel data and worked with GFR to assess the reasonableness of model predictions. 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, 90th, and 97th percentile fire weather conditions—conditions that occurred in the GFPD about 40%, 10%, and 3% of days between June 15th and October 15th (the period often associated with large fires in Colorado) from 2009 to 2019. Weather parameters came from data collected at the Lookout Mountain Remote Automatic Weather Station (RAWS) and fuel moisture conditions from FireFamilyPlus (Table 3b.1). Weather data from 2020 was not available at the time of this analysis.

The 97th percentile fire weather conditions we modeled would qualify for a red flag warning (Table 1c.1) and are similar to conditions that occurred during the Elephant Butte Fire on July 13, 2020 to the southwest of the GFPD. The fire weather zones that includes GFPD experienced 5 red flag warnings in 2019 and 16 red flag warnings in 2020 (Figure 2c.3). Conditions used for 90th percentile fire weather scenarios would constitute a red-flag warning day only if widespread thunderstorms were predicted for the area. Conditions used for 60th percentile weather scenarios have higher fuel moistures and lower wind speeds.

In the main body of the CWPP, we present some but not all results from the analysis with 60th percentile fire weather conditions; we intentionally focus on severe fire weather conditions that cause the most concern for large fire growth and risks to lives and property. Additional fire behavior predictions for 60th percentile fire weather conditions are available in Appendix C.

Winds across the Front Range of Colorado are unpredictable and can be extremely gusty in mountainous areas. Local firefighters informed us that wind directions at the Lookout Mountain RAWS station, which is north of I-70, are often different from winds in the GFPD. We utilized wind observations from three personal weather stations located across the GFPD as available through Weather Underground (https://www.wunderground.com/). These weather stations reported winds predominantly from the west-southwest and south-southeast.

Table 3b.1. Fire weather conditions utilized for fire behavior modeling are based on weather observations from the Lookout Mountain Remote Automatic Weather Station between June 15th and October 15th from 2009 to 2019, fuel moisture predictions from FireFamilyPlus, and wind speeds and directions from personal weather stations in the GFPD. Weather conditions on July 13, 2020 during the Elephant Butte Fire are presented for comparison.

Variable	60th percentile	90th percentile	97th percentile	Elephant Butte Fire (for comparison)
Temperature	76°	82°	85°	87°
Relative humidity	29%	16%	12%	14%
Energy Release Component[1]	54 BTU/ft²	68 BTU/ft²	74 BTU/ft²	73 BTU/ft²
Wind direction	Blowing out of the south-southeast (158°) or west-southwest (248°)			Blowing out of the north-northwest (336°)[2]
20-foot wind speed[3]	17 mph	18 mph	25 mph	11 mph (max of 26 mph)
Fuel moisture[4]				
1-hour	6%	3%	3%	3%
10-hour	6%	4%	4%	4%
100-hour	9%	7%	6%	6%
1000-hour	12%	10%	9%	10%
Live woody	32%	74%	65%	70%
Live herbaceous	92%	30%	30%	30%
Crown foliage	100%	80%	70%	Not reported

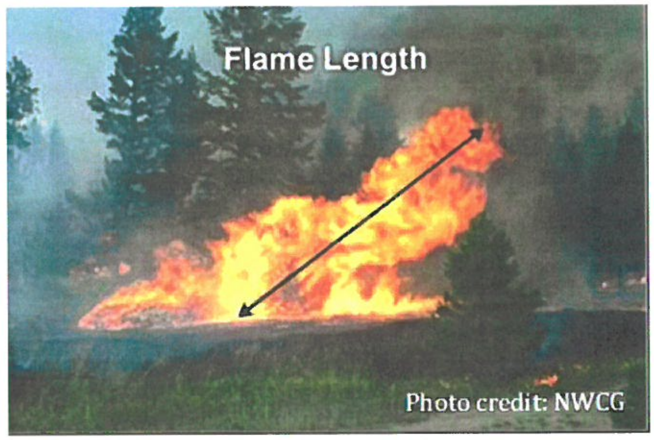
[1]Energy Release Component (ERC) is related to the available energy, BTU (British Thermal Units) per unit area in square foot, that could be within the flaming front at the head of a fire based on the moisture content of live and dead fuels.

[2]During the Elephant Butte Fire, winds shifted to blowing out of the southeast (143°) on July 14.

[3]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).

[4]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.

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 3b.2).

Predicted mean flame length across the GFPD is 6 feet under 90th percentile fire weather conditions (range of 0 to 47 feet) and 11 feet under 97th percentile fire weather conditions (range of 0 to 65 feet). This means that extreme fire weather conditions could result in wildfires that cannot be attacked directly with equipment and personnel and will be exceptionally difficult to control. The potential for high flame lengths is scattered across the GFPD, with a large concentration of potentially extreme fire behavior around Genesee Estates and the southwestern portion of the GFPD (Figure 3b.2).

Table 3b.2. 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	8-12	20-50	Indirect attack
Very High	12-25	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.

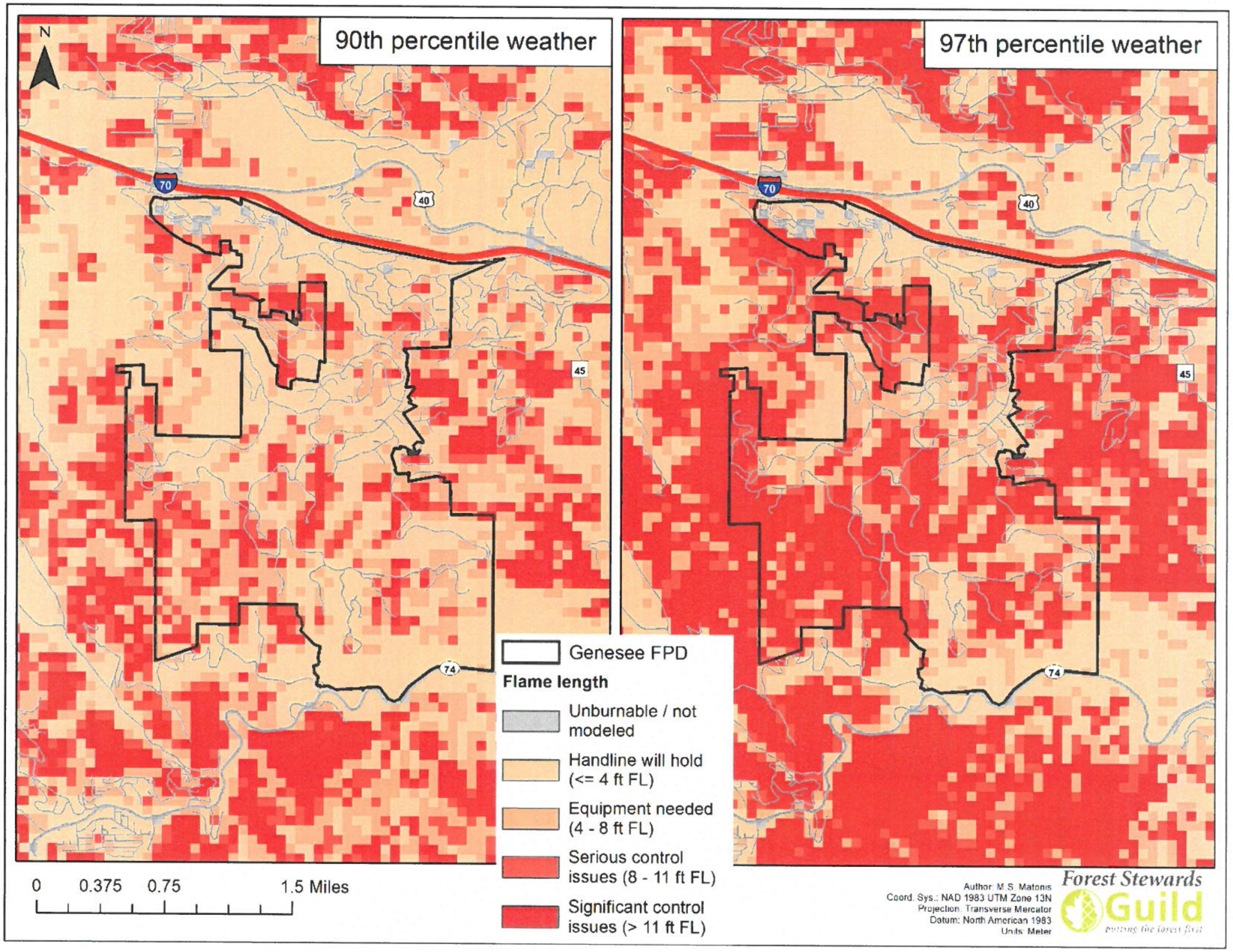


Figure 3b.2. Flame lengths in the Genesee Fire Protection District under 90th and 97th percentile fire weather conditions, categorized by the Haul Chart (Table 3b.2). See Appendix C for predicted flame lengths under 60th percentile fire weather conditions.

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 the introduction of the CWPP (Section 1c. 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 90th percentile fire weather conditions, 5% of the GFPD is predicted to experience active crown fire and 60% is predicted to experience passive crown fire. The portion of the GFPD that could experience active crown fire increases to 20% under 97th percentile fire weather conditions. There is substantial potential for active crown fire (1) around Genesee Estates and Chimney Creek HOAs, (2) in the southwestern portion of the GFPD, and (3) south of Highway-74 (Figure 3b.3). An active crown fire burning in dense timber south of Highway-74 could produce embers and potentially ignite a spot fire within the GFPD and/or produce enough radiant heat to ignite fuels across the highway.

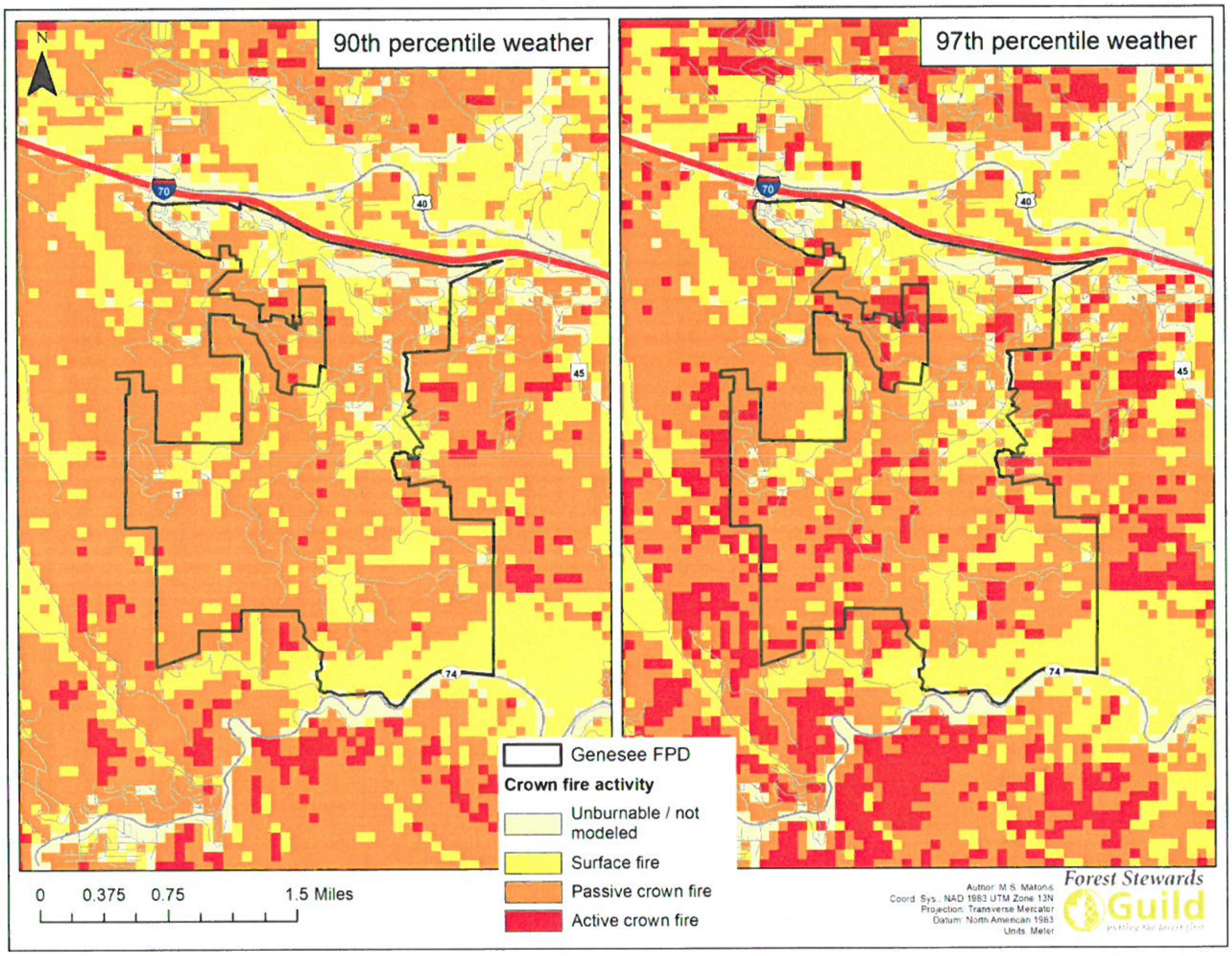


Figure 3b.3. Crown fire activity under 90th and 97th percentile fire weather conditions in the Genesee Fire Protection District. See Appendix C for predicted crown fire activity under 60th percentile fire weather conditions.

Predicted Conditional Burn Probability and Fire Sizes

Conditional burn probability indicates how likely an area is to burn during a wildfire. 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. We simulated 1,000 random ignitions in an area that is 20 times larger than and centered on the GFPD, and we allowed each of these simulated wildfires to burn for 4-hours in the absence of firefighter suppression and control measures. Areas with higher estimates of conditional burn probability experienced more simulated fires, indicating a higher risk for experiencing wildfires than other areas. For example, an area with a conditional burn probability of 7.5% was burned by 75 of the 1,000 simulated fires.

Conditional burn probabilities across the GFPD is greater under more severe fire weather conditions and generally greater with winds blowing out of the west-southwest than blowing out of the south-southeast (Figure 3b.4). A greater percentage of simulated wildfires reached at least some portion of the GFPD with prevailing winds blowing out of the west-southwest (Table 3b.3). After 4-hours of unchecked spread and under 97th percentile fire weather conditions, a larger number of simulated wildfires burned over at least half of the GFPD with winds blowing out of the west-southwest than with winds blowing out of the south-southeast (Figure 3b.5). Figure 3b.6 further illustrates the significant influence of wind direction on fire spread during dry days with strong winds—a wildfire igniting to the west of the GFPD could potentially miss most of the GFPD if driven by winds blowing out of the south-southeast, but it could spread across much of the GFPD if driven by winds blowing out of the west-southwest. Unpredictable wind conditions along the Colorado Front Range make it difficult to predict potential fire spread, making it imperative for residents across the GFPD to take measures to mitigate their home ignition zone (see Section 4b. Mitigating the Home Ignition Zone).

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 I-70, Route-40, and Highway-74. Rapid fire growth and spotting across roadways is more likely under higher windspeeds and with drier fuel conditions. Fires that ignite south of Highway-74 could pose a risk to the GFPD particularly if strong winds are blowing out the south-southeast.

There is a real potential for wildfires to spread across large swaths of the GFPD 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.**

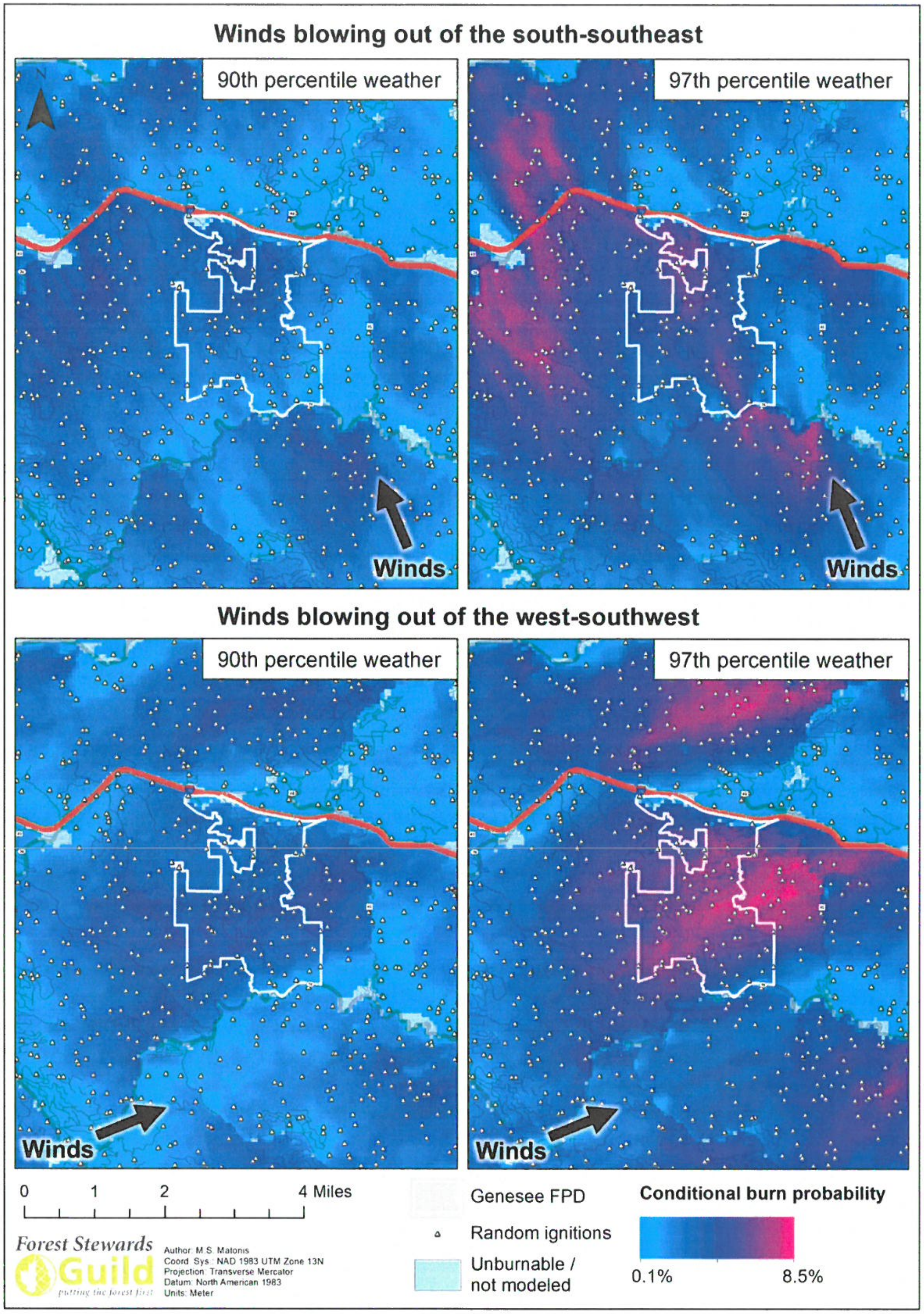


Figure 3b.4. Conditional burn probability under 90th and 97th percentile fire weather conditions (see Appendix C for conditional burn probabilities under 60th percentile fire weather conditions). Wildfire spread was simulated for 4-hours without suppression activities from 1,000 random ignition locations across an area 20 times larger than and centered on the GFPD.

Table 3b.3. Conditional burn probabilities (the percentage of 1,000 simulated wildfires that burned the same 0.2-acre portion of the GFPD) and the percentage of simulated wildfires that burned any portion of the GFPD was influenced by the severity of fire weather conditions, wind speeds, and the direction of prevailing winds. Wildfire spread was simulated for 4-hours without suppression activities from 1,000 random ignition locations across an area 20 times larger than and centered on the GFPD.

	Winds blowing out of the south-southeast			Winds blowing out of the west-southwest		
Percentile fire weather condition[1]	**60th**	**90th**	**97th**	**60th**	**90th**	**97th**
Greatest conditional burn probability (percentage of simulated fires burning the same 0.2-acre portion of the GFPD)	3%	5%	7%	3%	5%	8%
Percentage of simulated fires burning any portion of the GFPD	12%	16%	22%	16%	20%	25%

[1]We modeled 20-foot wind speeds of 17, 18, and 25 mph under 60th, 90th, and 97th percentile fire weather conditions, respectively. These 20-foot wind speeds would be approximately 3.4, 3.6, and 5 mph at ground-level with fully sheltered fuels. Vegetation and friction slow down windspeeds closer to ground level.

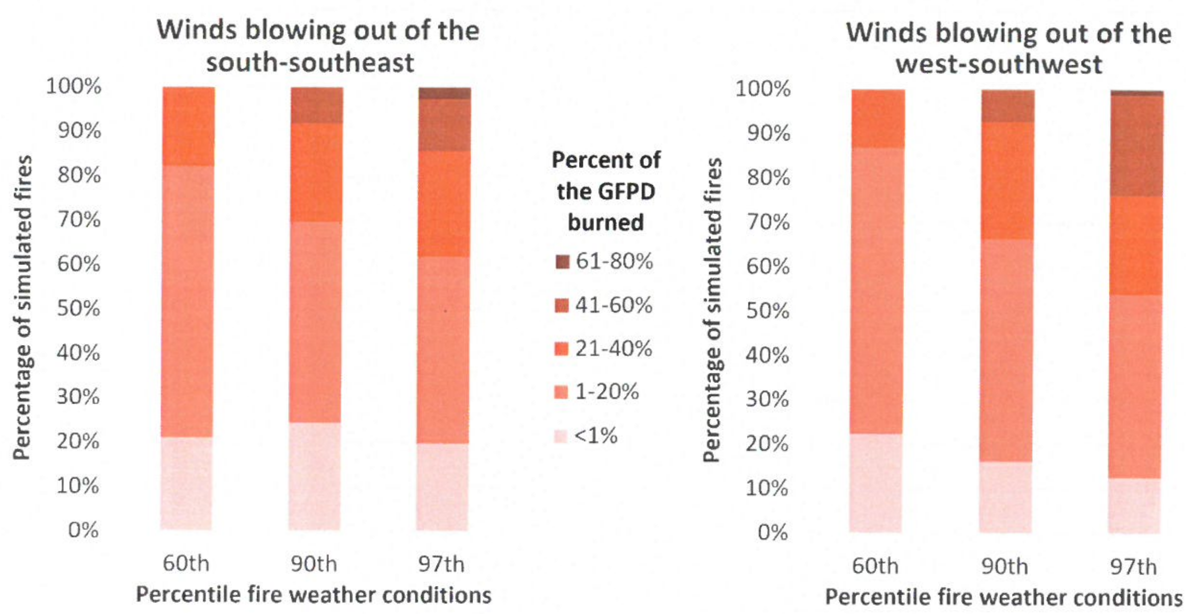


Figure 3b.5. The percentage of the GFPD that burned by simulated wildfires was influenced by the severity of fire weather conditions, wind speeds, and the direction of prevailing winds. Wildfire spread was simulated for 4-hours without suppression activities from 1,000 random ignition locations across an area 20 times larger than and centered on the GFPD.

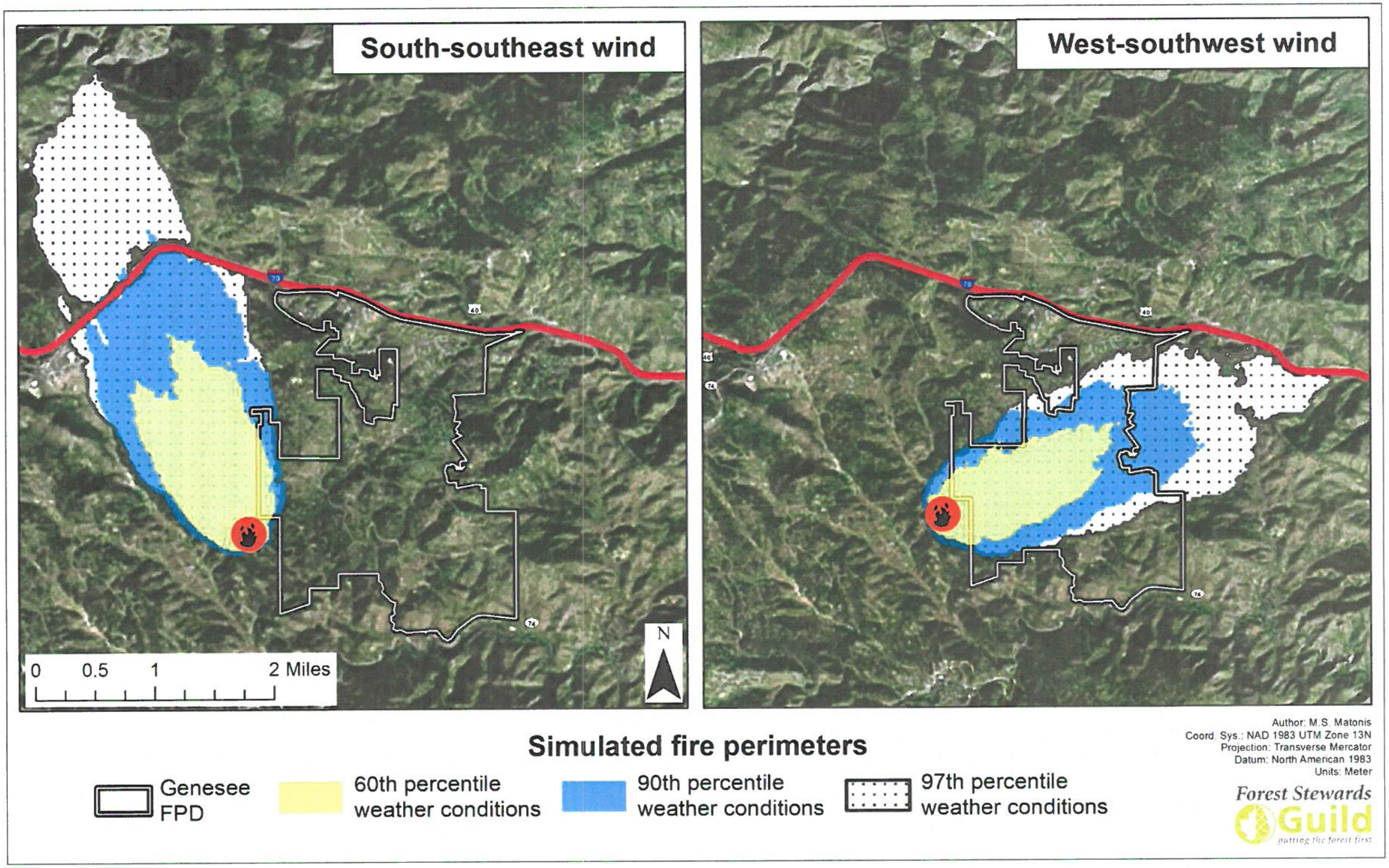


Figure 3b.6. Simulated fire perimeters after 4-hours of fire growth without suppression activities originating from an ignition to the west of the GFPD. We modeled fire growth using FlamMap's minimum travel time algorithm and 60th, 90th, and 97th percentile fire weather conditions under prevailing winds out of the south-southeast and west-southwest.

3c. Predicted Radiant Heat and Spotting Potential

We assessed the risk that radiant heat and short-range and long-range spotting pose to structures. See Section 1c (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 and others (2010) to assess home exposure to radiant heating and short-and long-range spotting (Figure 3c.1). Exposure is based on distance from long flame lengths and potential active crown fire assuming:

Embers can ignite homes even when the flaming front of a wildfire is far away. See Section 4b (Mitigating 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.

- Radiant heat can ignite homes when extreme fire behavior (flame lengths > 8 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.

Distance thresholds used by Beverly and others (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 igniting spot fires (Caton and others 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 and others 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 and others 2016). Therefore, using conservative estimates of distance allows us to identify areas with the greatest risk of ignition from short- and long-range embers.

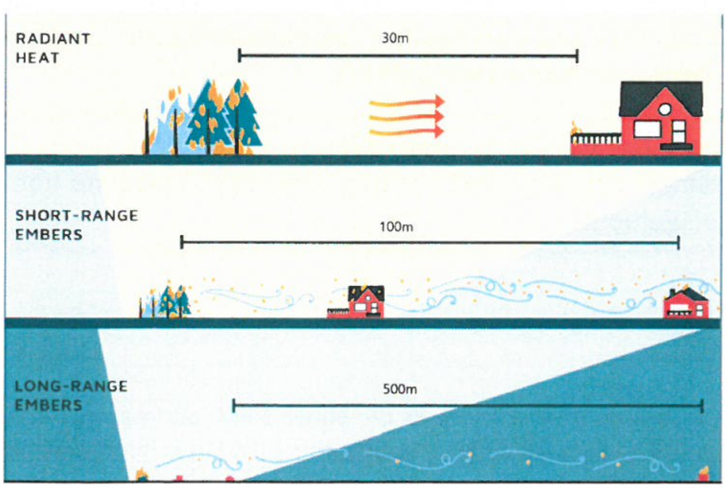


Figure 3c.1. Research by Beverly and others (2010) suggest that homes are exposed to radiant heat, short-range embers, and long-range embers depending on their distance from the flaming front.

Passive crown fires can produce embers that threaten homes, but we only considered exposure to embers from active crown fires because such a high percentage of the GFPD has potential for passive crown fire. We want to highlight areas with the greatest exposure to short- and long-range spotting to help identify priority areas for mitigation measures.

We determined whether exposure to radiant heat and short- and long-range spotting from active crown fires was possible within the home ignition zone (HIZ; 100-feet radius) of each structure in the GFPD. Structures for which greater than 50% of the HIZ was exposed to radiant heat, short-range spotting, and/or long-range spotting were defined as "at risk" from that hazard[3]. We categorized exposure potential into four categories:

- Low: Potential exposure to long-range spotting only.
- Moderate: Potential exposure to long- and short-range spotting.
- High: Potential exposure to long-range spotting and radiant heat.
- Extreme: Potential exposure to long- and short-range spotting and radiant heat.

About 23% of structures in the GFPD could have extreme exposure under 90th percentile fire weather conditions and 54% could have extreme exposure under 97th percentile fire weather conditions. This percentage is only 1% under fire weather conditions with higher fuel moisture and lower wind speeds (Figure 3c.2). **The entire GFPD has potential exposure to long-range spotting under 90th and 97th percentile fire weather conditions because of the proximity of all portions of the GFPD to areas that could support active crown fires (Figure 3c.3).**

The percentage of homes with high and extreme exposure varies among CWPP plan units (Figure 3c.4). Under 97th percentile fire weather conditions, the plan units Genesee Foundation A, E, F, and G and Genesee Estates have the greatest percentage of homes with high and extreme exposure. Although predictions of active crown fire are relatively low in the Genesee Foundation A plan unit, structures in this unit have high exposure because of potential fire behavior in the larger surrounding area. **It is important to remember that embers can ignite homes even when the flaming front of a wildfire is far away.**

Over 95% of homes within the GFPD are within 100 meters of at least one neighboring home and have a greater risk of home-to-home ignition from radiant heat and short-range spotting (Syphard and others 2012). (Figure 3c.5). Some homes are within short-range spotting distance of over 20 neighboring homes. Fuel treatments within HIZs and surrounding undeveloped areas could help reduce the exposure of homes to radiant heat and short-range spotting.

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

[3] It is recommended to use this analysis to assess relative risk across the entire GFPD 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.

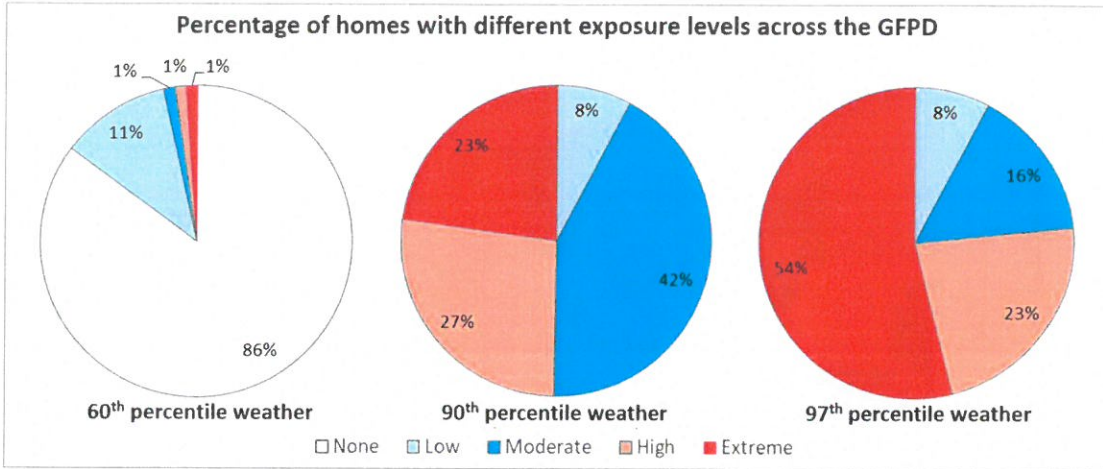


Figure 3c.2. Percentage of homes across the entire Genesee Fire Protection District with different levels of exposure to embers and radiant heat under 60th, 90th, and 97th percentile fire weather conditions. Structure exposure ratings are as follows: low ratings indicate potential exposure to long-range spotting only, moderate ratings indicate potential exposure to short- and long-range spotting, high ratings indicate potential exposure to long-range spotting and radiant heat, and extreme ratings indicate potential exposure to short- and long-range spotting and radiant heat.

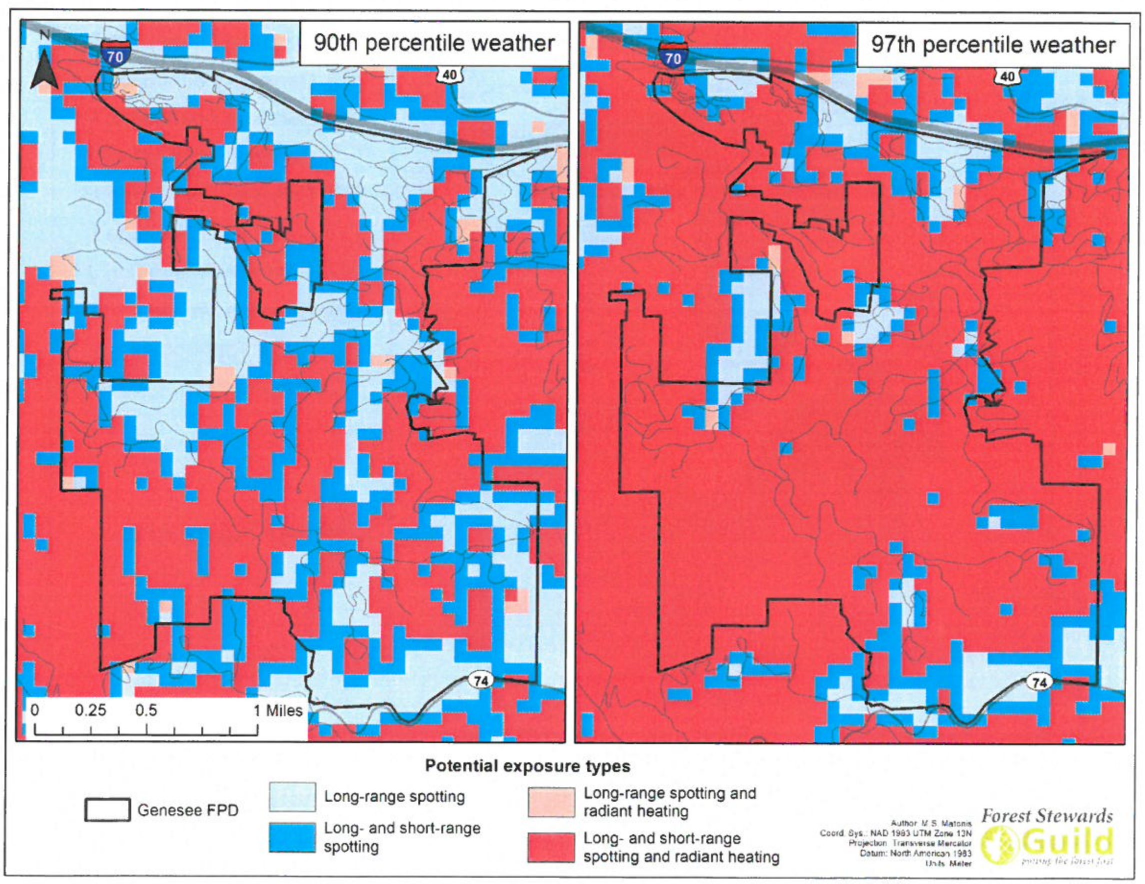


Figure 3c.3. Predicted exposure to short-and-long range embers and radiant heat under 90th and 97th percentile fire weather conditions in the Genesee Fire Protection District. See Appendix C for predicted exposure under 60th percentile fire weather conditions.

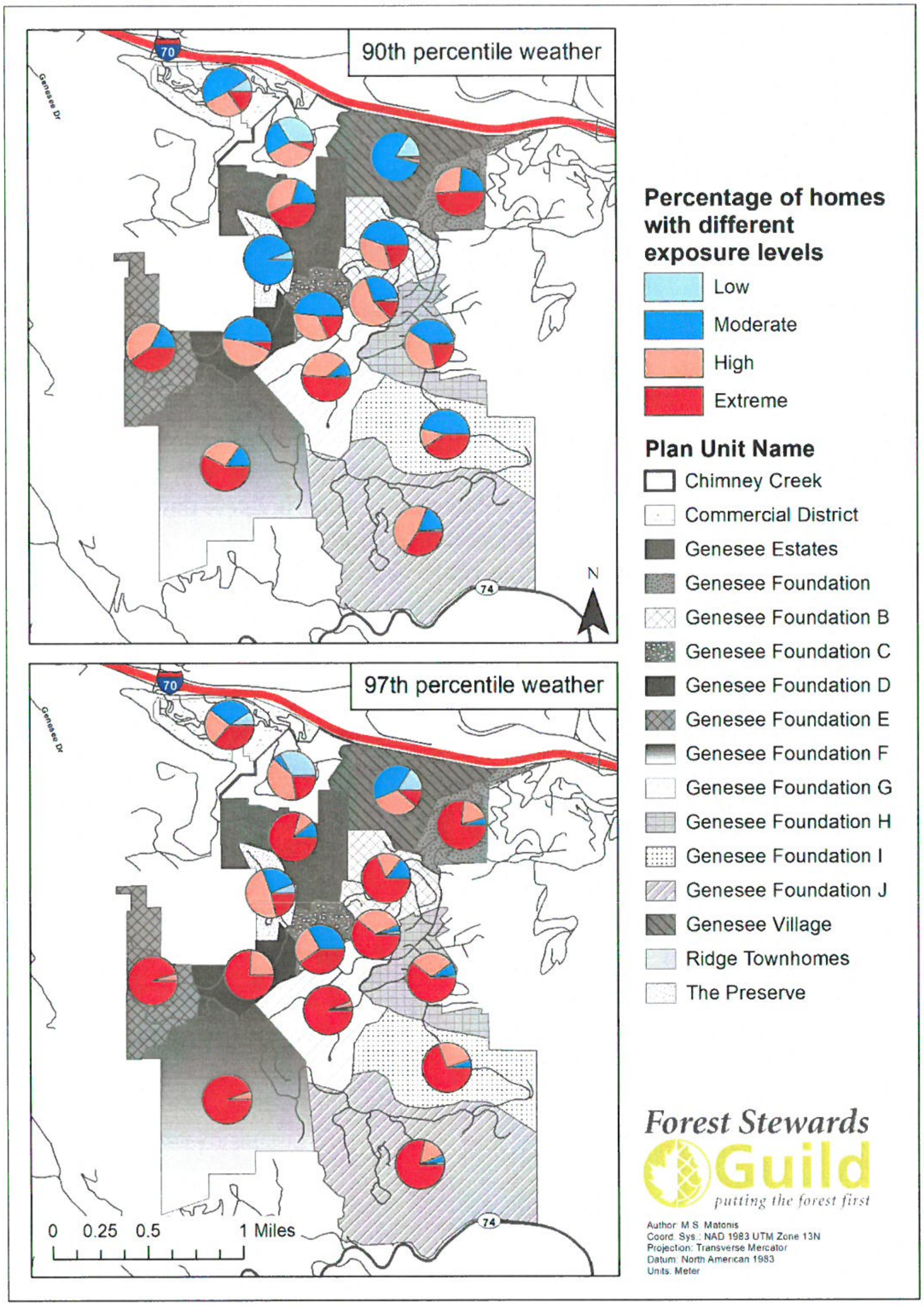


Figure 3c.4. Percentage of homes within CWPP plan units with different levels of exposure to embers and radiant heat under 90th and 97th percentile fire weather conditions. See Appendix C for predictions under 60th percentile fire weather conditions. Structure exposure ratings are as follows: low ratings indicate potential exposure to long-range spotting only, moderate ratings indicate potential exposure to short- and long-range spotting, high ratings indicate potential exposure to long-range spotting and radiant heat, and extreme ratings indicate potential exposure to short- and long-range spotting and radiant heat.

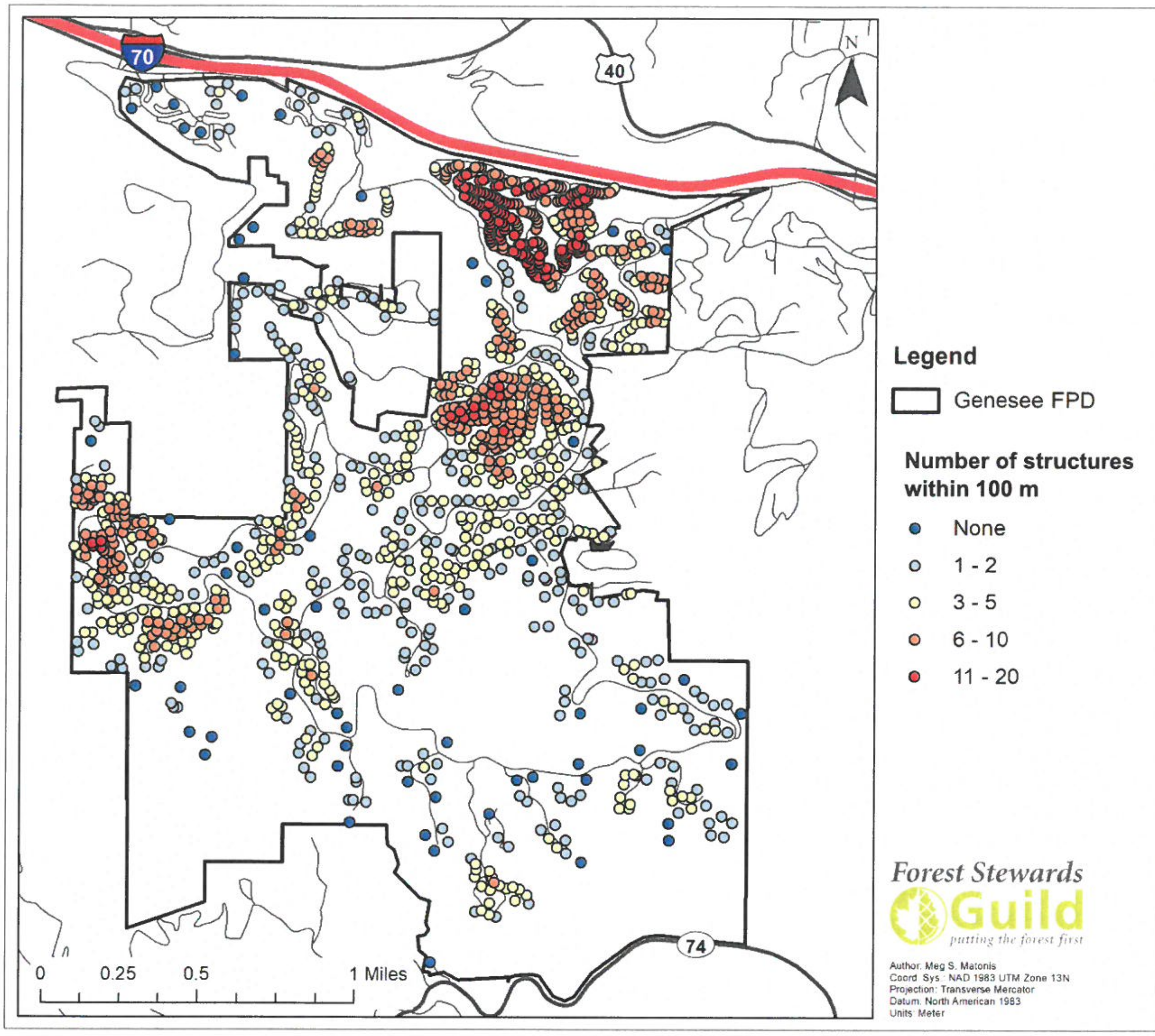


Figure 3c.5. Over 95% of homes are within 100 meters of at least one neighboring home and have a greater risk of home-to-home ignition from radiant heat and short-range spotting. Some homes are within short-range spotting distance of over 20 neighboring homes. This analysis looked at structures rather than addresses, so apartment buildings only counted as one structure even though they have multiple addresses.

3d. Evacuation

Evacuation concerns weigh heavily on the minds of residents in the GFPD (Appendix A). 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

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. ArcCASPER iteratively modifies the order that evacuees leave their homes and modifies the route each evacuee takes until the algorithm minimizes the time it takes for every single vehicle to evacuate the GFPD.

> **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.

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. See Appendix B for additional model specifications.

Based on research by Beloglazov and others (2016), we assumed that it takes 30 minutes for individuals to mobilize and depart their homes after receiving a mandatory evacuation order[4]. We assumed that evacuees were directed to Ralston Elementary School north of I-70, eastbound I-70, or eastbound Highway-74, whichever destination took the least time for each vehicle to reach. We assumed that some traffic would be routed from Genesee Ridge Road to South Grapevine Road to Highway-74 when traffic onto I-70 substantially backed up.

We modeled evacuation time and congestion assuming two vehicles departed each residential address, and we performed the analysis again assuming only one vehicle departed each residential address. Data from the Jefferson County Sherriff's Office indicates that the average number of vehicles per home is 2.5 in the GFPD. We modeled ten vehicles evacuating from each business address, Denver Mountain Parks recreational areas to the west of the GFPD, and Flatirons Church. Evacuation congestion could be substantially higher on weekends than our predictions suggest; there can be 500 to 750 cars in the Flatirons Parking lot on Sundays, 150 vehicles in parking lots at Denver Mountain Parks, and substantial traffic on I-70 on weekends.

[4] Many residents in the GFPD do not have evacuation plans or go-bags packed (Appendix A), so it could take them at least 30 minutes to gather possessions, pack a vehicle, and depart after receiving an evacuation order. Ideally residents should be prepared to leave within minutes of receiving an evacuation order. See recommendations in Section 4a (Evacuation Planning and Capacity) to increase your evacuation preparedness.

We conducted an evacuation assessment for (1) all addresses in GFPD receiving simultaneous evacuation orders, and (2) each of four evacuation zones receiving individual evacuation orders. The evacuation zones combined one to five evacuation units as defined by the Jefferson County Sherriff's Office (Figure 3d.1). Both scenarios (the district-wide evacuation and individual zone evacuations) included 222 addresses from the Riva Chase HOA because these addresses could potentially be evacuated along with the GFPD, and we included 111 address from the eastern part of Kittridge to account for additional traffic that could be encountered on Highway-74 during an evacuation event. In total, these scenarios evacuated 1,864 addresses.

The intent of running the evacuation model for all of the GFPD 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. Due to the small size of the GFPD and potential for rapid fire growth in the area, it is possible that evacuation orders could be simultaneously delivered to a large number of addresses during an actual evacuation event. Even if evacuation orders are staggered for different evacuation units, 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. Therefore, the estimates of evacuation times for each of the four evacuation zones individually is on the low end of potential evacuation times.

Estimates from ArcCASPER are useful for determining relative evacuation capacity and congestion across the GFPD 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).**

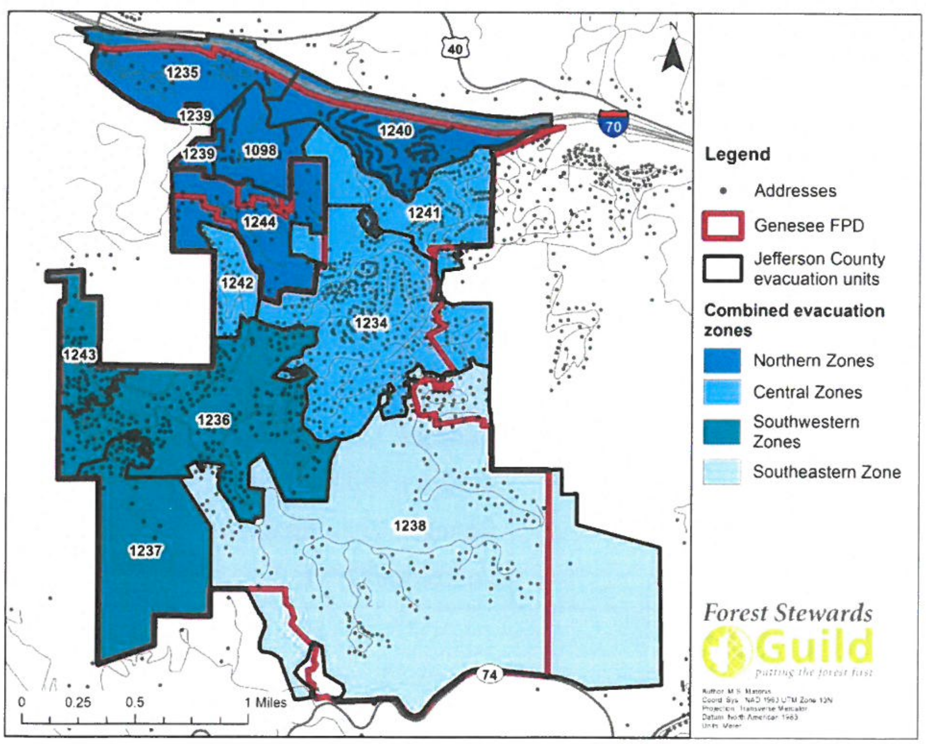


Figure 3d.1. We combined several evacuation units as defined by Jefferson County (outlined in black and numbered) to create four evacuation zones for evacuation modeling as part of the CWPP.

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 the GFPD. Several segments of road in the northern half of the GFPD could experience high congestion during an evacuation due to funneling of traffic towards a limited number of egress routes to I-70 (Table 3d.1; Figure 3d.2).

Congestion is greater under the assumption that two vehicles leave each residency instead of one, but congestion still builds up even with fewer vehicles leaving each residency. Segments of roads with extreme congestion could take over 15 times longer to traverse than they would without congestion. The length of roads predicted for extreme congestion is 7.8 miles under an assumption of two vehicles per residency and only 0.7 miles under an assumption of one vehicle per residency.

Table 3d.1. Segments of road in the GFPD with high to extreme congestion during a simultaneous evacuation simulated across the entire GFPD. Segments of roads with high congestion could take 5 to 15 times longer to traverse than they would without congestion, and segments with extreme congestion could take over 15 times longer to traverse.

	Scenario: One vehicle evacuating per residency	**Scenario: Two vehicles evacuating per residency**
Roads with high congestion	Genesee Trail Road Genesee Ridge Road Genesee Village Road Genesee Vista Road	Genesee Trail Road Genesee Ridge Road Genesee Village Road Genesee Vista Road Bluestem Drive High Meadow Drive Snowberry Drive Currant Drive Foothills Drive North Foothills Drive South Montane Drive East Shooting Star Drive
Roads with extreme congestion	Genesee Ridge Road	Genesee Ridge Road Genesee Trail Road Genesee Village Road Genesee Vista Road Eastwood Drive

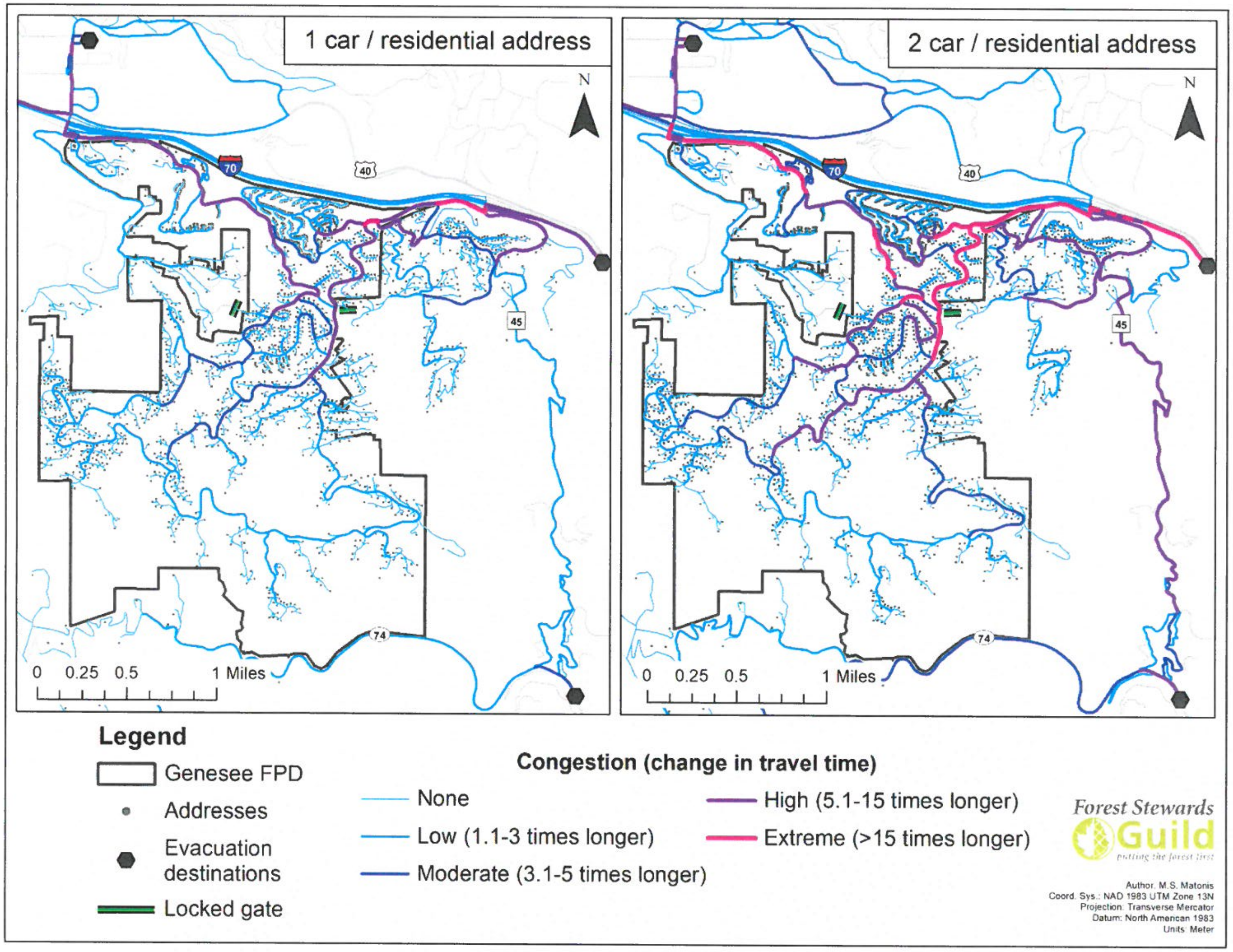


Figure 3d.2. Predicted congestion across the GFPD under a simultaneous district-wide evacuation order. Congestion categories (none, low, moderate, high, extreme) are based on the ratio between the time required to traverse a segment of road with congestion vs. without congestion. Evacuation times were simulated with one vehicle leaving each residency (left) and two vehicles leaving each residency (right). We modeled ten vehicles leaving each business address for both scenarios. The three simulated evacuation destinations were Ralston Elementary School north of I-70, eastbound I-70, and eastbound Highway-74.

Evacuation Time

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.

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 (in this case Ralston Elementary School, eastbound I-70, and eastbound Highway-74). Estimates of evacuation time can serve as a benchmark for emergency pre-planning and strategic decision making.

The number of vehicles entering the roadways dramatically impacts evacuation times, particularly in communities like the GFPD where there are limited egress routes. Based on our modeling of a district-wide evacuation, potentially evacuation times for individual addresses could vary from about 60 minutes to 155 minutes (average time of 120 minutes) if one vehicle departed each residency and from about 80 minutes to 280 minutes (average time of 215 minutes) if two vehicles departed each residency (Figure 3d.3). Reducing the number of vehicles departing each residential address from two to one decreases potential evacuation time by an average of 44%, ranging from a 27% decrease to a 50% decrease for individual residents. The high density of homes in the northeastern part of the GFPD results in near immediate congestion and long potential evacuation times. Evacuation times are great for homes in the southern part of the GFPD due to their distance from I-70 and accumulated congestion in the northern part of the GFPD.

Potential evacuation times are substantially lower if portions of the GFPD evacuate separately (Figure 3d.4). For example, addresses in the southwestern evacuation zone could take 235 to 280 minutes to evacuate if residents leave with two vehicles and these homes are evacuated simultaneously with the rest of the GFPD, but potential evacuation times drop to 95 to 120 minutes if only this zone is evacuated. However, as noted before, evacuation estimates for individual zones are on the low end of potential evacuation times; it is unlikely that one evacuation zone would fully evacuate before evacuation orders begin in another zone.

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. General trends from the model align with reality—significant congestion in the northern part of the GFPD, long evacuation times for homes in the southern part of the GFPD, and significantly shorter evacuation times with fewer vehicles departing each home. However, 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.

In 2013, the Jefferson County Sheriff's Office, GFR, Colorado State Patrol, Foothills Fire Department, and the Highland Rescue Team conducted an evacuation drill with about 400 residents from the Genesee Foundation, Genesee Village HOA, Riva Chase HOA, and Chimney Creek HOAs. Residents received information about the drill ahead of time, and they were sent notifications via text and email the morning of the drill with directions about when and where to evacuate. During the drill, about 87% of participants safely evacuated within 30 minutes; yet only a fraction of GFPD residents participated, participants received information ahead of time about the drill, and there was no true crisis impacting the decision making of participants. Conditions during an actual evacuation event would be vastly different and result in much longer evacuation times than suggested by this drill.

Traffic backing up during the 2013 evacuation drill for the GFPD.

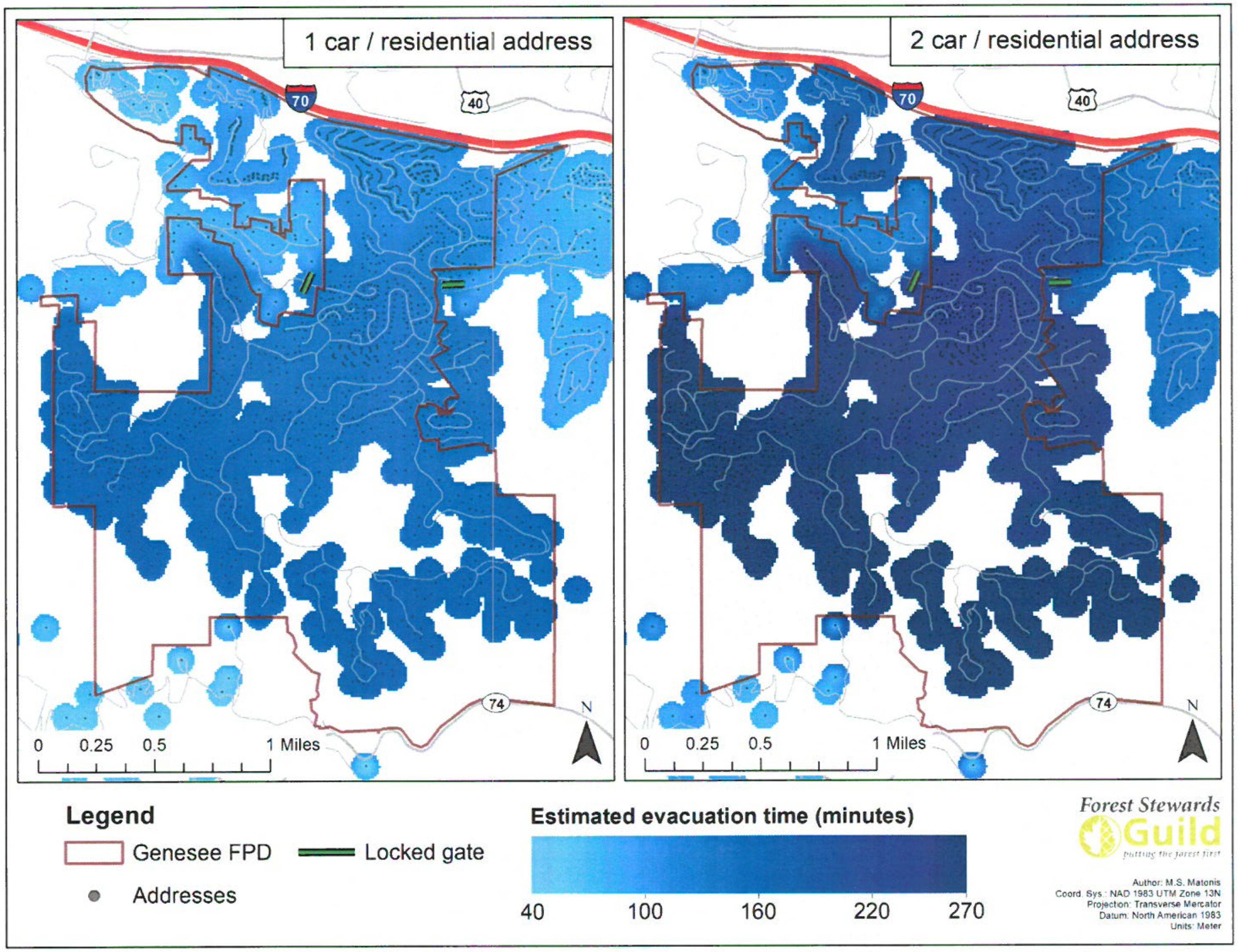


Figure 3d.3. Predicted evacuation times across the GFPD under a simultaneous district-wide evacuation order. Evacuation time is how long it takes for a resident to receive an evacuation order, prepare their belongings, depart, and reach an evacuation site (Ralston Elementary School north of I-70, eastbound I-70, or eastbound Highway-74.). We assumed that it takes 30 minutes for individuals to mobilize and depart after receiving an evacuation order. Evacuation times were simulated with one vehicle leaving each residency (left) and two vehicles leaving each residency (right). We modeled ten vehicles leaving each business address for both scenarios.

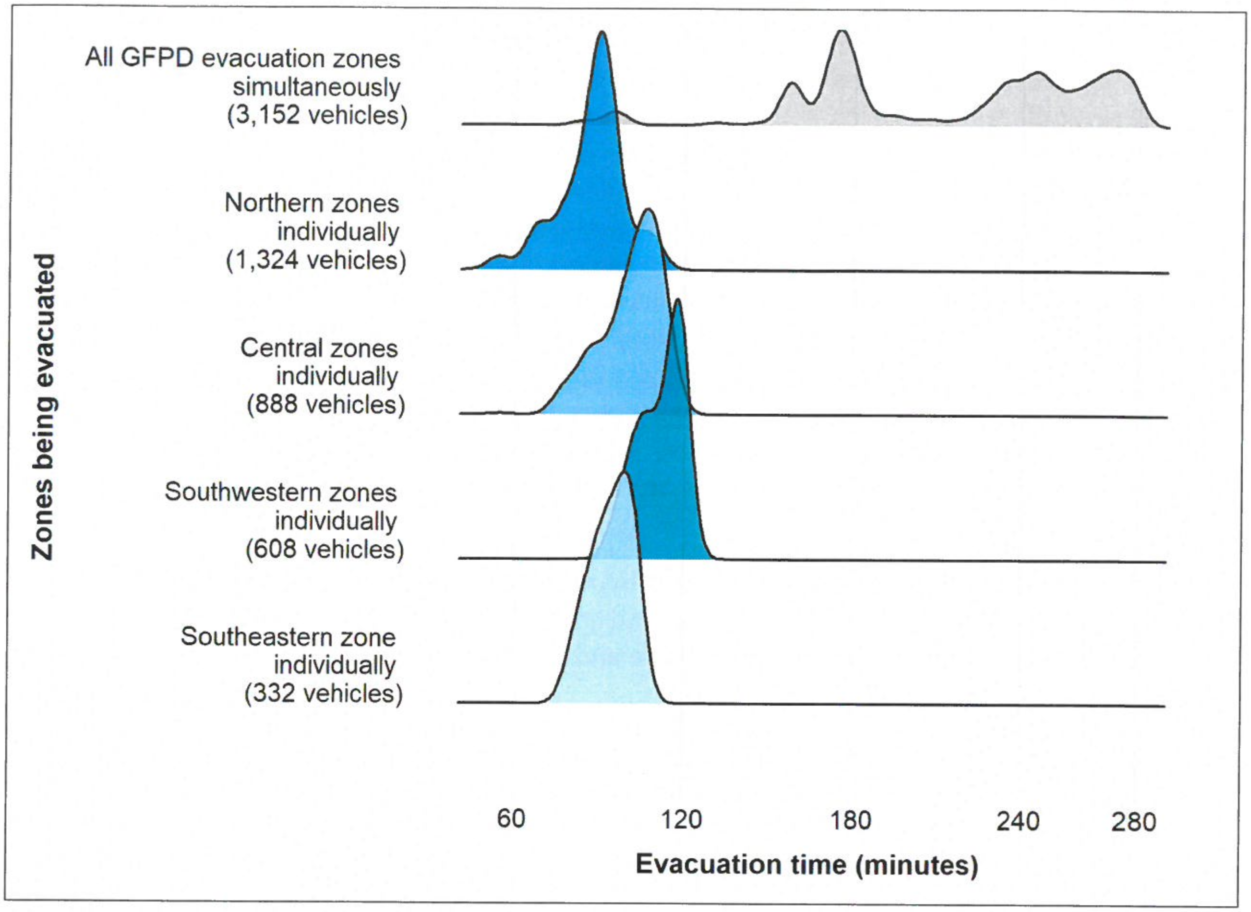


Figure 3d.4. Distribution of predicted evacuation times under a simultaneous district-wide evacuation order vs. under evacuation orders for individual zones one at a time. Peaks in the trendline correspond to potential evacuation times for a larger percentage of residents. We assumed that it takes 30 minutes for individuals to mobilize and depart after receiving an evacuation order. We modeled two vehicles leaving residential addresses and ten vehicles leaving business addresses. Colors correspond to evacuation zones in Figure 3d.1.

Evacuation Scenarios with Additional Egress Routes

> Modeling alternative evacuation routes does not represent a commitment to construct new roads or upgrade existing dirt roads. We recognize these alternate routes traverse private property, and additional conversations are required before pursuing options to ease evacuation congestion in the GFPD.

We used ArcCASPER to assess potential evacuation times under seven different scenarios with alternative evacuation routes (Table 3d.2). To explore the hypothetical impact of additional egress routes leaving the GFPD to the west and east, we modeled conditions with private gates closed vs. open at Genesee Springs Road in the northwestern part of the GFPD and at Shingle Creek Road in the northeastern part of the GFPD (see Figure 3d.5 for gate locations). Currently, Genesee Springs Road and Single Creek Road are impassible dirt roads that cross private land, so these scenarios represent hypothetical egress options. Utilizing these roads would require an investment in road maintenance and agreements with private landowners.

We also modeled conditions with two different hypothetical southern egress routes, one coming off Bitterroot Lane by the water treatment facility and another coming off Pine Drop Lane. We delineated hypothetical egress routes based on road grade and proximity to Highway-74 (see Appendix B for detailed maps of hypothetical egress routes).

Each of the seven scenarios assumed 2 cars per residential address and 10 cars per business address. We included 222 addresses from the Riva Chase HOA because these addresses could potentially be evacuated along with the GFPD, and we included 111 address from the eastern part of Kittridge to account for additional traffic that could be encountered on Highway-74 during an evacuation event. In total, these scenarios evacuated 1,864 addresses with 3,966 vehicles. We assumed that evacuees were directed to Ralston Elementary School north of I-70, eastbound I-70, or eastbound Highway-74, whichever destination took the least time for each vehicle to reach.

Our modeling showed that additional egress routes could reduce but not eliminate evacuation congestion and long evacuation times across the GFPD. Adding routes to the east, west, and/or south could result in lower evacuation times for many residents in the southern part of the GFPD, but rerouting traffic might increase evacuation times for some residents in the northern parts of the GFPD (Table 3d.2; Figure 3d.5). The purpose of the model is to minimize evacuation time for the entire district, not to minimize the evacuation time for each individual resident. ArcCASPER iteratively modifies the order that evacuees leave their homes and modifies the route each evacuee takes until the algorithm minimizes the time it takes for every single vehicle to evacuate the GFPD. Therefore, some addresses were evacuated at a later point in time during different scenarios to decrease evacuation times for other addresses, with the overall effect of reducing the evacuation time for the entire GFPD.

Each egress route scenario comes with potential benefits and drawbacks in terms of evacuation efficiency, safety, and road maintenance costs (Table 3d.3). Potential reductions in evacuation times by adding a new egress route were smaller in magnitude to potential reductions in evacuation times under the current road system if residents were to evacuate with only one vehicle. Of the alternative route scenarios, the greatest decrease in average evacuation times was brought about by adding a southern egress route and opening access to the east and west by unlocking gates at private drives. The position of the southern egress route impacted which addresses experienced a greater reduction in potential evacuation times—a southern egress route off Bitterroot Lane could decrease evacuation times for residents along Montane Drive West and southern portions of Montane Drive East, whereas a southern egress route off Pine Drop Lane might primarily benefit residents along Tamarac Drive and the western portion of Foothills Drive North and Foothills Drive South. Establishing a paved southern egress route with faster speed limits might decrease evacuation times relative to an unpaved southern egress route, but the decrease would be slight. Moderate to high levels of congestion were predicted for a southern egress route, resulting in slow rates of travel regardless of paving surface. Any southern egress route would require careful upkeep and vegetation management to provide a safe egress from the GFPD.

Unlocking the gate at Shingle Creek Road to allow traffic flow from the GFPD towards South Grapevine Road reduced average evacuation times more than unlocking the gate at Genesee Springs Route to allow traffic flow towards South Genesee Mountain Road. Unlocking the gate at Genesee Springs road might increase evacuation times for residents in the Genesee Estates area by drawing traffic from other parts of the GFPD in that direction. Routing traffic towards South Genesee Mountain Road does not address high congestion at I-70 on-ramps. In contrast, drawing traffic towards South Grapevine Road slightly decreases congestion at I-70 on-ramps by providing an opportunity to route evacuees south towards Highway 74.

Table 3d.2. Alternative evacuation route scenarios and their relative impact on evacuation times across the GFPD. We simulated a simultaneous district-wide evacuation order and assumed two vehicles leaving each residential address and ten leaving each business address. Scenarios include all addresses in the GFPD, Riva Chase HOA, and eastern part of Kittridge. The "western gate" is at Genesee Springs Road and the "eastern gate" is at Shingle Creek Road. Route 1 comes off Bitterroot Lane and route 2 comes off Pine Drop Lane (see gate and route locations in Figure 3d.5).

Egress scenario	Percent change in evacuation times (%) relative to baseline		
	Average	**Maximum decrease**	**Maximum increase**
Baseline. Current roadways with locked western and eastern gates.	--------	--------	
For comparison. Baseline but only one vehicle per residential address.	44% decrease	50% decrease	No increased evac. times
1. Current roadways with unlocked western gate and locked eastern gate.	2% decrease	28% decrease	110% increase
2. Current roadways with locked western gate and unlocked eastern gate.	6% decrease	25% decrease	37% increase
3. Hypothetical unpaved southern egress route 1 (speed limit 10 mph) and locked gates.	13% decrease	59% decrease	30% increase
4. Hypothetical paved southern egress route 1 (speed limit 20 mph) and locked gates.	15% decrease	63% decrease	26% increase
5. Hypothetical unpaved southern egress route 2 (speed limit 10 mph) and locked gates.	15% decrease	60% decrease	No increased evac. times
6. Hypothetical unpaved southern egress route 1 (speed limit 10 mph) and unlocked gates.	19% decrease	66% decrease	25% increase
7. Hypothetical unpaved southern egress route 2 (speed limit 10 mph) and unlocked gates.	20% decrease	66% decrease	71% increase

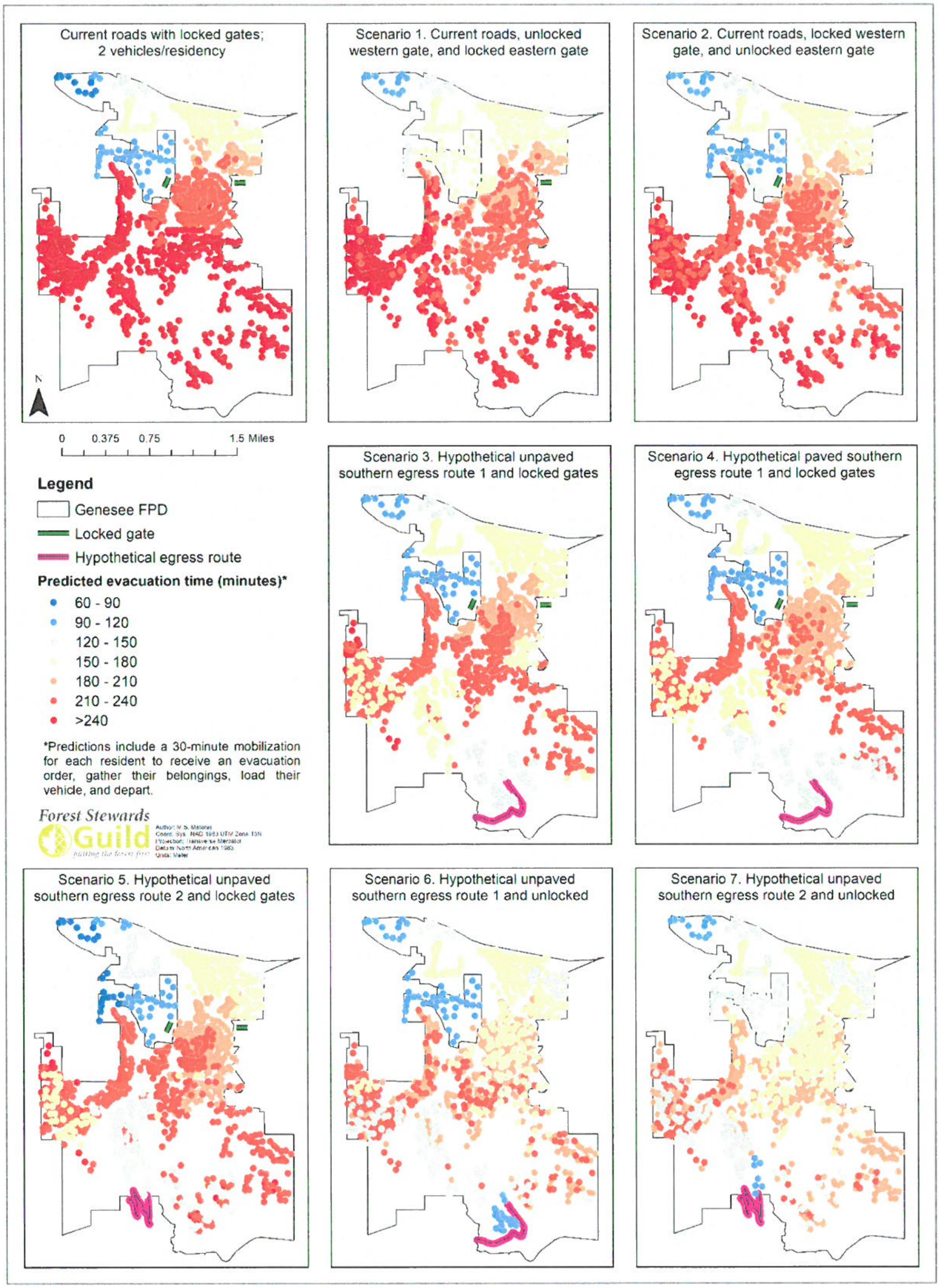


Figure 3d.5. Potential evacuation times for alternate egress scenarios. We simulated a simultaneous district-wide evacuation order and assumed that it takes 30 minutes for individuals to mobilize and depart after receiving an evacuation order. We modeled two vehicles leaving each residential address and ten leaving each business address. Scenarios included all addresses in the GFPD, Riva Chase HOA, and eastern part of Kittridge. See Table 3d.2 for scenario descriptions.

Table 3d.3. Potential benefits and drawbacks of creating new alternative egress route(s) from the GFPD.

Egress scenario	Potential benefits	Potential drawbacks
Baseline. Current roadways with locked western and eastern gates.	No need to construct new roads or route traffic across private property. Relatively fast evacuation times for businesses in the northwest corner of the GFPD and residents in Genesee Estates.	Concerningly long evacuation times in the central and southern parts of the GFPD.
For comparison. Baseline but only one vehicle per residential address.	No need to construct new roads or route traffic across private property. Substantial decrease in evacuation times for residents across the GFPD. No increases in evacuation times for individual residents.	Very difficult to secure agreement among all residents to evacuate with only one vehicle.
1. Current roadways with unlocked western gate and locked eastern gate.	Additional egress options to the west onto South Genesee Mountain Road. No need to construct new roads. Decreased evacuation times for residents in the central part of the GFPD.	Need to secure agreement of landowners to open gate at Genesee Springs Road during evacuations. Need to improve and maintain Genesee Springs Road for efficient and safe evacuations. Increased evacuation times for businesses in the northwest corner of the GFPD and residents in Genesee Estates. Marginal decreases in evacuation times for residents in the southern portion of the GFPD.
2. Current roadways with locked western gate and unlocked eastern gate.	Additional egress options to the east onto South Grapevine Road. No need to construct new roads. Decreased evacuation times for residents in the central part of the GFPD.	Need to secure agreement of landowners to open gate at Shingle Creek Road and permission to drive through the Riva Chase HOA. Need to improve and maintain Shingle Creek Road for efficient and safe evacuation. Marginal decreases in evacuation times for residents in the southern portion of the GFPD.
3. Hypothetical unpaved southern egress route 1 (speed limit 10 mph) and locked gates.	Significant decreases in evacuation times for residents in the southern part of the GFPD. Southern egress route could serve as a fuelbreak and control point for firefighters to slow the spread of fire into the GFPD.	Need to work with Genesee Water and Sanitation District to construct new road that would only be open during evacuations. Visual impacts of a new road. Cost of road construction and regular maintenance. Construction costs would be lower for an unpaved road. Need to create and maintain fuelbreaks along the new route.

Table 3d.3 (continued). Potential benefits and drawbacks of creating new alternative egress route(s) from the GFPD.

Egress scenario	Potential benefits	Potential drawbacks
4. Hypothetical paved southern egress route 1 (speed limit 20 mph) and locked gates.	Significant decreases in evacuation times for residents in the southern part of the GFPD. Faster evacuation times and lower congestion along southern egress route due to paved conditions and faster speed limit. Southern egress route could serve as a fuelbreak and control point for firefighters to slow the spread of fire into the GFPD.	Need to work with Genesee Water and Sanitation District to construct new road that would only be open during evacuations. Visual impacts of a new road. Cost of road construction and regular maintenance of paved road.
5. Hypothetical unpaved southern egress route 2 (speed limit 10 mph) and locked gates.	Significant decreases in evacuation times for residents in the southern part of the GFPD. Southern egress route could serve as a fuelbreak and control point for firefighters to slow the spread of fire into the GFPD.	Need to secure agreement of landowners to construct new road that would only be open during evacuations. Visual impacts of a new road. Cost of road construction and regular maintenance. Need to create and maintain fuelbreaks along the new route.
6. Hypothetical unpaved southern egress route 1 (speed limit 10 mph) and unlocked gates.	Significant decreases in evacuation times for residents in the central and southern parts of the GFPD. Lower congestion along southern egress route in comparison to scenario 3 with locked gates. Southern egress route could serve as a fuelbreak and control point for firefighters to slow the spread of fire into the GFPD.	Need to work with Genesee Water and Sanitation District to construct new road that would only be open during evacuations. Need to secure agreement of landowners to open gates at Genesee Springs and Shingle Creek Roads and permission to drive through the Riva Chase HOA during evacuations. Visual impacts of a new road. Cost of road construction and regular maintenance of unpaved road. Increased evacuation times for businesses in the northwest corner of the GFPD and residents in Genesee Estates.
7. Hypothetical unpaved southern egress route 2 (speed limit 10 mph) and unlocked gates.	Significant decreases in evacuation times for residents in the central and southern parts of the GFPD. Lower congestion along southern egress route in comparison to scenario 5 with locked gates. Southern egress route could serve as a fuelbreak and control point for firefighters to slow the spread of fire into the GFPD.	Need to secure agreement of landowners to construct new road that would only be open during evacuations. Need to secure agreement of landowners to open gates at Genesee Springs and Shingle Creek Roads and permission to drive through the Riva Chase HOA during evacuations. Visual impacts of a new road. Cost of road construction and regular maintenance of unpaved road. Increased evacuation times for businesses in the northwest corner of the GFPD and residents in Genesee Estates.

3e. 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 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 3b.2). 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 3e.1).

Under 90th percentile fire weather conditions, 13% of the 56 miles of roads, private drives, and driveways in the GFPD could potentially experience non-survivable conditions during a wildfire, and this percentage rises to 31% under 97th percentile fire weather conditions (Figure 3e.2). Some non-survivable road segments are part of key evacuation routes and a high priority for mitigation to reduce fuels and potential flame lengths. We identified these areas as evacuation pinch points and incorporated them into recommendations for roadway fuelbreaks across the GFPD (see Section 5d. Suggestions for Roadway Fuelbreaks).

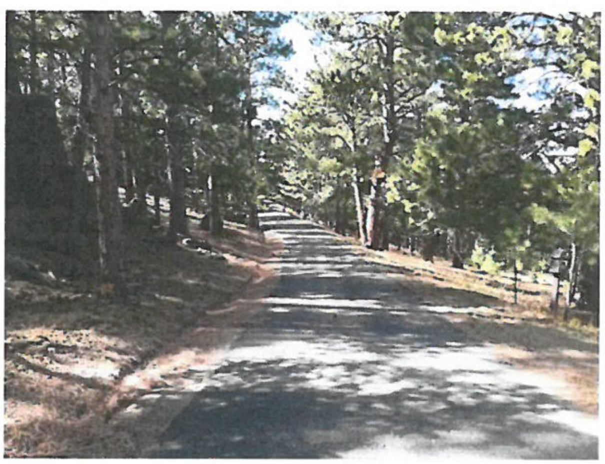


Figure 3e.1. Some roads in the GFPD could experience potentially non-survivable conditions because they are lined with thick forests that have an abundance of ladder fuels (left image). Other roads have been well mitigated by removing tall trees and saplings, removing limbs on the remaining trees, and keeping grass mowed (right image). Photographs from the Forest Stewards Guild.

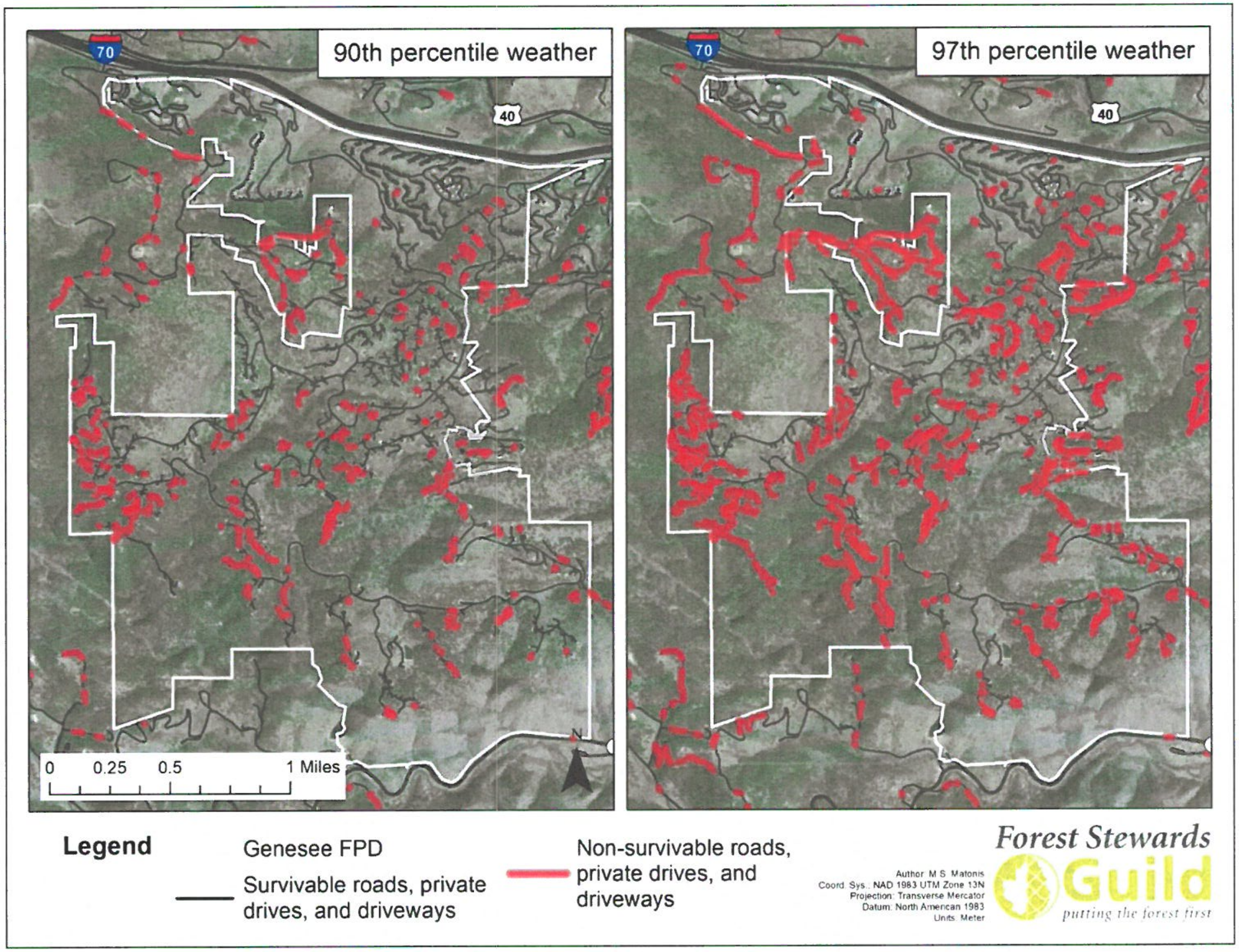


Figure 3e.2. Under 90th percentile fire weather conditions, 13% of the 56 miles of roads, private drives, and driveways in the Genesee Fire Protection District could potentially experience non-survivable conditions during wildfires (i.e., flame lengths over 8 feet). This percentage rises to 31% under 97th percentile fire weather conditions. See Appendix C for predictions under 60th percentile fire weather conditions.

3f. Designated Areas for Wildfire Evacuation Emergencies

Designated areas for wildfire evacuation emergencies are an outdoor area where residents might survive a wildfire if they are unable to safely evacuate. Designated areas for wildfire evacuation emergencies might be large parking lots, large open areas with limited vegetation, and areas around lakes. **Sheltering in place during a wildfire rather than evacuating is a worst-case, last-ditch effort to increase the chance of survival** when (1) exiting roads are blocked by fire or (2) evacuation is perceived as too risky due to fast-approaching wildfires and severe roadway congestion. There is currently no standard terminology for this concept. We do not use the term "safety zone" because this term has a specific meaning in the context of wildland firefighting.[5]

During a fast-moving wildfire, the best strategy is to promptly evacuate. During a wildfire, ONLY first responders will direct vehicles in the direction of a designated area for wildfire evacuation emergencies and determine the number of people and vehicles that can safely shelter in each location.

Designated areas for wildfire evacuation emergencies are particularly important in WUI communities where evacuation times are high due to limited egress routes (Cova 2005), as is the case in GFPD. There is evidence of residents surviving by sheltering in place while others perished during dangerous, last-minute evacuations (Cova and others 2009).

The size of an adequate designated area for wildfire evacuation emergencies depends on the height of surrounding vegetation, slope, windspeed, burning conditions, and the number of individuals and vehicles using the location. Taller vegetation can support longer flame lengths that emit more radiant heat, and steeper slopes and higher wind speeds result in faster-moving fires and greater exposure to convective heat. More extreme burning conditions also correspond to lower fuel moistures and greater fuel accumulations. Windspeed is impossible to predict before an incident, so planning for the worst-case scenario is important.

We used the revised safety zone standards from Butler (2019) to calculate safe separation distances from potential burnable locations within the GFPD. The revised equations are more conservative than the original equations used to calculate safety zones for wildland firefighters; the original methodology did not account for slope and wind, and therefore did not properly account for risk from convection heating in addition to radiant heating (Butler 2019).

We followed the approach of Campbell and others (2017) to delineate potential designated areas for wildfire evacuation emergencies. Areas considered for potential locations met the following criteria: (1) non-forested, (2) slopes less than 15%, (3) not on roadways, and (4) within 1/8th mile of roadways. Flaming shrubs can pose a hazard to people in designated areas for wildfire evacuation emergencies, but we assumed that shrubs could be cut and removed during annual maintenance of designated areas. We assumed extreme fire burning conditions and conducted the analysis for wind speeds of 0-10 mph, 10-20 mph, and >20 mph.

[5] A safety zone is a location where threatened firefighters can find adequate refuge from an approaching fire and survive without using a fire shelter (NWCG 2018b). Firefighters constantly re-evaluate the location of safety zones and modify tactics to ensure adequate access to safety zones. Designated areas for wildfire evacuation emergencies are also intended to provide refuge from an approaching fire, but they are intended for residents. They are pre-identified by fire departments and sheriff's offices prior to a wildfire incident and carefully maintained to prevent fuel accumulation that would potentially create non-survivable conditions.

Our rating of the relatively suitability of designated areas for wildfire evacuation emergencies is based on the number of trees that are tall enough and close enough to expose people to non-survivable radiant and convective heat during a wildfire. See Appendix B for more details on our assessment protocol for designated areas for wildfire evacuation emergencies.

Based on our analysis, there are currently no areas within the GFPD that could serve as a fully safe designated area for wildfire evacuation emergencies under 10-20 mph and >20 mph winds due to steep slopes and heavy fuel loads. Three locations are suitable under 0-10 mph winds (Figure 3f.1). During wildfires burning through dry fuels but under low wind speeds, the area around Flatiron Community Church in the northern portion of the GFPD could potentially hold around 3,000 people with no vehicles. A grassy area just to the west of the GFPD off Foothills Drive North could potentially hold about 300 people with no vehicles. The other location in the south-central portion of the GFPD is small and could only hold between 10 to 80 people with no vehicles. This is especially concerning since evacuation times for residents living far from I-70 could be lengthy, and wildfire behavior could be intense in this part of the GFPD.

Other flat parts of the GFPD could function as designated areas for wildfire evacuation emergencies, but only following substantial work to remove all trees and reduce surface fuel loads in an area large enough to create safe conditions during wildfires. Section 5e (Treatments to Create Designated Areas for Wildfire Evacuation Emergencies) provides recommendations to GFR and HOAs regarding the creation and maintenance of survivable areas.

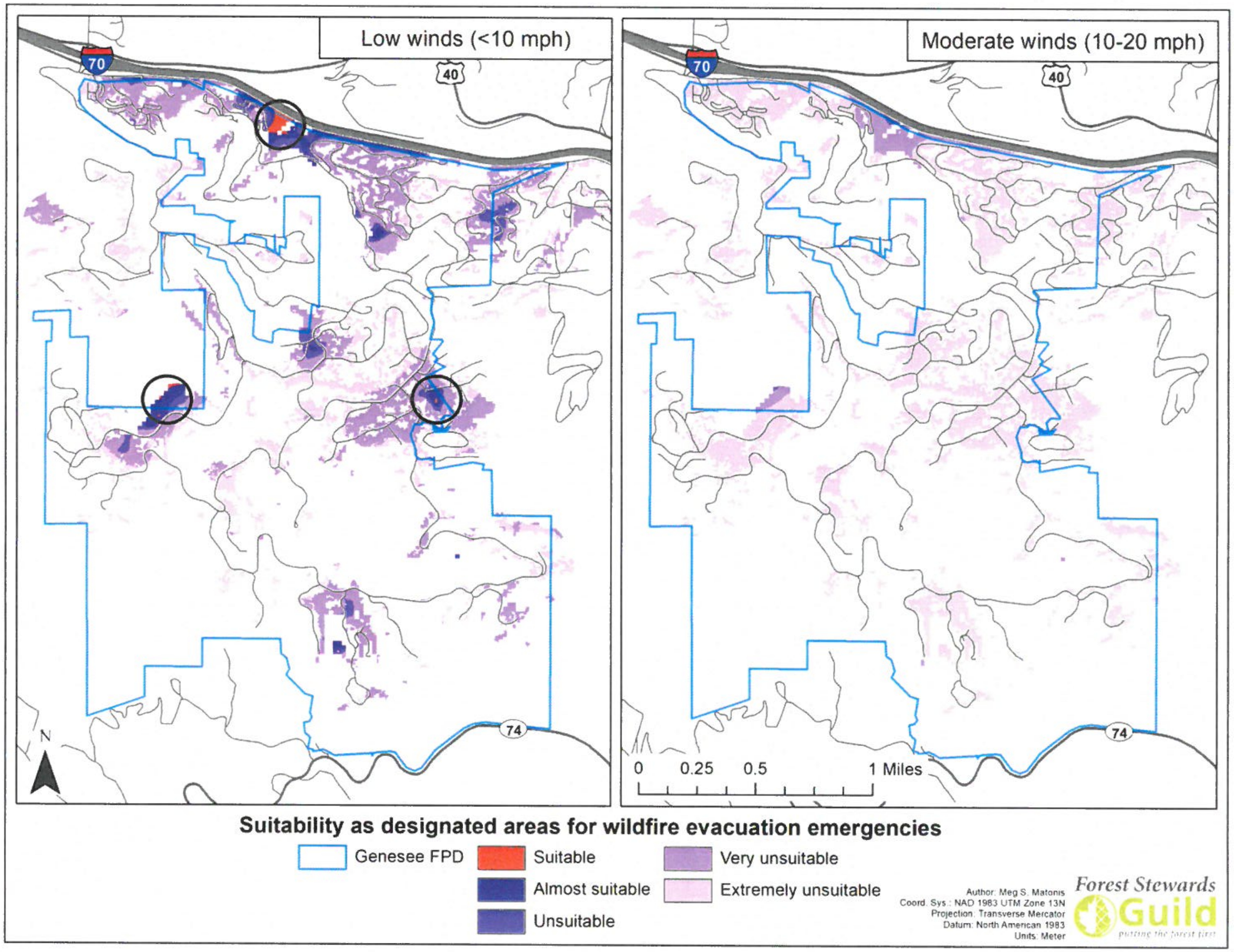


Figure 3f.1. Relative suitability of designated areas for wildfire evacuation emergencies across the GFPD (see Appendix B for a description of suitability categories). Only three locations had adequate separation distances from vegetation that could produce non-survivable radiant and convective heat during a wildfire if winds were less than 10 mph (areas circled in black for emphasis). No areas were fully suitable if winds were 10-20 mph. This figure does not include the suitability of locations for winds greater than 20 mph because every location was extremely unsuitable.

3g. Plan Unit Hazard Assessment

We compared the **relative** risk that wildfires pose to life and property in 16 plan units across the GFPD (Figure 3a.1). Homes across the GFPD have high 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 "low risk" has risk factors that are lower than risk factors in other plan units, but it is still an area with wildfire hazards; all portions of the GFPD could receive long-range spotting (Figure 3c.3). 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 the GFPD, so the assessment is not suitable for comparing GFPD to other communities.

Our assessment was based on predictions of fire behavior, radiant heat and spotting potential, roadway survivability, and evacuation time, as well as an on-the-ground assessment of each plan unit. In October 2020, members of the Forest Stewards Guild drove around the GFPD 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. We also utilized data collected by Shandian Wildfire Consulting and Fire Whirl Services Inc. in 2009 regarding the presence/absence of turnarounds and the lengths and widths of private drives and driveways within the GFPD—factors that strongly influence the accessibility of homes to firefighters. The condition of private drives and driveways in 2021 is assumed to be similar to the 2009 assessment because little work has been done to modify roadways, private drives, and driveways in terms of firefighter access. See Appendix D for the detailed methodology of our hazard assessment.

Relative Ratings

Plan units with the highest overall hazard ratings are concentrated in the southwestern portion of the GFPD (Figure 3g.1). Wildfire risk is high in these plan units because of steep slopes and dense vegetation with ladder fuels, particularly in adjacent private property to the west of the GFPD. Evacuation concerns are particularly high in the southwestern portion of the GFPD due to the greater distance from I-70 and lack of southern egress route.

Suppression capabilities are most limited in the Genesee Estates plan unit where there are a very limited number of cistern-supplied fire hydrants and roads are exceptionally narrow. The other plan units have 6 to 32 hydrants dispersed along roadways and private drives. Suppression capabilities are also limited across much of the Genesee Foundation due to an abundance of long and narrow private drives and driveways with inadequate turn arounds. Depending on fire behavior it, could be unsafe to drive structural fire engines or even smaller wildland firefighting type 6 engines down many of these narrow private drives and driveways.

Keep in mind: The Plan Unit Hazard Assessment describes ***relative*** risk among plan units within the Genesee Fire Protection District. Plan units with lower 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 GFPD. Plan units with higher relative risk are strong candidates for immediate action to mitigate hazardous conditions.

Home ignition zone hazards are particularly extreme in the Chimney Creek, Genesee Foundation A, and Genesee Foundation B plan units due to high housing densities, flammable siding and deck materials, and the proximity of dry, flammable vegetation to homes. Multi-occupancy dwellings in the Ridge Townhomes have high hazards due to wooden decks and fences. See Table 3g.1 for common concerns we identified in plan units with high to extreme relative ratings and Section 4d (Priority Plan Unit Recommendations) for specific recommendations to address hazards in each plan unit.

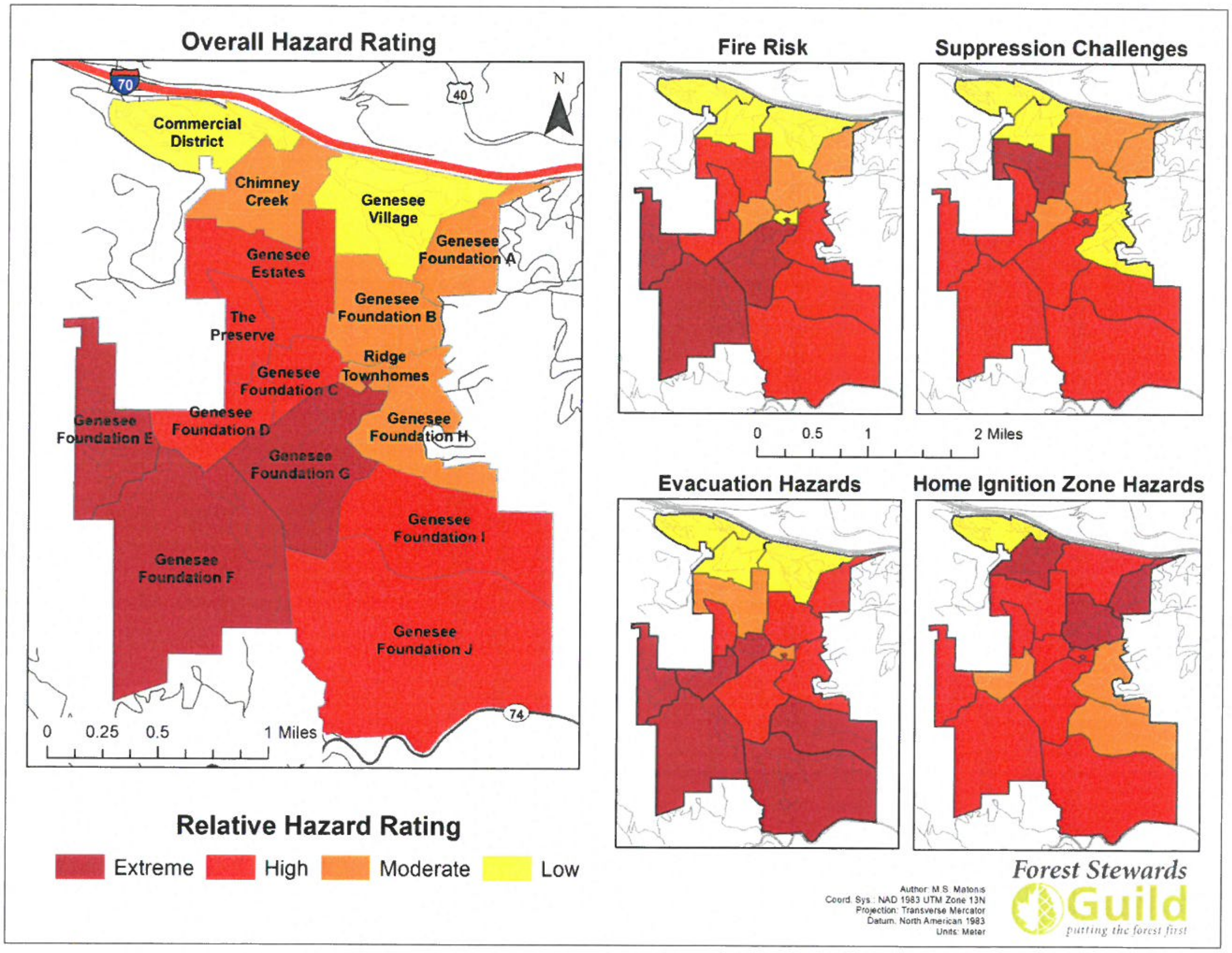


Figure 3g.1. We assessed relative hazards in four categories: fire risk, fire suppression challenges (e.g., limited hydrant availability and road access for fire engines), evacuation hazards, and home ignition zone hazards. Plan units with the highest overall hazard ratings are concentrated in the southwestern portion of the GFPD. Plan units with lower relative risk still possess conditions that are concerning for the protection of life and property in the case of a wildfire. See Appendix D for assessment methodology.

Table 3g.1. Notable concerns in plan units with high to extreme relative hazard ratings.

Hazard rating category	Notable concerns in plan units with high to extreme relative hazard ratings
Fire risk	• Homes located along steep slopes and on ridgetops. • Dense forest vegetation with ladder fuels and interlocking tree crowns adjacent to homes.
Fire suppression challenges	• Long, narrow, and steep private drives and driveways lacking turnarounds could be unsafe for structural fire engines or even smaller wildland firefighting type 6 engines under certain fire behavior conditions. • Very few fire hydrants along roadways and private drives. • Several locked gates that would slow or impede firefighter access.
Evacuation limitations	• Dense patches of saplings and closely spaced, tall trees adjacent to roadways, which creates the potential for non-survivable conditions were fire to encroach the road. • Homes located far from northern egress routes.
Home ignition zone hazards	• Flammable siding and decking materials. • Firewood stacked against or close to siding or under wooden decks. • Trees with low limbs growing near homes. • Needle cast on roofs and in gutters from tree limbs growing over homes. • Shrubs and saplings growing directly against flammable siding and under wooden decking. • Tall, dry grass growing directly against flammable siding.

4. Community Recommendations

4a. Evacuation Planning and Capacity

Residents are correct in feeling concerned about limited evacuation capacity in the GFPD—there is a high likelihood of evacuation congestion and long evacuation times during a wildfire. Evacuation times for individual residents could exceed 90 minutes in some parts of the GFPD due to the limited number of egress routes.

Some residents are concerned for 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 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. Having a plan in place ahead of time can ensure prompt evacuations and save lives during wildfires.

Reliable technology to provide warnings and information about evacuations is the most important factor that would make residents feel confident in their ability to evacuate during a wildfire (Appendix A). Jefferson County Communications Center Authority (JeffCom) uses CodeRED, also known as reverse 911, to communicate evacuation orders to residents. According to JeffCom, CodeRED participation in the GFPD is high, with over 80% of residents opted into the program by at least one method of contact. GFR, HOAs, and residents should actively extend awareness about CodeRED to neighbors that are unaware of the program. Residents of the Genesee Village HOA, Genesee Estates, and Chimney Creek HOAs have lower participation rates and awareness about CodeRED than residents of the Genesee Foundation.

> **CodeRED** is the reverse 911 system used by JeffCom 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 CodeRED website.

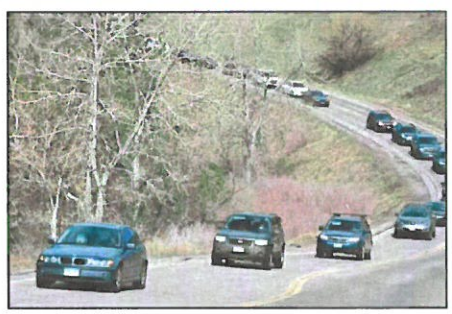
We recommend the following steps for residents, HOAs, community groups, GFR, and the Jefferson County Sherriff's Office to address evacuation concerns in the GFPD:

- Explore options to build a southern egress route to increase the GFPD's evacuation capacity. Our analysis suggests adding a southern egress route could significantly decrease evacuation times for residents in the southern part of the GFPD, although the potential for evacuation congestion would still exist depending on the number of residents evacuating and the staggering of evacuation orders. See Table 3d.3 for potential benefits and drawbacks of different alternate egress routes.
- Consider establishing and maintaining designated areas for wildfire evacuation emergencies across the GFPD, particularly in areas with predicted evacuation times greater than 1 hour (Section 5e. Treatments to Create Designated Areas for Wildfire Evacuation Emergencies).
- Conduct tree removal, cut low limbs, and mow grass along roadways to increase the likelihood of survivable conditions during a wildfire (Section 5d. Suggestions for Roadway Fuelbreaks).

- Coordinate with the Jefferson County Sherriff's Office to conduct evacuation drills to practice safe and effective evacuation for the entire GFPD.
- Coordinate with JeffCom to increase participation in CodeRED across the GFPD. 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 (see callout box below).
- 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. Visit the Rotary Wildfire Ready website to learn about preparing go-bags and evacuation planning.
- 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.

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

- 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.



4b. Mitigating 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 the home and other structures (e.g., sheds and garages) and area within 100 feet of each structure (NWCG 2018b). The Insurance Institute for Home and Business Safety (IIHBS) found that firefighter intervention, adequate defensible space, and home hardening measures were common factors for homes that survived major wildfires in 2017 and 2018 (IIHBS 2019).

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 private drive or driveway.

Defensible space is the area around a building in which 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 (NWCG 2018b). The term "defensible" reflects that firefighters can more safely defend a home during wildfire because of reduced hazards and the availability of safety zones. When multiple neighbors create defensible space around their homes, it creates linked defensible space and makes entire neighborhoods defensible. Firefighters and residents attest to the important role defensible space played in allowing homes to survive during previous wildfires in Colorado (Jolley 2018).

Home hardening is the practice of making a home less susceptible to ignition from 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). 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 – Recommended Practices

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. Removing flammable materials decreases radiant heat exposure to your home and gives firefighters an opportunity to defend it. Defensible space creates a buffer between your home and grass, 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 and others 2016). Substantially reducing vegetation within the HIZ and removing vegetation that overhangs decks and roofs can reduce structure loss, especially for homes on slopes (Syphard and others 2014).

During a wildland fire, homes that have clear defensible space are identified as sites for wildland firefighters to engage in home protection. 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 Colorado State Forest Service (CSFS) defines zone 1 as 0 to 5 feet from the home—the "noncombustible zone", zone 2 as 5 to 30 feet from the home—the "lean, clean, and green zone", and zone 3 as 30 to 100 feet from the home.[6] Residents should establish defensible space around each building on their property, including detached garages, storage buildings, barns, and other structures. Specific recommendations are outlined in Figure 4b.1, Table 4b.1, and the 2021 CSFS publication *The Home Ignition Zone: A guide for preparing your home for wildfire and creating defensible space*.

Tall grass, tight crown space, and dense ladder fuels could endanger these upslope homes due to radiant and convective heating and short-range embers during a wildfire. Photo from the Forest Stewards Guild.

[6] Zone delineations are based on the updated 2021 Home Ignition Zone Guide from the Colorado State Forest Service. Some organizations use different zone delineations, but the general concept is the same—remove all flammable vegetation directly adjacent to your home and reduce fuel loads in larger zones around your home.

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. Over 95% of homes within the Genesee FPD are within short-range spotting distance of at least one neighboring home (Figure 3c.5), and many homes abut undeveloped areas with dense forests and are potentially exposed to radiant heat and short-range spotting from these areas. Overlapping HIZs are most common in the Genesee Village, Genesee Foundation A, Genesee Foundation B, and Genesee Foundation E plan units. Neighbors can increase their homes' chances of survival during a wildfire if they work together to reduce hazards in their overlapping defensible space.

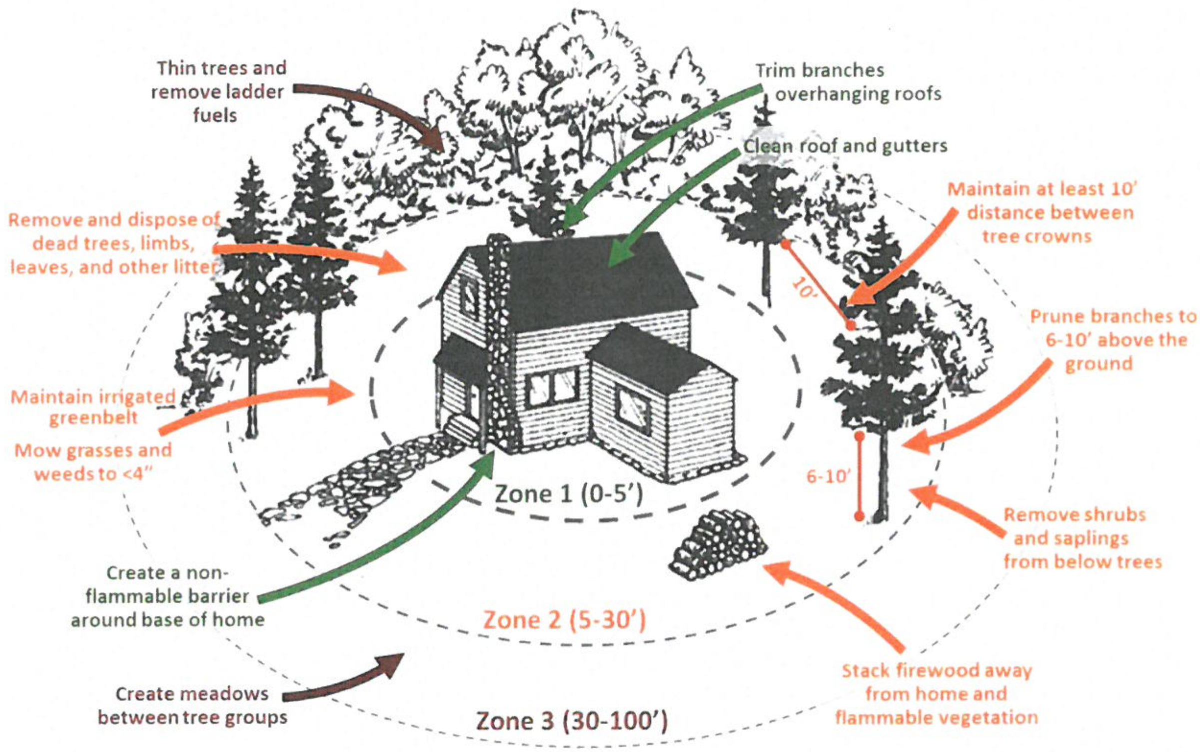


Figure 4b.1. Defensible space zones and mitigation measures recommended by the Colorado State Forest Service (CSFS 2020). Image from the CFSF with modification by M.S. Matonis.

Table 4b.1. Defensible space recommendations for homes in the WUI based on the CSFS publication *The Home Ignition Zone: A guide for preparing your home for wildfire and creating defensible space* and Rotary Wildfire Ready. This is not an all-inclusive list of activities. Specific measures will depend on the placement and condition of your property.

Zone 1: 0 to 5 feet from your home (noncombustible zone)
Goal: Prevent flames from coming in 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. • Prune tree branches hanging over your roof to reduce leaf accumulation and ignition risk. • 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. remove all fuels within 10 feet of your chimney. • Annually remove dead or dry leaves, pine needles, and dead plants from around your home and off your deck and roof.
Zone 2: 5 to 30 feet from your home (lean, clean, and green zone)
Goal: Reduce heat production and slow the movement of flames approaching your home.
• Irrigate and mow or trim grasses adjacent to your home to a maximum height of 4 inches. • Replace flammable vegetation like junipers 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 all trees, or at the minimum, 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 4b.2). See Figure 4b.2 for a depiction of how to measure crown spacing. • Remove limbs than hang less than 10 feet above the ground on remaining trees. See Figure 4b.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. • Keep spacing between shrubs at least 2-3 times their height. • 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.
Zone 3: 30 to 100 feet from your home
Goal: Slow movement of flames approaching your home, reduce the likelihood of crown fires, and improve forest health.
• Thin trees to increase spacing and remove ladder fuels to reduce the likelihood of torching, crown fires, and ember production. • Create meadows between groups of trees so that fire must transition to the ground to keep moving rather than spreading from tree crown to tree crown. • 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 Section 5c. Suggestions for Ecological Restoration and Stand-Level Fuel Treatments.

Table 4b.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 %	15 feet[1]	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

[1]The Colorado State Forest Service recommends a minimum of 10 feet spacing on flat terrain, but we recommend minimum crow spacing of at least 15 feet to significantly reduce the likelihood of tree-to-tree ignitions.

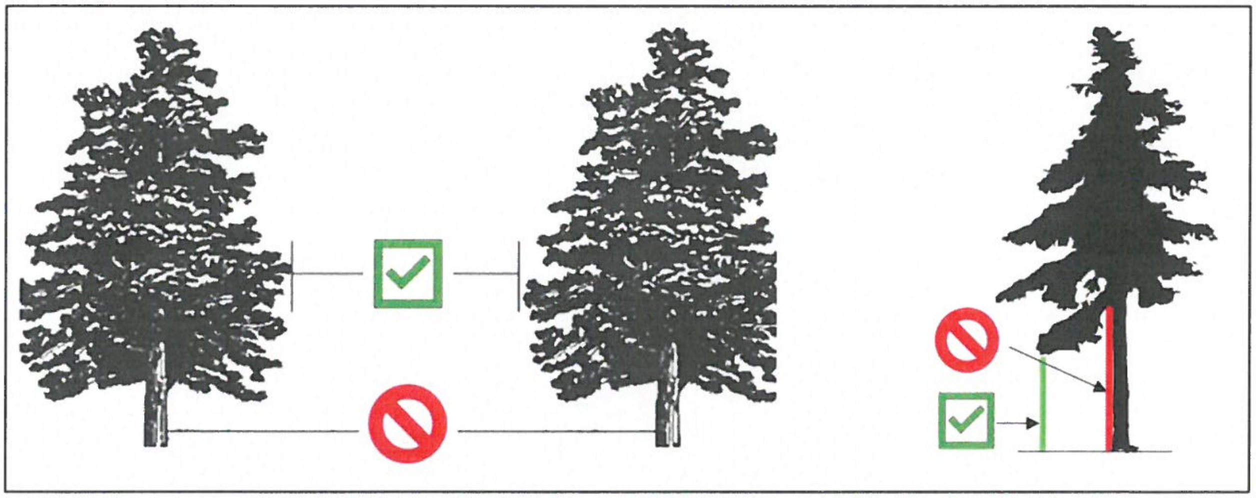


Figure 4b.2. Spacing between tree crowns is measured from the edge of tree crown to tree crown, NOT from tree stem to tree stem (left). Height of limbs above the ground is measured from the ground to the lowest point of the limb, NOT from where the limb attaches to the tree (right).

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 2c.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 4b.3).

According to the Director for the Jefferson Conservation District, 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 5c (Suggestions for Ecological Restoration and Stand-Level Fuel Treatments) for more information on treatments that achieve ecological and fuel reduction objectives.

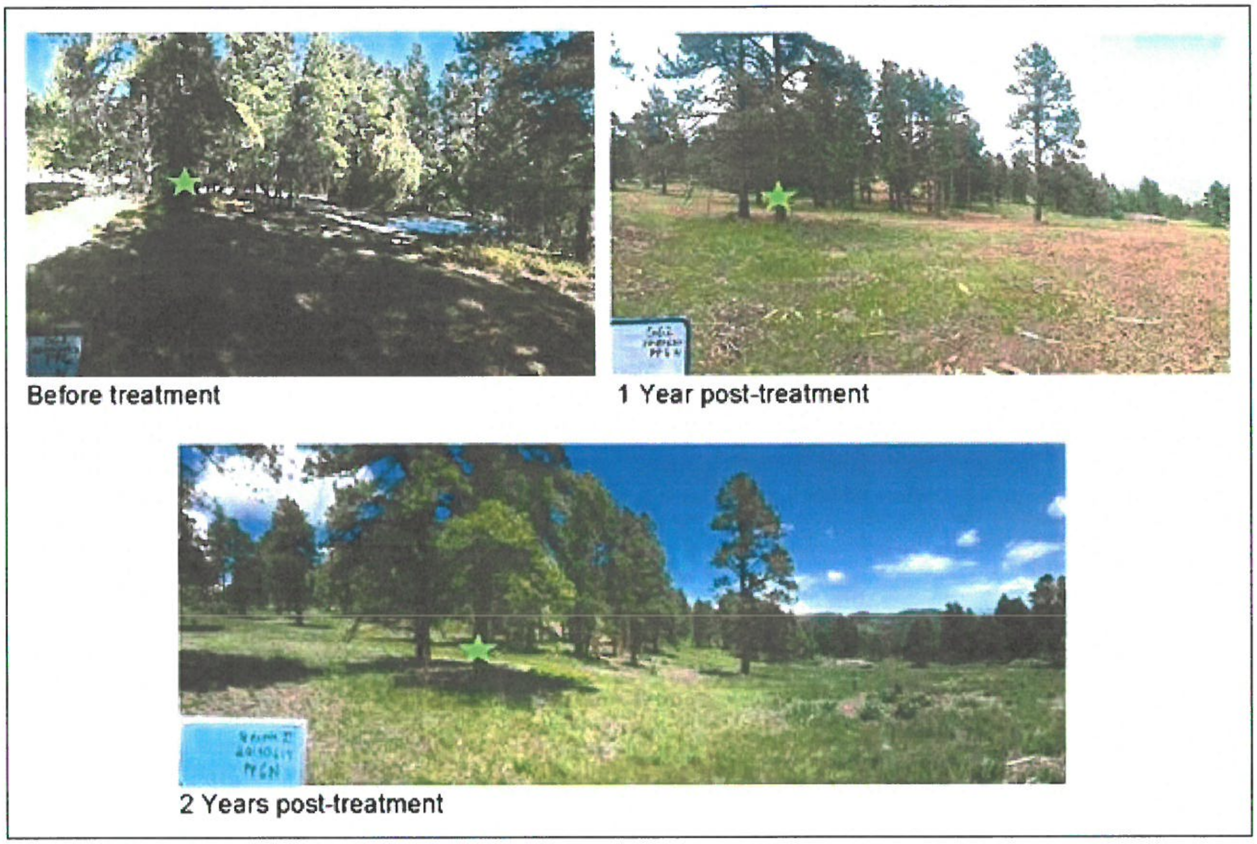
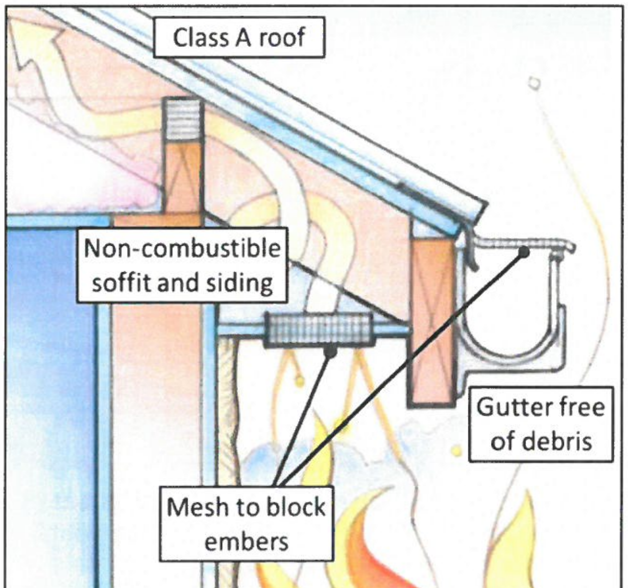


Figure 4b.3. Grasses, shrubs, and wildflowers quickly respond to increased light availability after tree removal, resulting in beautiful ecosystems with lower fire risk. The green star in each photo indicates the same tree. Image sizes vary due to the use of different cameras over the years. Photos from the Jefferson Conservation District.

Home Hardening – Recommended Practices

Home hardening involves modifying your home to reduce the likelihood of structural ignition. All homes in the GFPD are at risk of long-range embers from nearby burning vegetation, and many portions are at risk of short-range embers and radiant heat as well. **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 4b.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 and others 2016; 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).

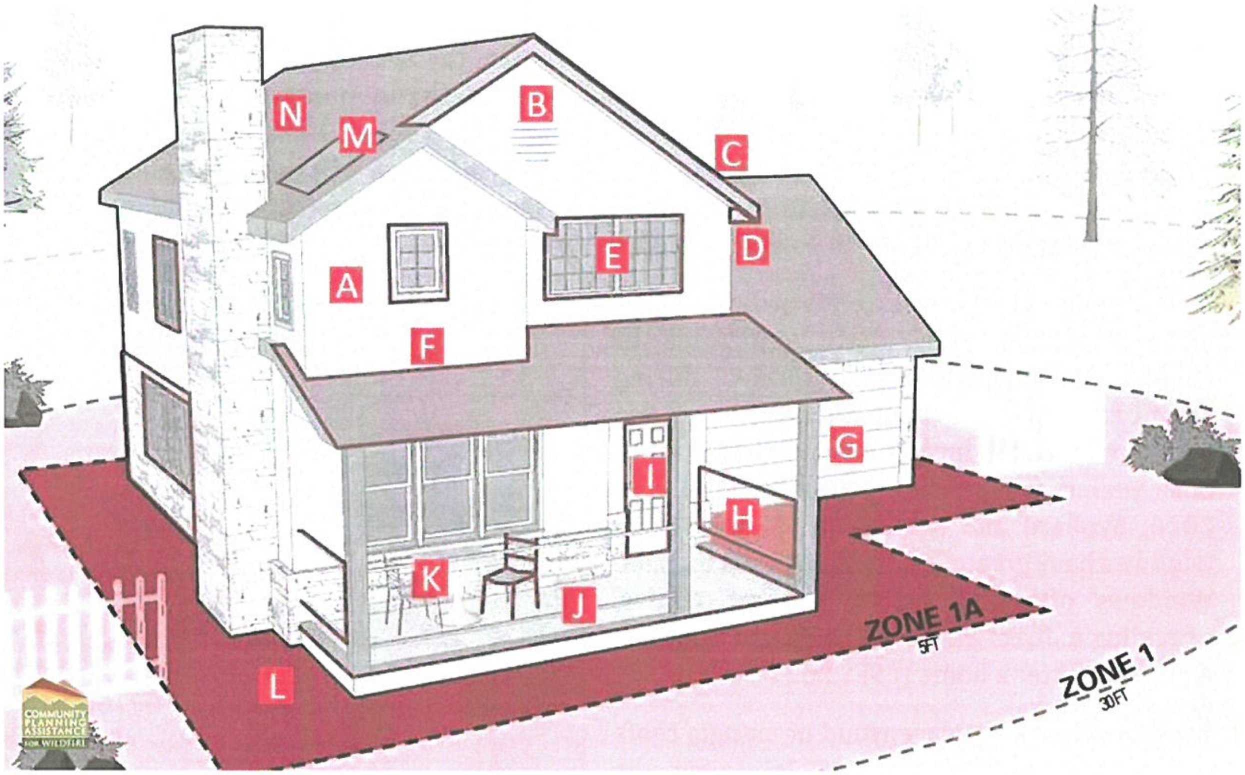


Residents can increase their homes' chance of survival by making it harder for embers to enter and ignite their homes (image from Healthy Building Science).

It is important to replace wood or shingle roofs with noncombustible materials[7] 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.

Almost 60% of survey respondents in the GFPD have replaced their roofs with less flammable materials (Figure 2f.2). However, only 17% of residents have installed screens to block embers, only 2% have replaced their siding or decking, and only 1% have created non-flammable barriers around their homes. There are many low-cost actions you can start with to harden your home (see Defensible Space and Home Hardening—Barriers and Opportunities below). Keep home-hardening practices in mind and use ignition-resistant materials if you replace a hail-damaged roof or remodel your home. In January 2020, Jefferson County approved new building construction regulations for homes above 6,400 feet in elevation, and the Jefferson County Department of Development and Transportation provides a list of approved building materials to help address the high potential for home loss in the WUI. New construction and replacement construction that require a building permit must comply with the new building standards.

[7] 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).



A. Use noncombustible or ignition resistant siding and trim (e.g., stucco, fiber cement, fire-retardant treated wood).

B. Cover vent openings with 1/16th to 1/8th inch corrosion-resistant metal mesh.

C. Clear debris from roof and gutters regularly. Install noncombustible gutters, gutter covers, and downspouts.

D. Install ignition-resistant or noncombustible roofs (composition, metal, or tile). Use noncombustible eaves and cover eaves with screened vents.

E. Install multi-pane windows with at least one tempered-glass pane and metal mesh screens. Use noncombustible materials for window frames. Limit the size and number of windows facing large areas of vegetation.

F. Install a 6-inch vertical noncombustible surface on all gables above roofs.

G. Install weather stripping around and under garage doors. Consider installing 1-hour fire rated garage doors.

H. Avoid combustible lattice, trellis, or other decorative features.

I. Install weather stripping around and under doors. Consider installing a 1-hour fire rated door.

J. Use ignition-resistant or noncombustible decking. Enclose crawl spaces. Remove combustible materials from underneath, on top of, or within 5 feet of deck.

K. Use noncombustible patio future.

L. Establish and maintain a 5-foot noncombustible buffer around the home. Use noncombustible fencing within this zone.

M. Use glass panes for skylights, not materials that can melt (e.g., plexiglass).

N. Cover chimneys and stovepipe outlets with 3/8th to ½ inch corrosion-resistant metal mesh.

Figure 4b.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 CAL FIRE (2019).

Mitigating the Home Ignition Zone – Barriers and Opportunities

Many residents in the GFPD have already created defensible space and undertaken home hardening measures ([Figure 2f.2](#)). Over 80% of survey respondents annually remove debris from their gutter and roof, clear debris from around their homes, and cut trees or remove low limbs in their HIZ. However, only 1% of residents have created non-flammable barriers around their home, which is a recommended practice to reduce a home's exposure to direct flame. Residents of the GFPD shared several barriers to mitigation actions (Figure 4b.5), and Table 4b.3 proposes several opportunities to address these challenges.

Defensible space works!

In 2020 a spark from a contractor's equipment ignited a fire in the GFPD, but the fire was easily contained because the homeowner created defensible space across their property.

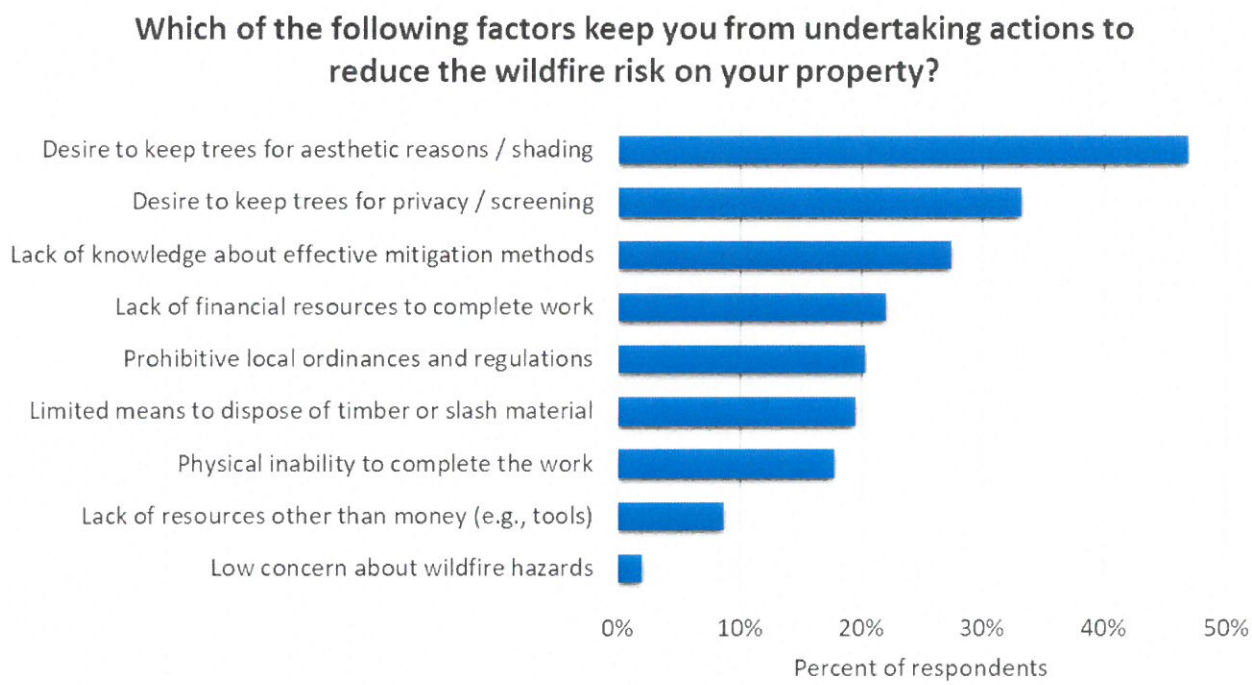


Figure 4b.5. The desire to keep trees near homes for aesthetic reasons, shading, or privacy screening and lack of information are top barriers to mitigation work by residents in the Genesee Fire Protection District.

Table 4b.3. Common concerns expressed by residents in the GFPD 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 4b.1, Table 4b.1, and read the CSFS publication *The Home Ignition Zone: A guide for preparing your home for wildfire and creating defensible space* for recommendations. Visit Rotary Wildfire Ready and the Colorado State Forest Service for useful information and tips about defensible space creation. Reach out to GFR to learn about defensible space and home hardening tactics from their qualified specialists. Talk to neighbors who have taken steps to mitigate fire risk on their property.
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 withing 5 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 withing 30 feet of all structures. ✓ Participate in community slash pickup dates organized by the Genesee Foundation or by Jefferson County. See https://www.jeffco.us/2493/Slash-Collection for more information on county slash-pickup dates. ✓ Apply for cost-sharing grants with your neighbors to subsidize the creation of defensible space (see Section 4f. Funding Opportunities for Wildfire Hazard Mitigation and Emergency Preparedness).

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 (Quarles and Pohl 2018).

Many home hardening practices are required in Jefferson County per building construction regulations approved in January 2020 for homes above 6,400 feet in elevation. New construction and replacement construction that requires a building permit 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.

HOA rules hinder my ability to establish defensible space around my home.	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.
My neighbors haven't mitigated risk on their property.	Some residents in the GFPD are rightfully concerned about high hazards on their neighbors' properties and HOA open space. 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 GFPD create defensible space and harden their homes. Fortunately, about 50% of respondents in the GFPD are willing to work with their neighbors to reduce hazards on and around their property (Appendix A). Ideas to inspire action by your neighbors include: • Participating in a neighborhood ambassador program (Wildfire Adapted Partnership 2018). • Working with GFR, your HOA, and other community groups to help educate your community about the benefits of defensible space and home hardening. • Organizing 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 aestheitcally pleasing, can encourage others to follow suit. • Inviting 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. **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.

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. Drive around the community and look for homes that have followed the guidelines in Figure 4b.1 and Table 4b.1. Some properties in the GFPD have exemplary defensible space and beautiful landscaping at the same time. 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). The TEDx talk *Living (Dangerously) in an Era of Megafires* also provides fantastic information about forest changes brought about by fire suppression. 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 2 can be aesthetically pleasing. Limbed and thinned trees in zone 3 (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.

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 CodeRED. Visit the CodeRED website for more information.
- ✓ Review the contents of your "go-bag" and make sure it is packed and ready to go. Visit the Rotary Wildfire Ready website to learn about preparing go-bags. 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 100 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 private drive or 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.
- ✓ Dispose of leaves, needles, and branches during slash pickup dates organized by the Genesee Foundation or by Jefferson County. See https://www.jeffco.us/2493/Slash-Collection for more information on County slash-pickup dates.
- ✓ 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.

4c. Accessibility and Navigability for Firefighters

Creating defensible space and hardening your home can enhance the safety of firefighters staying to defend your home. It is equally important to ensure emergency responders can locate and access your home. According to a strategic analysis of structure triage during WUI fires, **"The principal factor jeopardizing firefighter safety while attempting to defend structures in wildland fires is impeded or obstructed egress...Therefore, narrow driveways with fuel-canopy overhangs or proximate accumulations of heavy or down-dead fuels contraindicate attack or active defensive efforts by emergency responders" (Brown 1994, pg. 10).**

According to a private drive survey by the Genesee Foundation in 2008, over half of private drives do not have a turnaround, which creates access issues for structural and wildland fire engines. An analysis across the GFPD in 2009 showed an abundance of roadway access issues (Figure 4c.1). Some narrow private drives and driveways were compliant with construction codes when they were built, but they are no longer consistent with requirements for road widths and turnarounds.

Where feasible, residents and HOAs should improve roadway access, and where this is not feasible, it is paramount that homeowners prioritize 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. See the callout box on the next page for suggestions to improve access to your home.

Many driveways and private drives within the GFPD do not meet current access requirements and pose safety issues that are difficult to mitigate. Long, narrow, and steep driveways and private drives lacking turnarounds can create challenges for emergency response vehicles during wildfires. Home hardening and fuel mitigation practices are particularly important to reduce wildfire risk around homes with accessibility issues. Photo by the Forest Stewards Guild.

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 at least 20 feet—the minimum width currently required for emergency access according to the City of Golden Site Development Regulations. Prune low-hanging branches of remaining trees so the unobstructed vertical clearance is at least 13 feet and 6 inches per the 2015 International Wildland-Urban Interface Code.
- ✓ 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.

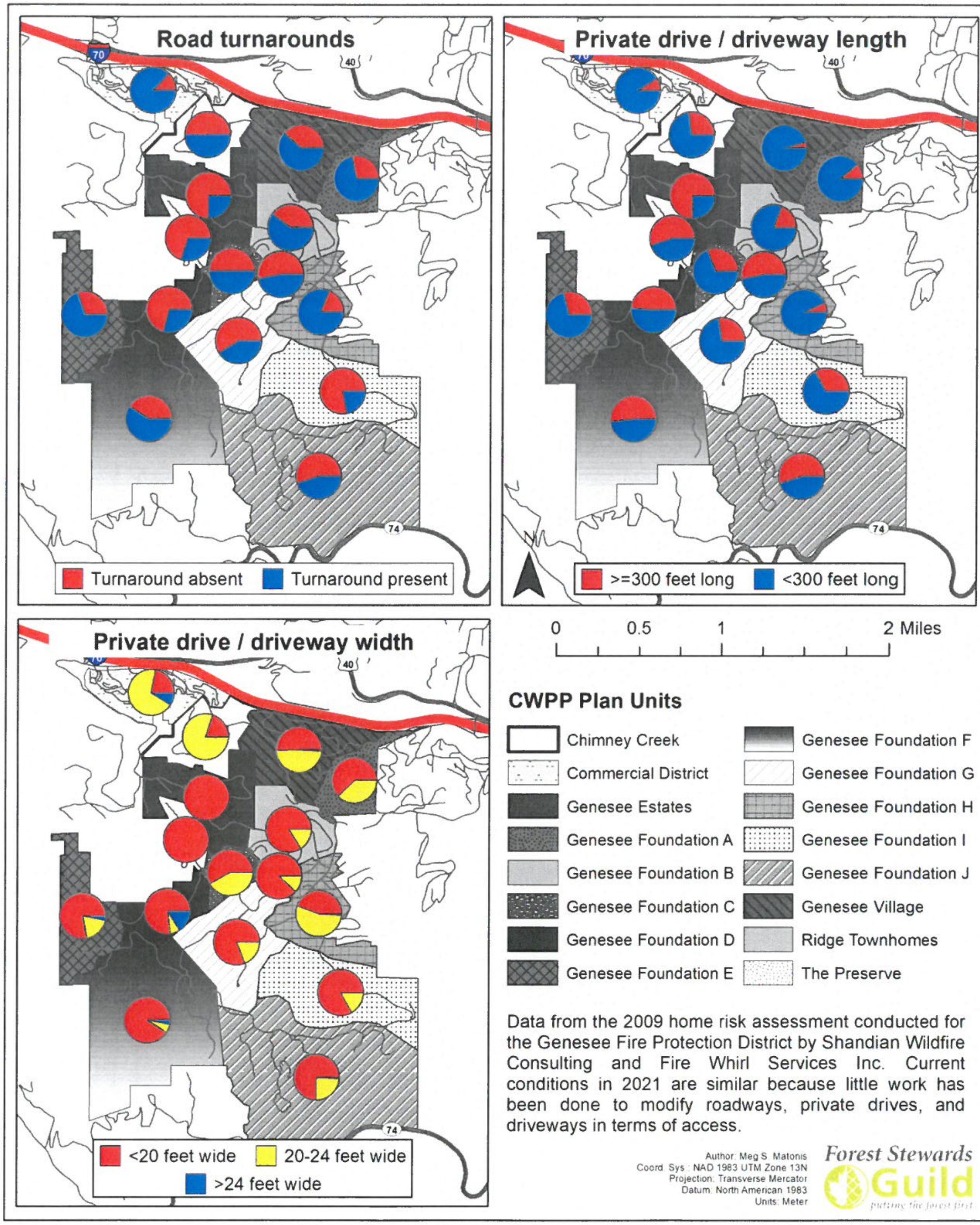


Figure 4c.1. Access to homes is substantially limited across the GFPD due to an abundance of long, narrow driveways and private drives without turnarounds. Data collected by Shandian Wildfire Consulting and Fire Whirl Services, Inc. in 2009.

4d. Priority Plan Unit Recommendations

Table 4d.1 provides priority recommendations for defensible space, home hardening, and road access within each CWPP plan unit (Figure 4d.1) based on our Plan Unit Hazard Assessment (Section 3g). The risk rating scale was developed specifically for the GFPD. Risk ratings are **relative** to other plan units within the GFPD and are not suitable for comparing the GFPD to other communities. Plan units with lower relative risk still possess conditions that are concerning for the protection of life and property in the case of a wildfire. Plan units with higher relative risk are strong candidates for immediate action to mitigate hazardous conditions.

Recommendations in Table 4d.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 4b (Mitigating the Home Ignition Zone) and Section 4c (Accessibility and Navigability for Firefighters). Even homes in the interior of the GFPD have the potential for ignition from long-range spotting during wildfires.

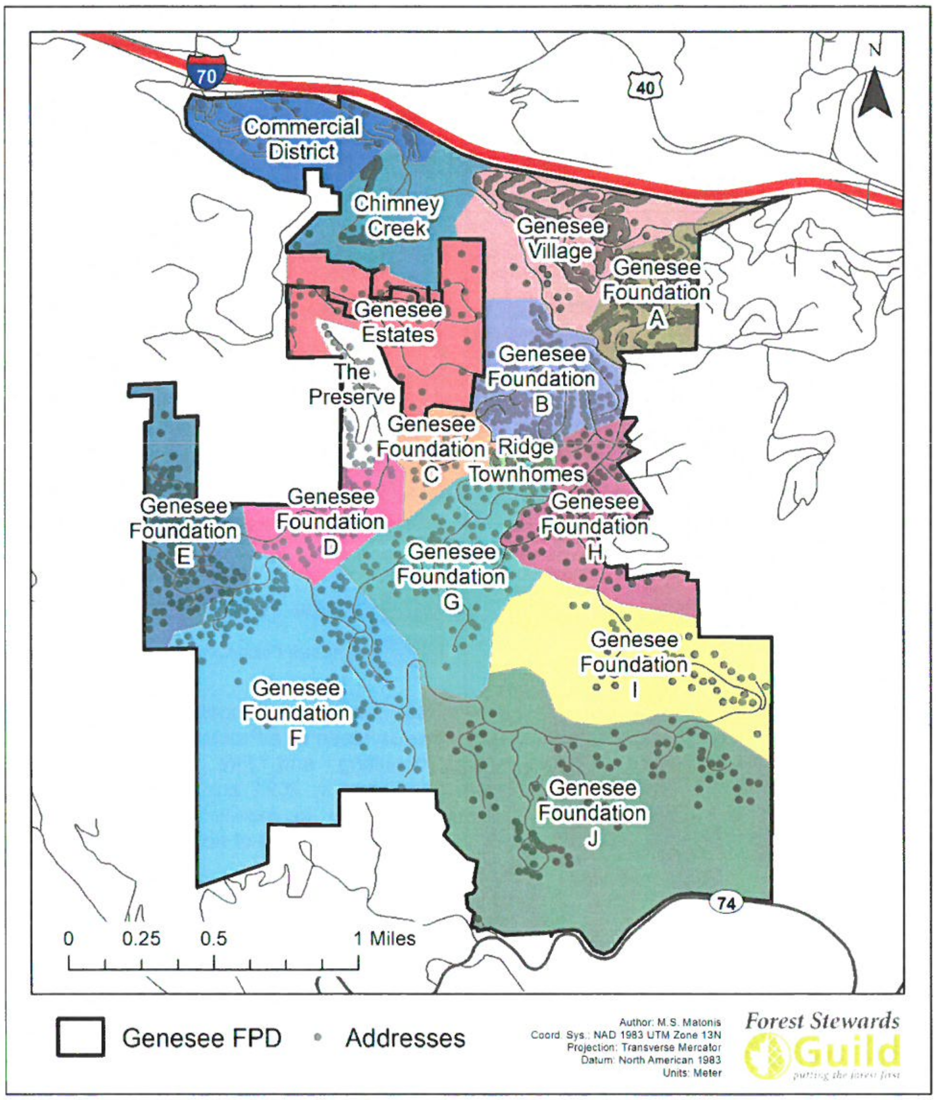


Figure 4d.1. CWPP plan units located across the GFPD.

Table 4d.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 GFPD can benefit from all actions outlined in Section 4b (Mitigating the Home Ignition Zone) and Section 4c (Accessibility and Navigability for Firefighters).

Plan Unit Name	Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior
Genesee Foundation E	Extreme	Many homes are located mid-slope and on ridgetops. Home materials are mainly stucco, with some flammable siding materials. Flammable landscaping is abundant. Thick timber and ladder fuels are present throughout the unit and to the west. The eastern portion of the unit contains ponderosa pine stands with grass understories. Most private drives and driveways have adequate turnarounds and are relatively short, but most are narrow and lined with conifer regeneration that could decrease firefighter access and increase the risk of non-survivable conditions.	Mitigate fuels in home ignition zones by improving defensible space (see Section 4b). Increase canopy spacing and remove ladder fuels on steep slopes beneath homes to reduce the risk of torching and active crown fire (see Section 5c). Implement a stand-level fuel treatment in the western portion of the unit to reduce the risk of torching and active crown fire (see Section 5c). If possible, improve firefighter access by widening private drives and driveways. Remove trees to increase horizontal and vertical clearance for fire engines and decrease the risk of non-survivable conditions.	Under 90th percentile fire weather conditions, about 40% of homes are at risk of extreme exposure to radiant heat and spotting, 80% of the unit and surrounding area are at risk of passive or crown fire activity, and 25% of roads, private drives, and driveways have potentially non-survivable conditions.
Genesee Foundation F	Extreme	Many homes are located mid-slope and were built with a mixture of fire-resistant and flammable construction materials. Many homes have flammable landscaping and no defensible space. Ravines and steep slopes are covered by dense forest with ladder fuels. Firefighter access is adequate on main roads, but long, narrow private drives and driveways without turnarounds could be an obstacle for fire engines.	Harden homes with fire resistant construction materials, particularly by removing and replacing flammable siding and decking (see Section 4b). Mitigate fuels in home ignition zones by improving defensible space (see Section 4b). Increase canopy spacing and remove ladder fuels on steep slopes beneath homes and in ravines to reduce the risk of active crown fire (see Section 5c). If possible, improve firefighter access by building turnarounds and widening private drives and driveways. Remove trees to increase horizontal and vertical clearance for fire engines.	Under 90th percentile fire weather conditions, about 60% of homes are at risk of extreme exposure to radiant heat and spotting, 80% of the unit and surrounding area are at risk of passive or crown fire activity, and 25% of roads, private drives, and driveways have potentially non-survivable conditions.

Plan Unit Name	Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior
Genesee Foundation G	Extreme	Many homes were built with a mixture of fire-resistant and flammable construction materials, including some wooden decks. Defensible space is present in places, but many homes have hazards in the home ignition zone, including gutters full of debris and vegetation growing up to the base of the home. Work has been done to remove ladder fuels and remove logs and other heavy surface fuels in undeveloped areas and along roads. Some slopes have dense forest and abundant ladder fuels. Firefighter access is adequate on main roads, but narrow private drives and driveways without turnarounds could be an obstacle for fire engines.	Harden homes with fire resistant construction materials, particularly by removing and replacing flammable siding and decking (see Section 4b). Mitigate fuels in home ignition zones by improving defensible space (see Section 4b). Implement a stand-level fuel treatment in the center of the unit to reduce the risk of torching and active crown fire (see Section 5c). If possible, improve firefighter access by building turnarounds and widening private drives and driveways. Remove trees to increase horizontal and vertical clearance for fire engines and decrease the risk of non-survivable conditions.	Under 90th percentile fire weather conditions, about 50% of homes are at risk of extreme exposure to radiant heat and spotting, 75% of the unit and surrounding area are at risk of passive or crown fire activity, and 25% of roads, private drives, and driveways have potentially non-survivable conditions.
Genesee Estates	High	Many homes are situated mid-slope and on ridgetops and were built with a mixture of fire-resistant and flammable construction materials. Hazards in home ignition zones are abundant, including wood piles and dense vegetation touching and surrounding homes. North-facing slopes have dense forests with abundant ladder fuels, and south-facing slopes have more open ponderosa stands. A dense forest on Ski Hill north and downslope of the unit could burn with high-intensity crown fire. Numerous locked gates; the abundance of steep and narrow roads, private drives, and driveways without turnarounds; and lack of hydrants make this a risky plan unit for firefighter safety.	Mitigate fuels in home ignition zones by improving defensible space (see Section 4b). Implement a stand-level fuel treatment on Ski Hill to reduce the risk of torching and active crown fire (see Section 5c). If possible, improve firefighter access by building turnarounds and widening roads, private drives, and driveways. Remove trees to increase horizontal and vertical clearance for fire engines and decrease the risk of non-survivable conditions.	Under 90th percentile fire weather conditions, about 45% of homes are at risk of extreme exposure to radiant heat and spotting, about 60% of the unit and surrounding area are at risk of passive or crown fire activity, and 30% of roads, private drives, and driveways have potentially non-survivable conditions.

Plan Unit Name	Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior
Genesee Foundation C	High	Homes are predominately situated on south-facing slopes with high variability in home construction materials and defensible space quality. Many homes have wood siding, fencing, retention walls, and walkways. Flammable landscaping is common, as are needles and combustible materials at the base of many homes. Undeveloped areas are dominated by continuous grass and widely spaced ponderosa pine trees, but there are some dense pockets of forest with ladder fuels. About half of private drives and driveways are relatively short and have adequate turnarounds, but over half of private drives and driveways are narrow and could be an obstacle for fire engines.	Harden homes with fire resistant construction materials (see Section 4b). Mitigate fuels in home ignition zones by improving defensible space (see Section 4b). Increase canopy spacing and remove ladder fuels in undeveloped areas to reduce the risk of torching and active crown fire (see Section 5c). If possible, improve firefighter access by widening private drives and driveways. Remove trees to increase horizontal and vertical clearance for fire engines and decrease the risk of non-survivable conditions.	Under 90th percentile fire weather conditions, about 20% of homes are at risk of extreme exposure to radiant heat and spotting, 70% of the unit and surrounding area are at risk of passive or crown fire activity, and 5% of roads, private drives, and driveways have potentially non-survivable conditions.
Genesee Foundation D	High	Homes were built with a mixture of fire-resistant and flammable construction materials, including some wooden siding, decking, and fences. Some defensible space work is evident, but vegetation has since regrown in places. Ponderosa pine stands with grassy understory and ladder fuels dominate undeveloped areas, creating a risk of high rates of spread and crown fire potential. An abundance of long, narrow private drives and driveways without turnarounds could be an obstacle for fire engines.	Harden homes with fire resistant construction materials, particularly by removing and replacing flammable siding, decking, and fencing (see Section 4b). Mitigate fuels in home ignition zones by improving defensible space and retreating previously mitigated areas (see Section 4b). Increase canopy spacing and remove ladder fuels in undeveloped areas to reduce the risk of torching and active crown fire (see Section 5c). If possible, improve firefighter access by building turnarounds and widening private drives and driveways. Remove trees to increase horizontal and vertical clearance for fire engines and decrease the risk of non-survivable conditions.	Under 90th percentile fire weather conditions, about 7% of homes are at risk of extreme exposure to radiant heat and spotting, 60% of the unit and surrounding area are at risk of passive or crown fire activity, and about 10% of roads, private drives, and driveways have potentially non-survivable conditions.

Plan Unit Name	Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior
Genesee Foundation I	High	Many homes are situated mid-slope and on ridgetops and were built with fire-resistant construction materials, though some wooden siding and decks are present. Vegetation is dense and close to many homes. Steep slopes below some homes have dense forests with grassy understories, creating a risk of high rates of spread and crown fire potential. A ravine with dense forest in the western portion of the unit poses a risk for active crown fire. Firefighter access is adequate on main roads, but an abundance of narrow private drives and driveways without turnarounds could be an obstacle for fire engines.	Mitigate fuels in home ignition zones by improving defensible space and retreating previously mitigated areas (see Section 4b). Increase canopy spacing and remove ladder fuels on steep slopes beneath homes and within ravines to reduce the risk of torching and active crown fire (see Section 5c). Implement a stand-level fuel treatment in the western portion of the unit to reduce the risk of torching and active crown fire (see Section 5c). If possible, improve firefighter access by building turnarounds and widening private drives and driveways. Remove trees to increase horizontal and vertical clearance for fire engines and decrease the risk of non-survivable conditions.	Under 90th percentile fire weather conditions, about 40% of homes are at risk of extreme exposure to radiant heat and spotting, 65% of the unit and surrounding area are at risk of passive or crown fire activity, and 20% of roads, private drives, and driveways have potentially non-survivable conditions.
Genesee Foundation J	High	Many homes are situated mid-slope, and most homes were built with fire-resistant construction materials. Defensible space work is evident, but some vegetation has regrown. Slopes below some homes contain dense forests and ladder fuels. Grasses are contiguous in some ponderosa pine stands and will contribute to high rates of spread. About half of private drives and driveways are relatively short and have adequate turnarounds, but most private drives and driveways are narrow and could be an obstacle for fire engines.	Mitigate fuels in home ignition zones by improving defensible space and retreating previously mitigated areas (see Section 4b). Increase canopy spacing and remove ladder fuels on steep slopes beneath homes to reduce the risk of torching and active crown fire (see Section 5c). If possible, improve firefighter access by widening private drives and driveways. Remove trees to increase horizontal and vertical clearance for fire engines and decrease the risk of non-survivable conditions.	Under 90th percentile fire weather conditions, about 35% of homes are at risk of extreme exposure to radiant heat and spotting, 55% of the unit and surrounding area are at risk of passive or crown fire activity, and 10% of roads, private drives, and driveways have potentially non-survivable conditions.

Plan Unit Name	Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior
The Preserve	High	The entire unit resides in a subdrainage with one road in and out. Homes were built with a mixture of fire-resistant and flammable construction materials. Some homes have adequate defensible space. The primary carrier of fire is light grass fuels with widely space ponderosa pine trees. Homes on steeper slopes within this unit have dense forests with little mitigation work. An abundance of steep, long, and narrow private drives and driveways without turnarounds could be an obstacle for fire engines.	Harden homes with fire resistant construction materials (see Section 4b). Mitigate fuels in home ignition zones by improving defensible space (see Section 4b). Implement a stand-level fuel treatment to the west of this unit to reduce the risk of torching and active crown fire (see Section 5c). If possible, improve firefighter access and evacuation capabilities by building turnarounds and widening roads, private drives, and driveways. Remove trees to increase horizontal and vertical clearance for fire engines.	Under 90th percentile fire weather conditions, almost all homes are at risk of exposure to short- and long-range spotting, and 65% of the unit and surrounding area are at risk of passive or crown fire activity. Very few roads were predicted for non-survivable conditions.
Chimney Creek	Moderate	Housing density is high, and homes are situated mid-slope or on ridgetops. Flammable siding and decking materials are present, and flammable landscaping is adjacent to many homes. Defensible space is interrupted by undeveloped areas with thick mixed-conifer forests. A dense forest on Ski Hill south of the unit could burn with high-intensity crown fire. An abundance of narrow private drives, driveways, and parking areas without turnarounds could be an obstacle for fire engines.	Harden homes with fire resistant construction materials, particularly by removing and replacing flammable decking (see Section 4b). Mitigate fuels in home ignition zones by improving defensible space (see Section 4b). Implement a stand-level fuel treatment on Ski Hill to reduce the risk of torching and active crown fire (see Section 5c). If possible, improve firefighter access by building turnarounds and widening private drives, driveways, and parking areas. Remove trees to increase horizontal and vertical clearance for fire engines.	Under 90th percentile fire weather conditions, almost all homes are at risk of exposure to short- and long-range spotting, and 50% of the unit and surrounding area are at risk of passive or crown fire activity. Very few roads were predicted for non-survivable conditions.

Plan Unit Name	Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior
Genesee Foundation A	Moderate	Housing density is moderate, and homes were built with a mixture of fire-resistant and flammable construction materials. A variety of defensible space measures are evident, with some exemplary properties. However, other homes have vegetation growing beneath decks, vegetation overhanging roofs, and flammable landscaping. Adjacent undeveloped areas have been mitigated for wildfire risks. Most private drives and driveways have adequate turnarounds, but an abundance of long and narrow private drives and driveways could be an obstacle for fire engines. Dense vegetation and ladder fuels abut some roads, private drives, and driveways.	Harden homes with fire resistant construction materials, particularly by removing and replacing flammable siding and decking (see Section 4b). Mitigate fuels in home ignition zones by improving defensible space (see Section 4b). Increase canopy spacing and remove ladder fuels in undeveloped areas to reduce the risk of torching and active crown fire (see Section 5c). If possible, improve firefighter access by widening private drives and driveways. Remove trees to increase horizontal and vertical clearance for fire engines and decrease the risk of non-survivable conditions.	Under 90th percentile fire weather conditions, about 50% of homes are at risk of extreme exposure to radiant heat and spotting, 55% of the unit and surrounding area are at risk of passive or crown fire activity, and 15% of roads, private drives, and driveways have potentially non-survivable conditions.
Genesee Foundation B	Moderate	Housing density is moderate, and homes were built with a mixture of fire-resistant and flammable construction materials. Wooden siding is common. A variety of defensible space measures are evident, but some homes have branches overhanging homes and other hazards in home ignition zones. Forests are dense on north-facing slopes. Most private drives and driveways have adequate turnarounds and are relatively short in length, but most are narrow and could be an obstacle for fire engines.	Harden homes with fire resistant construction materials, particularly by removing and replacing flammable siding (see Section 4b). Increase canopy spacing and remove ladder fuels in undeveloped areas to reduce the risk of torching and active crown fire, particularly on north-facing slopes. Mitigate fuels in home ignition zones by improving defensible space (see Section 4b). If possible, improve firefighter access by widening private drives and driveways. Remove trees to increase horizontal and vertical clearance for fire engines.	Under 90th percentile fire weather conditions, about 20% of homes are at risk of extreme exposure to radiant heat and spotting, 60% of the unit and surrounding area are at risk of passive or crown fire activity, and 5% of roads, private drives, and driveways have potentially non-survivable conditions.

Plan Unit Name	Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior
Genesee Foundation H	Moderate	Most homes are situated on flat terrain, with only a few homes on ridgetops. Homes were built with a mixture of fire-resistant and flammable construction materials. A variety of defensible space measures are evident around homes. Grass is abundant and may result in rapid rates of spread during wildfires. A ravine with dense forest in the western portion of the unit poses a risk for active crown fire. Most private drives and driveways have adequate turnarounds and are relatively short in length, but shrubs and conifer regeneration along roadways could decrease firefighter access and increase the risk of non-survivable conditions.	Harden homes with fire resistant construction materials, particularly by removing and replacing flammable siding (see Section 4b). Mitigate fuels in home ignition zones by improving defensible space (see Section 4b). Implement a stand-level fuel treatment in the western portion of the unit to reduce the risk of torching and active crown fire (see Section 5c). Remove trees and ladder fuels along narrow private drives and driveways to increase horizontal and vertical clearance for fire engines and reduce the risk of non-survivable conditions.	Under 90th percentile fire weather conditions, about 20% of homes are at risk of extreme exposure to radiant heat and spotting, 70% of the unit and surrounding area are at risk of passive or crown fire activity, and 5% of roads, private drives, and driveways have potentially non-survivable conditions.
Ridge Townhomes	Moderate	Multi-occupancy dwellings are situated closely together on flat terrain. Structures have wooden siding, decks, and fences. A variety of defensible space measures are evident, but many hazards remain in home ignition zones, such as flammable landscaping. Undeveloped areas are dominated by ponderosa pine forests with grassy understories. Firefighter access is limited due to narrow parking areas without turnarounds.	Harden homes with fire resistant construction materials, particularly by removing and replacing flammable decking and fencing (see Section 4b). Mitigate fuels in home ignition zones by improving defensible space (see Section 4b). If possible, improve firefighter access by building turnarounds and widening parking areas. Remove trees to increase horizontal and vertical clearance for fire engines.	Under 90th percentile fire weather conditions, about 15% of homes are at risk of extreme exposure to radiant heat and spotting, and 50% of the unit and surrounding area are at risk of passive or crown fire activity. Very few roads were predicted for non-survivable conditions.

Plan Unit Name	Relative Risk	Unit Description	Priority Mitigation Suggestions	Potential Fire Behavior
Commercial District	Low	Buildings have a mixture of fire-resistant and flammable construction materials, many with metal roofs. Much of the area is paved and there is minimal landscaping. A dense forest on Ski Hill south of the commercial district could burn with high-intensity crown fire. Firefighter access is adequate; most private drives and parking areas have turnarounds. However, this area could become congested with traffic during workdays and Sunday mass, causing evacuation delays.	Harden structures with fire resistant construction materials (see Section 4b). Implement a stand-level fuel treatment on Ski Hill to reduce the risk of torching and active crown fire (see Section 5c).	Under 90th percentile fire weather conditions, about 15% of structures are at risk of extreme exposure to radiant heat and spotting, and 50% of the unit and surrounding area are at risk of passive or crown fire activity. Very few roads were predicted for non-survivable conditions.
Genesee Village	Low	Homes and condos in this high-density subdivision were built with flammable siding materials, and many homes have wooden decks. Many homes have grass, flammable shrubs, or mulch adjacent to wooden siding. Grass throughout the unit could contribute to high rates of spread. Higher moisture is evident in this unit by the presence of cottonwood and aspen. Firefighter access is mostly adequate except in narrow parking areas and along narrow private drives and driveways without turnarounds.	Harden homes with fire resistant construction materials, particularly by removing and replacing flammable siding, decking, and fencing (see Section 4b). Mitigate fuels in home ignition zones by improving defensible space (see Section 4b). Remove ladder fuels in undeveloped areas to reduce the risk of torching. Mow grasses in large open spaces and adjacent to homes to reduce the risk of intense surface fires. If possible, improve firefighter access by building turnarounds and widening parking areas, private drives, and driveways. Remove trees to increase horizontal and vertical clearance for fire engines.	Under 90th percentile fire weather conditions, almost all homes are at risk of exposure to short- and long-range spotting, and 50% of the unit and surrounding area are at risk of passive or crown fire activity. Very few roads were predicted for non-survivable conditions.

4e. Outreach and Education

Residents in the GFPD identified lack of knowledge about effective mitigation measures as a top barrier to mitigation action (Figure 4b.5). Newer residents feel particularly unfamiliar with practical steps they can take to reduce wildfire hazards. Educational opportunities could enable additional mitigation actions by residents in the GFPD. Over 65% of residents who completed the CWPP survey are interested in presentations on wildfire behavior and risk, trainings on ways to reduce wildfire hazards, and one-on-one consultations about wildfire hazards on their properties. Most residents receive information on wildfire mitigation from their HOAs and GFR, so it is important for these organizations to continue reaching out and educating residents.

We suggest that GFR, 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 4e.1). The Fire Adapted Community Learning Network is an online community dedicated to supporting wildfire mitigation and education efforts. Residents can utilize the FAC framework and network when developing local projects and overcoming obstacles to fire mitigation adaptation.

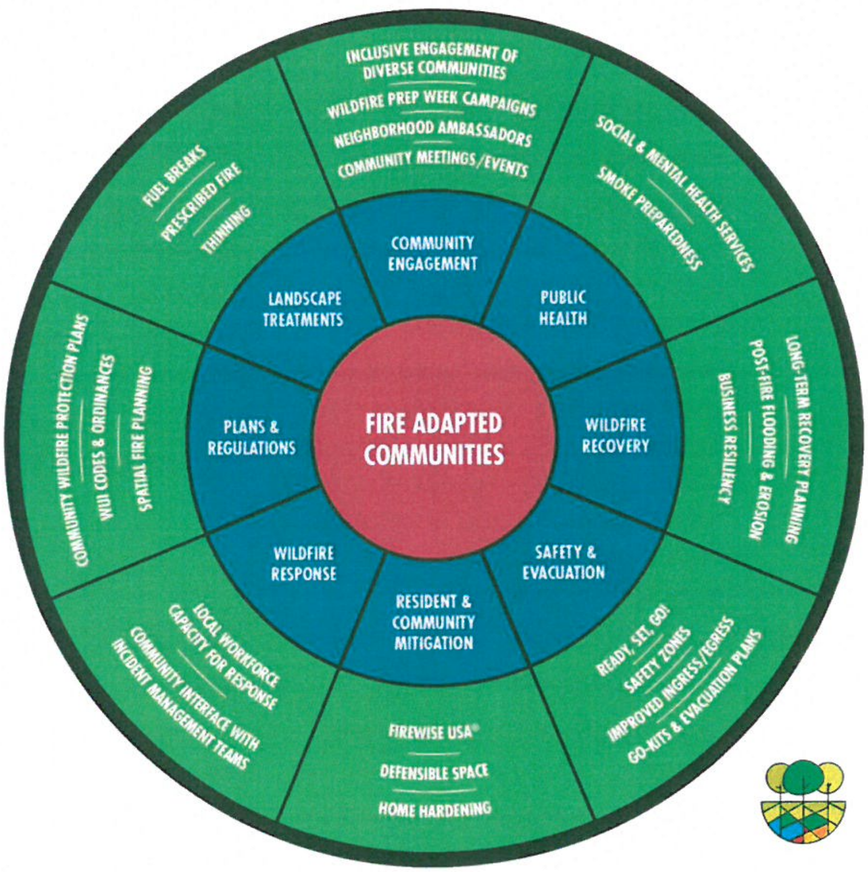


Figure 4e.1. The Fire Adapted Communities graphic provides specific programs and activities that communities can take to reduce their wildfire risk and increase their resilience (figure from the Fire Adapted Community Learning Network).

Fire Adapted Colorado (FACO) has developed a regional network to provide educational and networking opportunities for communities, groups, and individuals focused on reducing the negative impacts of wildfires. FACO supports and amplifies local wildfire mitigation work by connecting practitioners, community members, and organizations statewide. Visit their website for more information on their programs and upcoming events.

This CWPP can only result in on-the-ground change if residents and community groups work with GFR to address shared risk. Starting a **Neighborhood Ambassador Programs** could help residents better understand wildfire risks and spark coordinated action that effects positive change in the GFPD. The neighborhood ambassador approach requires engaged volunteers (aka, ambassadors) and a dedicated lead coordinator. See Table 4e.1 from the guide *Fire adapted communities neighborhood ambassador approach: Increasing preparedness through volunteers* for effective activities that neighborhood ambassadors can undertake.

Table 4e.1. Potential activities for a neighborhood ambassador program. Ambassadors are engaged volunteers from the community and the coordinator is a dedicated individual that spearheads the program. Table adapted from Wildfire Adapted Partnership (2018).

Example activity	Ambassador responsibility	Coordinator responsibility
Educational programs about defensible space and home hardening	Gauge interest of neighbors and select topics. Find meeting location. Encourage neighbors to attend.	Arrange for specialists to make presentations. Advertise program through HOA newsletters, social media, etc.
Emergency planning	Organize an event for people to ask firefighters and law enforcement personnel about emergency planning and evacuation. 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.	Provide information to residents about emergency planning and go-bags. Arrange for specialists to make presentations. Advertise program through HOA newsletters, social media, etc.
Community chipping day	Secure HOA buy-in and request financial support. Select a date and organize event logistics. Encourage neighbors to attend.	Secure grants or other financial support. Address liability and safety concerns. Advertise program through HOA newsletters, social media, etc.

Table 4e.1 (continued). Potential activities for a neighborhood ambassador program.

Example activity	Ambassador responsibility	Coordinator responsibility
Defensible-space walking tour[1]	Identify homeowners with exemplary defensible space. Select a date and organize event logistics. Encourage neighbors to attend.	Arrange for fuel treatment specialists to attend and make presentations. Provide handouts and other educational material about defensible space. Advertise program through HOA newsletters, social media, etc.
Defensible space projects	Work with neighbors to identify high-priority project locations using insights from the CWPP (see priority locations in Section 5c. Suggestions for Ecological Restoration and Stand-level Fuel Treatments). Secure HOA buy-in and request financial support. Select contractors and solicit bids. Oversee project completion.	Work with a certified forester for insights about effective treatment location and prescriptions, following guidelines in Section 5c (Suggestions for Ecological Restoration and Stand-level Fuel Treatments). Identify potential contractors. Write scope of work for contract. Inspect project upon completion. Celebrate success through social media posts and newspaper articles.
Roadway fuelbreak projects	Work with neighbors to identify private drives and driveways with potentially non-survivable conditions using insights from the CWPP (see priority locations in Section 5d. Suggestions for Roadway Fuelbreaks). Secure HOA buy-in and request financial support. Select contractors and solicit bids. Oversee project completion.	Work with a certified forester for insights about effective treatment location and prescriptions, following guidelines in Section 5d (Suggestions for Roadway Fuelbreaks). Identify potential contractors. Write scope of work for contract. Inspect project upon completion. Celebrate success through social media posts and newspaper articles.

[1]GFR and the Forest Stewards Guild organized two defensible-space walking tours in June 2021 to visit different properties across the GFPD and discuss mitigation practices. Future events could be sponsored by neighborhood ambassadors.

4f. Funding Opportunities for Wildfire Hazard Mitigation and Emergency Preparedness

Opportunities from Colorado Agencies

- The Colorado State Forest Service (CSFS) **Forest Restoration and Wildfire Risk Mitigation (FRWRM)** program provides funding for projects focused on fuel reduction, forest health, and capacity building on non-federal lands in Colorado. 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 **Jefferson Conservation District** helps landowners navigate forestry projects to promote forest health and complete wildfire mitigation projects.

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

- The Western Forestry Leadership Coalition administers the **Landscape Scale Restoration Competitive Grant Program** which focuses on activities that address priority areas, challenges, and opportunities facing Western lands, including wildfire risk reduction, watershed protection and restoration, and the spread of invasive species, insect infestation and disease. Grant submissions must go through state forestry agencies, but projects can include local governments and private entities.

- 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 Upper South Platte can aid with small-acreage wildfire mitigation measures through their **Neighborhood Fuels Reduction Program**.

- 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.

5. Fuel Treatment Recommendations

5a. General Objectives and Implementation of Fuel Treatments

Purposes and Benefits 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).

Many residents, HOAs, and local agencies that manage land within and around the GFPD are actively reducing wildland fuels and reducing the likelihood of destructive, high-severity wildfires. Additional strategic work is required to mitigate wildfire risks across the GFPD as described in Section 3 (Community Risk Assessment). Strategic fuel treatments, in tandem with work by individual residents to mitigate hazards in their home ignition zone (Section 4b), can help protect life and property across the GFPD and surrounding landscape.

A fuel treatment is a land management project designed to reduce wildfire hazard by reducing the amount and altering the distribution of fuel available to burn. Fuel treatment methods include tree thinning, pruning, pile burning, broadcast prescribed burning, and fuel mastication (Hunter and others 2007).

Decreasing the density of trees and ladder fuels, increasing the space between tree crowns, increasing the distance between surface fuels and tree canopies, and reducing surface fuels can lower the intensity of wildfires and the risk of active crown fires under certain fire weather conditions. Removing trees can increase the growth of grasses, forbs, and shrubs and dry out these fuels by increasing their exposure to sun and wind. Fire burning through abundant, dry grasses have rapid rates of spread; however, the fundamental goal of fuel treatment is not to reduce the rate of fire spread but to reduce burn severity (Reinhard and others 2008).

Strategically located, high-quality fuel treatments can create tactical options for fire suppression (Plucinski 2019; Jolley 2018; Reinhardt and others 2008). **Fuel treatments cannot serve as a firebreak due to the ability of fires to jump across containment lines with short- and long-range spotting.** Ember production is common during wildfires burning on windy days through heavy fuel loads located on steep terrain. Fuel treatments cannot occur at the spatial scale and rate needed to reduce the potential for long-range spotting in the GFPD, but fuel treatments can provide opportunities for firefighters to slow the spread of wildfires and reduce the likelihood that long-range spotting will ignite running crown fires.

All fuel treatments are not created equal, and there is no "one size fits all" fuel treatment design (Reinhardt and other 2008). Local knowledge and professional expertise are needed to design effective, site-specific fuel treatments. Contact the Genesee Foundation Open Space Manager, Golden Field Office of the Colorado State Forest Service, Jefferson Conservation District, or other forestry professionals for assistance with developing and implementing a forest management plan.

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 2 are typically more intensive than treatments in zone 3 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. Treatments to create designated areas for wildfire evacuation emergencies require complete removal of trees and annual maintenance to reduce surface fuel loads.

Treatment Categories

We discuss four categories of fuel treatments and suggest priority locations and general guidelines for each:

- **Ecological restoration:** 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 and others 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 and others 2018).

- **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 and others 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.

- **Roadway fuelbreaks:** Roadway fuelbreaks 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. Fuelbreaks are also used along trails, ridgelines, and other features that can be utilized by firefighters to contain fire spread. Fuelbreaks are referred to as shaded fuelbreaks when overstory trees are retained in the area.

- **Creation and maintenance of designated areas for wildfire evacuation emergencies:** Designated areas for wildfire evacuation emergencies are intended to provide survivable conditions for a specific number of residents and vehicles during a wildfire. These locations need to be large enough to prevent exposure to lethal levels of radiant and convective heat. All canopy fuels must be removed from designated areas for wildfire evacuation emergencies, and surface fuel loads must be substantially reduced. Designated areas for wildfire evacuation emergencies require regular maintenance to prevent surface fuel accumulation.

A Note on Perimeter Fuelbreaks

We recommend the creation of fuelbreaks along roadways, but we do not recommend a moat of linear fuelbreaks around the perimeter of the GFPD. It is not feasible or advisable to create fuelbreaks around the GFPD for several reasons:

- Fuelbreaks along roads, ridgetops, and valley bottoms can assist with fire suppression tactics, but fuelbreaks on secondary or lateral ridges can facilitate rapid upslope fire spread (Ingalsbee 2005).
- Fuelbreaks are most effective when used as control points for active suppression tactics (Agee and others 2000; Syphard and others 2011). There are locations around the perimeter of the GFPD where it would be unsafe for firefighters to engage with the fire, regardless of the presence of a fuelbreak.
- Strategically placed fuelbreaks and stand-level fuel treatments can alter fire behavior and support tactical fire suppression without the need to surround an entire area with fuelbreaks (Agee and others 2000).
- Creating a perimeter fuelbreak might foster a false sense of security among residents and fire suppression personnel (Dennis 2005). Fuelbreaks do not replace the critical need for residents to mitigate their home ignition zones due to the risk of short- and long-range spotting.
- Most land along the perimeter of the GFPD is privately owned, and landowners might oppose the construction of fuelbreaks through their property.
- Some locations around the GFPD are steep and would require expensive helicopter logging to treat and/or the creation of miles of new roads to access the area. Fuelbreaks require maintenance over time, which would be costly in inaccessible areas and divert limited funds away from other strategic treatments.

Rather than creating a perimeter of fuelbreaks, we recommend ecological restoration and stand-level fuel treatments in strategic locations within and around the GFPD. Interlocking fuel treatments that span multiple ownerships are crucial for reducing fuel loads, altering potential fire behavior, and creating control points for firefighters.

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). Treatments conducted by Denver Mountain Parks in the Genesee Mountain Park cost $804 to 1,434 per acre between 2010 and 2019. Costs of $1,500 to $2,500 per acre are not uncommon along the Colorado Front Range where there is little biomass or timber industry to provide financial return (Jones and others 2017). 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 and others 2020; Loomis and others 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 and others 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 and others 2008). However, when fuel treatments follow the principles of ecological restoration, they result in positive ecological benefits regardless of economic costs.

5b. Fuel Treatment History in and Around the GFPD

Homeowners, HOAs, and land management agencies have taken steps to ameliorate fire risk by reducing fuel loads in and around the GFPD (Figure 5b1). Annual acres treated varied from 20 to 740 acres between 1984 to 2019, for a total of about 1,600 acres during this 25-year period (Figure 5b.2). From 2000 to 2019, the Genesee Foundation completed treatment on 427 acres of HOA open space, amounting to about 40% of all open space owned by the Genesee Foundation. In 2014, the Foundation received a $99,100 grant under the Wildfire Risk Reduction Grant Program to provide a 50-50 cost share for residents who created or maintained defensible space. The grant supported 46 defensible space projects across 73 acres. Between 2015 to 2019, additional grant funding supported defensible space projects across 18 acres around 20 homes, and an unknown number of homeowners have conducted defensible space projects without grant funding.

Between 2010-2019, Denver Mountain Parks completed numerous large-scale management projects in Genesee Mountain Park to the west, Katherine Craig Park to the north, and Corwina, O'Fallon, and Pence Parks to the south of the GFPD. Projects were designed to increase ecosystem health, reduce fuel loads, and protect watersheds from post-fire erosion. Denver Mountain Parks manages slash (logging debris left behind after harvesting, such as small trees, treetops, and branches) by masticating the material or lopping and scattering it. They used to manage slash through pile burning, but they have not done so in 10 years due to community concerns about smoke and ember production. However, as discussed below, pile burning can be a very effective and safe method to reduce fuel loads and mitigate fire risk.

Jefferson County Open Space (JCOS) conducts forest management projects on county open space to restore historical forest conditions, improve wildlife habitat, enhance recreational opportunities, and/or reduce fuel loads. JCOS is currently prioritizing treatment locations through a forest management planning process. As of now, JCOS does not have projects planned for Lair of the Bear Park, which is directly south of the GFPD. JCOS is currently planning treatments in Alderfer/Three Sisters Park and Elk Meadows Park, which are southwest of the GFPD in the Evergreen Fire Protection District.

The Jefferson Conservation District has assisted landowners in the Evergreen Fire Protection District with forest restoration treatments under the Environmental Quality Incentives Program (EQIP). The Colorado State Forest Service has helped several landowners adjacent to the GFPD prepare forest management plans and conduct treatments through the ForestAg Program.

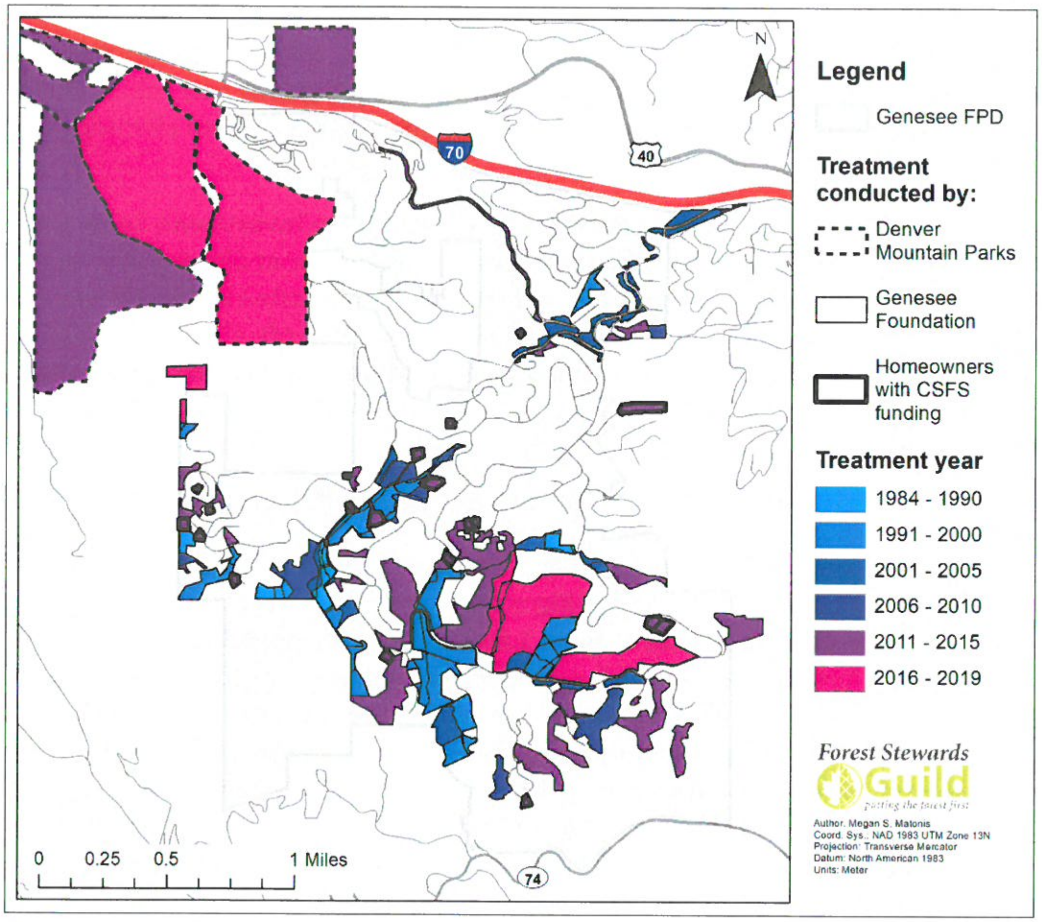


Figure 5b.1. Locations of forest management treatments from 1984-2019 conducted by Denver Mountain Parks, the Genesee Foundation, and private landowners. Data provided by the Genesee Foundation and Colorado Forest Restoration Institute.

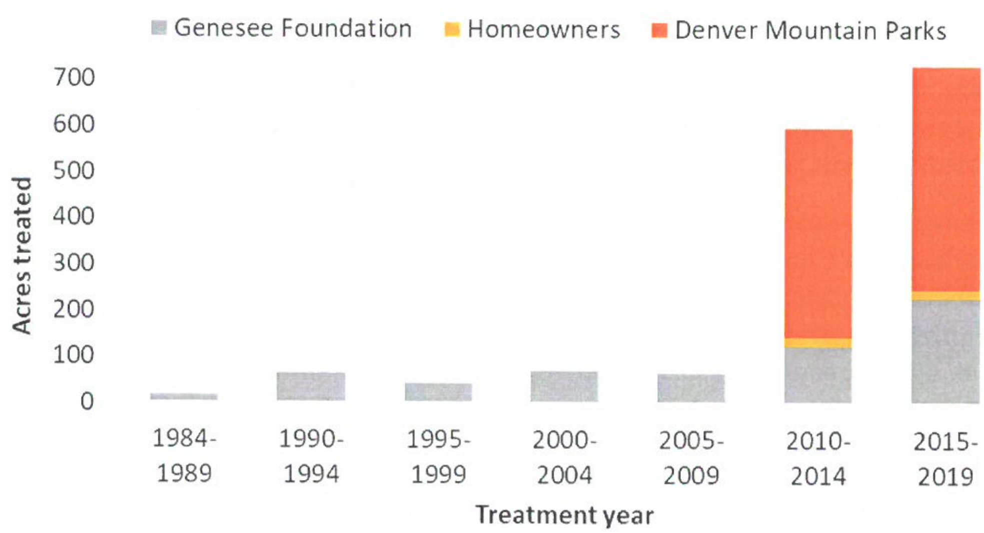


Figure 5b.2. Acres of forest management treatments from 1984-2019 conducted by Denver Mountain Parks, the Genesee Foundation, and private landowners. Data provided by the Genesee Foundation and Colorado Forest Restoration Institute.

5c. Suggestions for Ecological Restoration and Stand-Level Fuel Treatments

Priority Locations

We located and prioritized potential locations for ecological restoration and/or stand-level fuel treatments within and around the GFPD (Figure 5c.1). In January 2021, we shared our assessment with land managers from the Colorado State Forest Service, Genesee Foundation, Jefferson County Open Space, Jefferson Conservation District, and Denver Mountain Parks for their input.

Our prioritization scheme assigned higher priority to locations with (1) higher predicted occurrence of active crown fire, (2) higher conditional burn probability under 90th percentile fire weather conditions, (3) greater number of homes threatened by short-range spotting, (4) greater percentage of operable ground (slopes less than 50%), (5) higher fuel loads due to the absence of recent fuel treatments, and (6) greater number of roadways, private drives, and driveways with non-survivable conditions. The boundaries of the proposed treatment units follow the edges of forest cover and topographic features. See Appendix B for a full description of our prioritization methods.

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. GFR, 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 5c.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 and others 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.

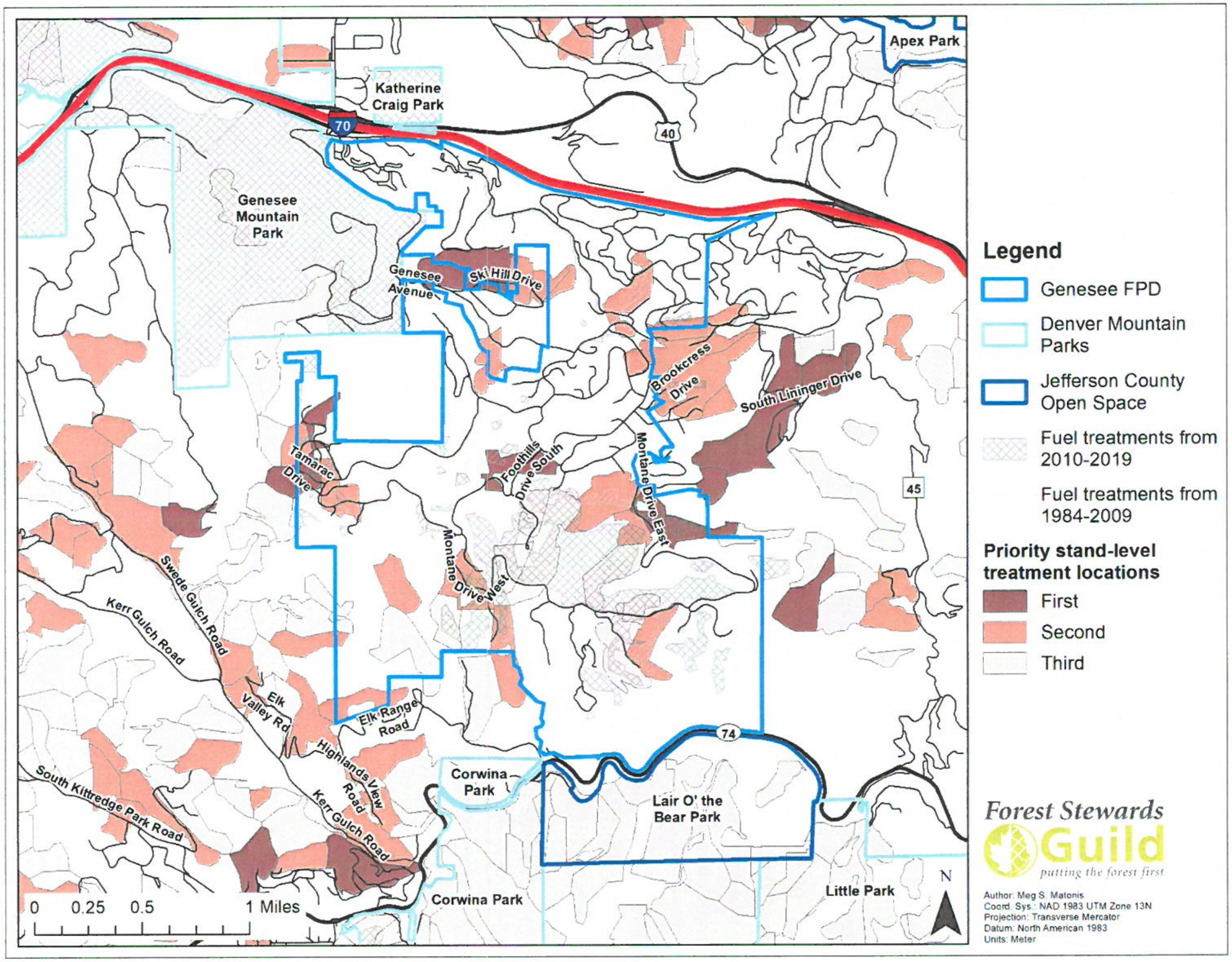


Figure 5c.1. Potential priority locations for ecological restoration and/or stand-level fuel treatments based on predicted fire behavior, conditional burn probability, the abundance of threatened structures, operability based on slope, occurrence of previous fuel treatments, and presence of non-survivable roadway conditions. Boundaries of potential treatment units follow the edges of forest cover and topographic features. See Appendix B for a description of hillslopes and a full description of our prioritization methods.

We identified 38 priority treatment units that are fully or partially within the GFPD, and there are many priority locations surrounding the GFPD (Figure 5c.1). Within the GFPD, there are four areas with first-priority treatment units (Figure 5c.2):

Area A (48 acres): The steep, north-face slope north of Genesee Avenue and Ski Hill Drive is covered in dense conifer forest with abundant ladder fuels and has a high potential for active crown fire. None of the area has been treated since it reverted from a ski hill in the mid-1950s. High-intensity fire in this area would threaten homes in Genesee Estates and Chimney Creek HOAs. Almost half of the priority unit is owned by Chimney Creek HOAs and the other half spans nine private parcels. There are nine structures within the potential treatment unit. The forest and surrounding residents would benefit from ecological restoration to dramatically reduce tree densities, create a mosaic of forest conditions, and reduce the risk of active crown fire.

Area B (22 and 10 acres): The western edge of the GFPD off Tamarac Drive abuts dense, steep forest with abundant ladder fuels and has a high potential for active crown fire. Winds often blow out of the west-southwest, so it is important to address fuel loads to the west of the GFPD. This area contains two first-priority treatment units, two second-priority units, and three third-priority units. Crown fire risk is high in the third-priority treatment units, but slopes are generally too steep for mechanical treatments and dangerous for handcrews. Much of the priority treatment units falls outside the GFPD on one parcel of private land. Parts of the two first-priority treatment units are located on land owned by the Genesee Foundation and span about 23 private parcels. There are 28 structures within the two first-priority treatment units and dozens of additional homes within short-range spotting distance. Most of the area owned by the Genesee Foundation has been treated over the past several decades, but forests are still extremely dense and would benefit from ecological restoration to dramatically reduce tree densities and create a mosaic of forest conditions. The Genesee Foundation's 2021 Open Space Management Plan includes a 15-acre thinning project in this area.

Area C (22 acres): This heavily forested area in the center of the GFPD off Foothills Drive South has a high potential for active crown fire. Almost half of the priority area is owned by the Genesee Foundation and the other half is divided among 18 private parcels. There are 17 structures within the potential treatment unit and dozens within short-range spotting distance. The northwestern corner of the treatment unit was treated within the past 10 years by the Genesee Foundation. The rest of the unit has not been treated for at least 40 years, resulting in substantial fuel accumulation. Forests within this treatment unit are extremely dense and would benefit from ecological restoration to dramatically reduce tree densities and create a mosaic of forest conditions.

Area D (28 acres): A topographic ravine at the eastern edge of the GFPD off Montane Drive East is covered in dense forest with abundant ladder fuels and has a high potential for active crown fire. The area contains several first-, second-, and third-priority treatment units. A small portion of the first-priority unit falls outside the GFPD on one parcel of private land, and the rest of the unit is owned by the Genesee Foundation and spans 13 private parcels. There are eight structures within the potential treatment unit and dozens within short-range spotting distance. Much of the area has been treated by the Genesee Foundation over the past several decades, but forests are still extremely dense and would benefit from ecological restoration to dramatically reduce tree densities and create a mosaic of forest conditions.

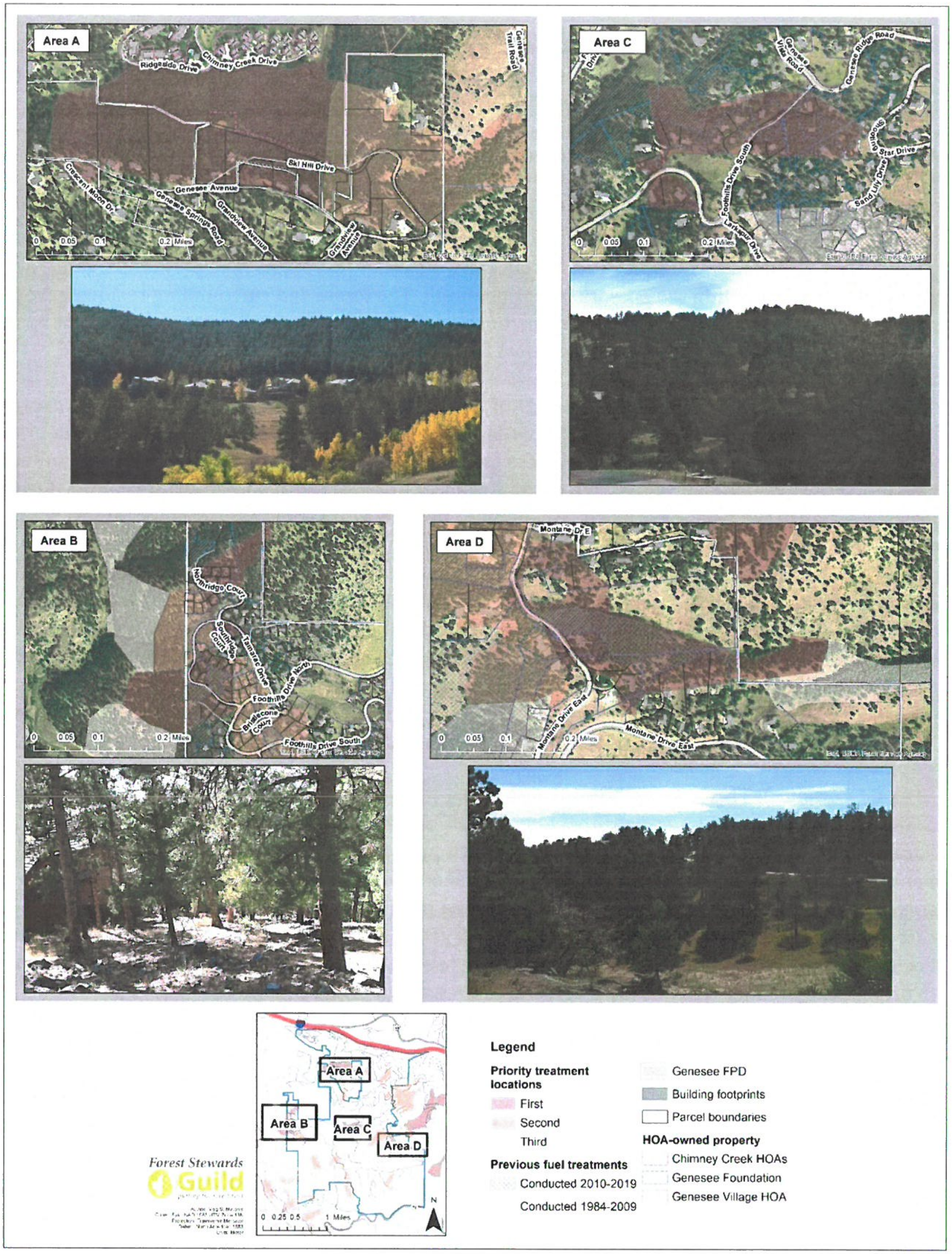
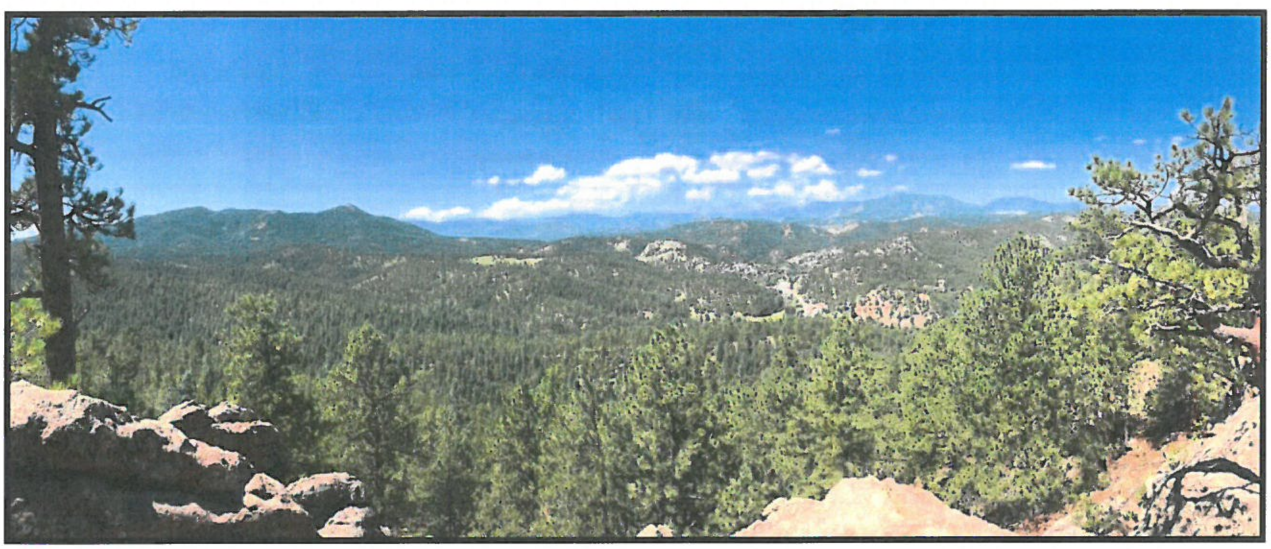


Figure 5c.2. We identified four areas across the GFPD that are top-priority for ecological restoration and/or stand-level fuel treatments based on potential fire behavior and conditional burn probability, the abundance of threatened structures, and operability based on slope.

Several second- and third-priority treatment units occur in the southern part of the GFPD (Figure 5c.3). Active crown fires in this area could threaten numerous homes and create non-survivable conditions along roadways. Portions of these treatment units are owned by the Genesee Foundation and were treated within the past 10 years. Even these previously treated forests could benefit from additional removal of trees and ladder fuels. Firefighters might use Montane Drive East and some of the open grassy areas in the southern part of the GFPD as locations to directly engage wildfires and prevent fire spread northwards. If a new egress route is planned and constructed, treating these locations in the southern GFPD should become a higher priority.

Numerous second- and third-priority treatment units are located to the southwest of the GFPD along Swede Gulch Road and Kerr Gulch Road. Strategic fuel treatments in this area could make it easier for firefighters to contain wildfires spreading towards the GFPD. Third-priority treatment units cover much of Corwina Park managed by Denver Mountain Parks and Lair O' the Bear Park managed by Jefferson County Open Space to the south of the GFPD. There is high potential for active crown fire in this area due to dense forest conditions, but much of the topography is too steep to implement large restoration treatments. Strategically placed treatments along ridgetops and trails could create tactical opportunities for firefighters. **The difficulty of treating much of the steep, forested landscape around the GFPD underscores the need for residents to create defensible space and hardening their homes.**



Much of landscape to the south of the GFPD falls within Corwina Park managed by Denver Mountain Parks and Lair O' the Bear Park managed by Jefferson County Open Space. These forests are extremely dense and have high risk of active crown fire, but much of the landscape is very steep and could not be accessed by logging equipment. Image along Bear Creek Trail by Weston Taylor, AllTrails.com.

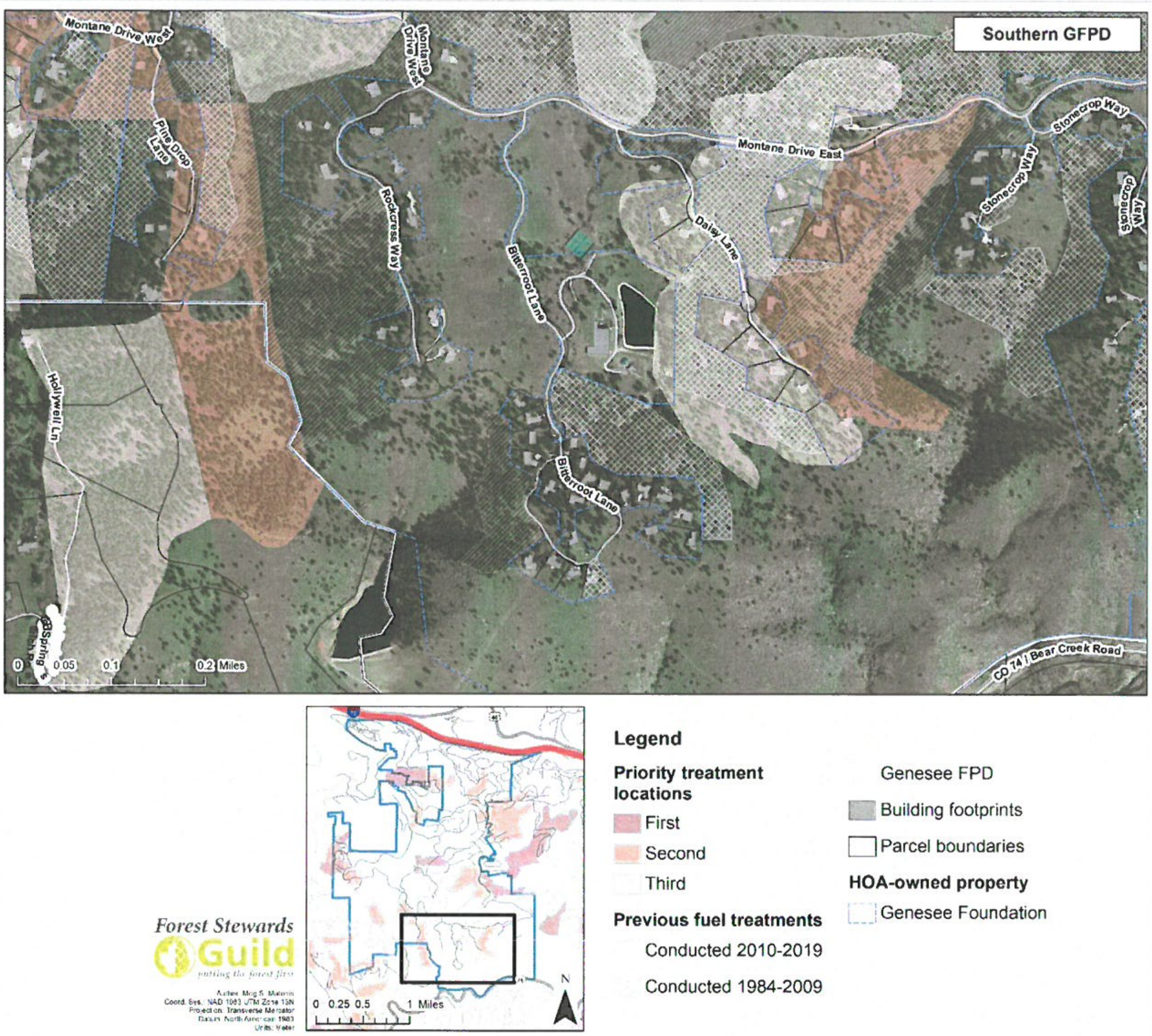


Figure 5c.3. Potential treatment units in the southern GFPD. Dense forests and abundant ladder fuels in these areas could support active crown fire, result in long flame lengths, and create non-survivable conditions along roadways. If a new egress route is planned and constructed, treating locations in the southern GFPD should become a higher priority. Firefighters could potentially use a southern egress route and surrounding fuel treatments to slow the spread of wildfires northwards into the GFPD.

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 and others 2018; Fulé and others 2012). Most of the forested area within and around the GFPD are ponderosa pine or mixed-conifer forest types (Figure 2a.1), and many of these forests had far fewer trees prior to Euro-American settlement due to a higher frequency of wildfires (Figure 2c.1; Addington and others 2018). The Jefferson Conservation District and other land management agencies encourage an approach to forest management that transforms 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.

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 and others 2018). We suggest that foresters, other land managers, and landowners reference this document when preparing and implementing forest treatments in and around the GFPD. 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 and others 2017).

We provide general guidelines for fuel treatments in the defensible space zone 3 (30 to 100 feet from the home)[8] and larger forested areas within and around the GFPD. The guidelines below are based on *Principles and practices for the restoration of ponderosa pine and dry mixed-conifer forests of the Colorado Front Range* (Addington and others 2018), *A comprehensive guide to fuels treatment practices for ponderosa pine in the Black Hills, Colorado Front Range, and Southwest* (Hunter and others 2007), *Basic principles of forest fuel reduction treatments* (Agee and Skinner 2005), and defensible space and shaded fuelbreak recommendations from the Colorado State Forest Service (CSFS 2021; Dennis 2005):

- Follow the principles of ecological restoration as outlined in Addington and others (2018) to help achieve fuel reduction and ecosystem restoration objectives. Restoration treatments 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 5c.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

[8]Fuel treatment recommendations for defensible space zones 1 and 2 are different than recommendations for zone 3 and larger forested areas. Refer to Section 4b. Mitigating the Home Ignition Zone for treatment recommendations closer to your home.

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 and others 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 Table 5c.2 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 and others 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 4b.3 for an example of repeat photographs pre- and post-treatment).

Table 5c.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 %	15 feet[1]
11 to 20%	15 feet
21 to 40%	20 feet
>40%	30 feet

[1]The Colorado State Forest Service recommends a minimum of 10 feet spacing on flat terrain, but we recommend minimum crow spacing of at least 15 feet to significantly reduce the likelihood of tree-to-tree ignitions.

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 and others 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 and others 2009; Paysen and others 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 and others 2008; Hunter and others 2007), and fire has unique impacts on vegetation and soils that cannot be replicated by mechanical treatments alone (McIver and others 2013). Thinning and burning treatments tend to achieve fuel reduction objectives and modify fire behavior to a greater extent than thinning alone (Prichard and others 2020; Fulé and other 2012). In the words of the Director for the Jefferson Conservation District, “not all fires are bad, and not all trees are good.”

Slash Management

Thinning operations often increases 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. 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.

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 5c.2). 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

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).

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 much of the surface fuel, and is relatively cost-effective (Prichard and others 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, and when they do, the wildland fire community soberly reviews those escapes to produce lessons learned and make improvements (Dether 2005). Although the public is often fearful of prescribed burns escaping and damaging their property, agencies have successfully conducted prescribed burns in WUI areas (Hunter and others 2007). Prescribed burns can actually reduce property damage during wildfires because they are so effective at altering forest fuel loads (Loomis and others 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, conflagration 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 and others 2019). Mitigation measures, such as raking the burnt soil and seeding with 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).

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 Jefferson County Public Health Environmental Health Services. Pile burning is not allowed in Jefferson County during fire restrictions or burn bans.

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.

Table 5c.2. 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 much of the surface fuel, and is relatively cost-effective (Prichard and others 2020; Fulé and other 2012). Broadcast burning is carefully 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 and others 2020; Fulé and other 2012). Can restore ecosystem function in frequent-fire forests (McIver and others 2013; Addington and others 2018). Generally cheaper than mechanical treatments (Prichard and others 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 and others 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.	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.	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 because of requirements for snowpack and wind ventilation.

Method	Description	Benefits	Challenges
Pile burning (cont.)	Pile burning requires smoke permits and burn permits, and is not allowed during fire restrictions or burn bans in Jefferson County.	Can be safe and successful with proper planning and implementation by qualified firefighters.	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. Intense heat can sterilize soils and result in slow recovery of plants (Miller 2015).
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. 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 and others 2007; Agee and Skinner 2005).
Mastication or chipping	Mastication involves using specialized machines like 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.	Mastication can increase the distance between canopy fuels by grinding up standing saplings and shrubs. Can reduce fire intensity and slow rates of spread, enhancing suppression efficacy (Kreye and others 2014).	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 and others 2014).

Method	Description	Benefits	Challenges
Mastication or chipping (cont.)	Deep layers of masticated and chipped fuels can result in longer periods of smoldering when burned and have detrimental impacts on plant regeneration (Kreye and others 2014; Jain and others 2018).	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.	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 and others 2014). Masticated and chipped fuels can impede plant regeneration, particularly when the depth of masticated and chipped fuels exceeds 4 inches (Jain and others 2018).
Slash removal	Removal involves physically dragging and transporting slash away from the site. Where there are active beetle infestations, material might need to be covered with plastic to prevent beetles from emerging and spreading.	Decreases surface fuel loads by removing material from the site.	Can be expensive and labor intensive. Not feasible in areas far from roads. Can spread insects like mountain pine beetles and emerald ash borer to other locations.
Mowing	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 and others 2011).

5d. Suggestions for Roadway Fuelbreaks

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 fuelbreaks along roads, private drives, and driveways within and around the GFPD (Figure 5d.1). We prioritized treatments along roadway corridors based on predicted roadway survivability under 90th and 97th 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 for a full description of our prioritization methods.

We classified about 1 mile of road segments as first-priority treatment locations (Table 5d.1). These areas are both evacuation pinch-points and lined with vegetation that could fuel intense flames and create non-survivable conditions during wildfires. The largest segments of first-priority roadways were on Foothills Drive South and Genesee Ridge Road towards the center of the GFPD and along Genesee Vista Road, Currant Drive, and Snowberry Road as they feed into Genesee Ridge Road. Emergency personnel and forestry professionals should visit these priority locations to assess current conditions and determine specific locations for fuelbreak treatments. Our fire behavior analyses occurred at the scale of 0.2 acres (30 x 30 meters), so locations of priority treatments are approximate.

Effective roadway fuelbreaks remove enough trees to result in widely space crowns, remove ladder fuels (seedlings, saplings, shrubs, and low limbs), and reduce surface fuels. The treatment above was conducted by the Genesee Foundation.

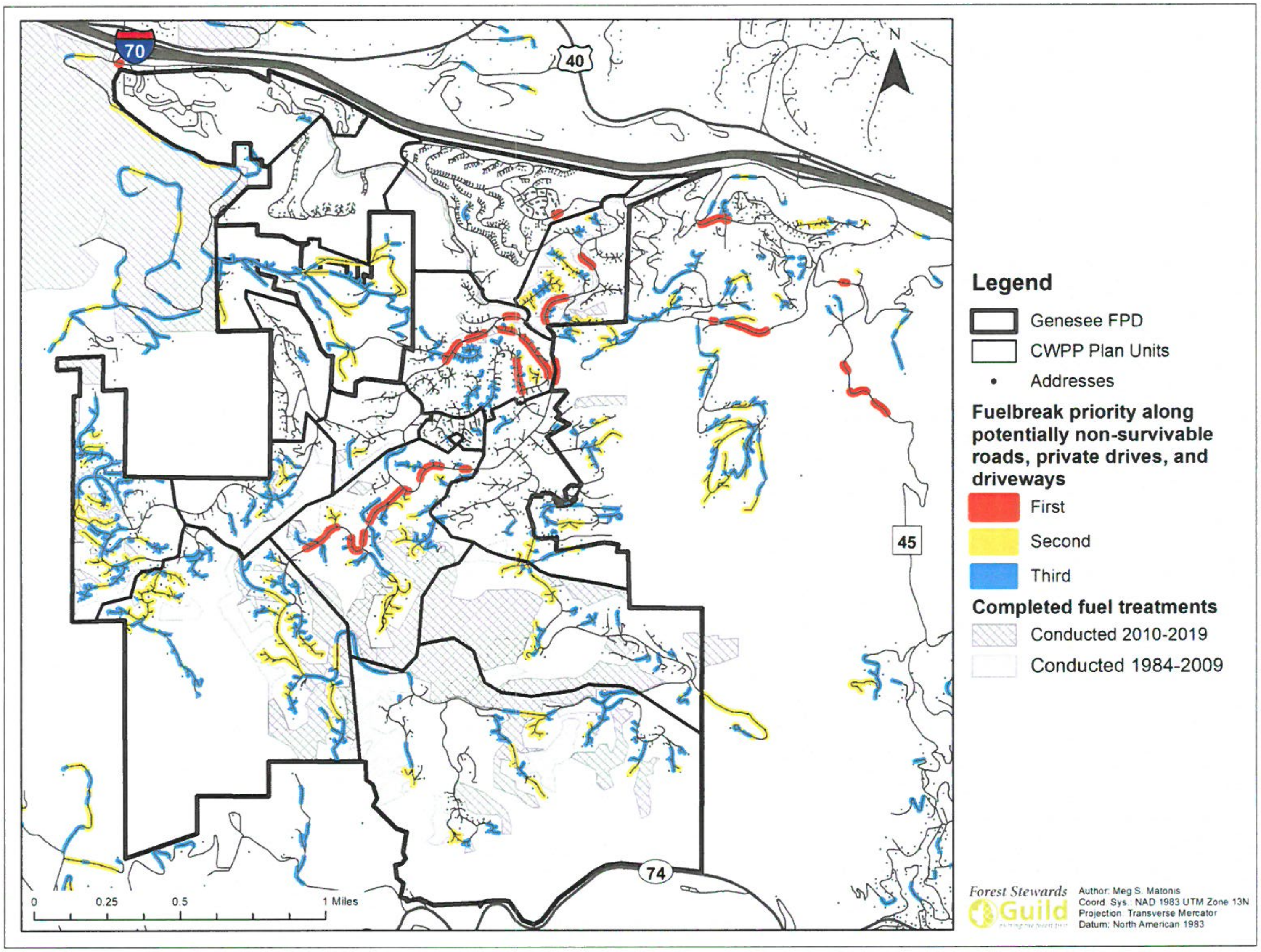


Figure 5d.1. Priority locations for fuelbreaks along roadways, private drives, and driveways based on potential fire behavior and evacuation congestion. Our fire behavior analyses occurred at the scale of 0.2 acres (30 x 30 meters), so locations of priority treatments are approximate. See Appendix B for a full description of our prioritization methods.

Table 5d.1. Segments of roads, private drives, and roadways within the GFPD and Genesee Estates that are priority candidates for fuelbreaks.

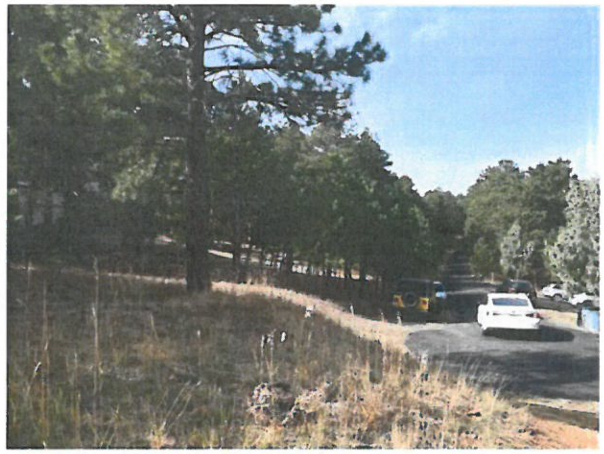
Treatment priority	First priority	Second priority	Third priority
Total length of road segments	1.2 miles	7.3 miles	13.2 miles
Road names	Chokecherry Drive Currant Drive Foothills Drive South Genesee Ridge Road Genesee Village Road Genesee Vista Road Snowberry Drive Sumac Drive	Bitterroot Lane Columbine Court Coneflower Drive Daisy Lane Dogwood Drive Foothills Drive North Foothills Drive South Genesee Avenue Genesee Springs Road Grandview Avenue Juniper Court Larkspur Drive Montane Drive East Montane Drive West Pine Drop Lane Rockcress Way Ski Hill Drive Tamarac Drive Twisted Pine Road Wood Lily Drive	Bitterroot Lane Bristlecone Court Chokecherry Drive Columbine Court Coneflower Drive Crescent Moon Drive Currant Drive Daisy Lane Dogwood Drive Foothills Drive North Foothills Drive South Genesee Avenue Genesee Springs Road Genesee Vista Road Grandview Avenue Holly Court Larkspur Drive Montane Drive East Montane Drive West Northridge Court Pine Drop Lane Pine View Place Pomegranate Lane Rockcress Way Sand Lily Drive Shooting Star Drive Silverberry Lane Ski Hill Drive S. Genesee Mountain Road Southridge Court Stonecrop Way Sumac Drive Tamarac Drive Twisted Pine Road Waynes Way Wood Lily Drive

Effective Treatment Design

The primary objective within fuelbreaks is to dramatically reduce fuels to create potentially survivable conditions during wildfires. 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 fuelbreaks are provided below. Figure 5d.2 includes pictures of roadways from GFPD with suggestions for improvement.

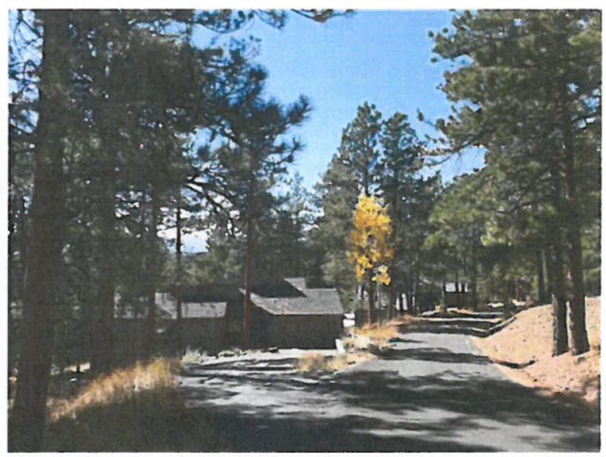
- The width of an effective roadway fuelbreak (distance to the left and right of a road) is dependent on slope, forest type, stand density, and the amount and arrangement of fuels. CSFS recommends that treatments extend 150 to 240 feet off the downhill side of the road and 100 to 150 feet off the uphill side (Figure 5d.3). 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 5d.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 private drives and 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 5c.1).
- 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 Table 5c.2 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 4b.3 for an example of repeat photographs pre- and post-treatment).

The mowed grass and non-burnable barrier along this road are excellent, but the density of regenerating conifers should be substantially reduced to prevent torching and reduce flame lengths along the roadway.



The density of regenerating conifers should be substantially reduced to prevent torching and reduce flame lengths along the roadway, and grasses should be mowed to slow fire spread. Cars should not be parked along narrow roads because this reduces fire engine access.

Narrow driveways can be challenging for fire engines to navigate. Remove trees so the horizonal clearance is at least 20 feet and prune branches hanging less than 13.5 feet to create adequate vertical clearance. Construction of new driveways needs to comply with updated requirements from Jefferson County.



Trees have been limbed, but trees need to be removed to create 15-foot crown spacing on both sides of the roads. The height of grasses is low on the uphill side of the road, but mowing is necessary on the downhill side. Narrow driveways can be challenging for fire engines to navigate.

Figure 5d.2. Examples of conditions occurring along roadways in the GFPD and suggestions for improvement.

Trees have been removed and limbed, but more trees need to be removed to create 15-foot crown spacing, especially on the downhill side. The height of grasses is low on the uphill side of the road, but mowing is necessary on the downhill side. Narrow driveways can be challenging for fire engines to navigate.

The low height of surface fuels and pruning of lower branches is excellent, but more trees should be removed to create at least 15 foot spacing between tree crowns. Trees near roads and remaining low branches should be removed to create horizontal clearance of at least 20 feet and vertical clearance of at least 13.5 feet for fire engine access. Rake and remove pine needles from along the roadway.

Trees are adequately offset from the road, but additional trees need to be removed to create 15-foot crown spacing. Grasses are sufficiently low and should be maintained by mowing and/or burning every year.

Conditions along this private drive are exemplary because of adequately spaced trees with no low limbs, no trees immediately adjacent to the road, and no tall grasses. Continue maintaining these conditions as vegetation regrows.

Figure 5d.2 (continued). Examples of conditions occurring along roadways in the GFPD and suggestions for improvement.

Table 5d.2. Minimum fuelbreak distances 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 fuelbreak 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 5d.3 for a visual representation of roadway fuelbreak measurements.

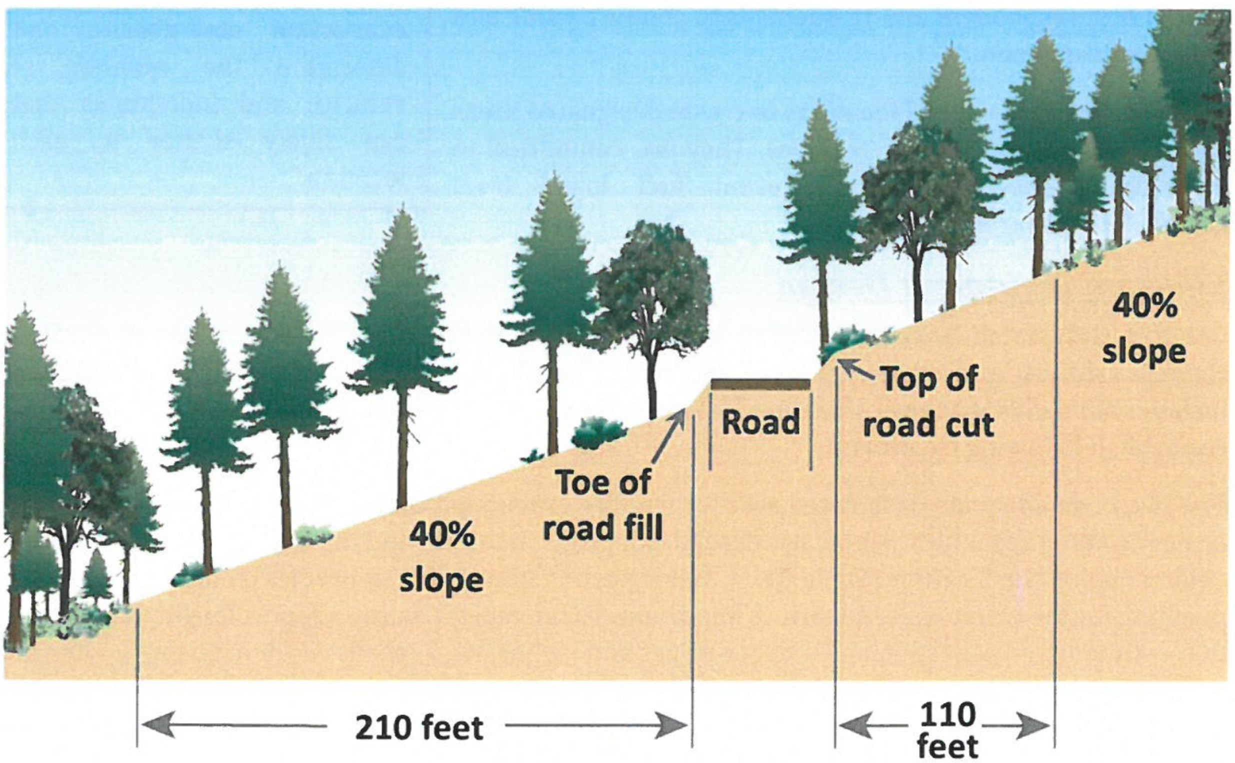


Figure 5d.3. Fuelbreak width must be greater on the downhill side of the road due to the exacerbating impact of slope on fire intensity when fires travel uphill. Figure modified from Bennett and others (2010).

Slash Management

Thinning operations often increases surface fuel loads and can fail to achieve fire mitigation objectives if slash is not addressed (Agee and Skinner 2005). Leaving untreated slash within roadway fuelbreaks is particularly counterproductive. The risk of active crown fire might be lower after a thinning operation, but untreated slash in fuelbreaks 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. Chipping and masticating, physical removal, and mowing can also be appropriate slash management techniques along roadways (see Table 5c.2).

5e. Treatments to Create Designated Areas for Wildfire Evacuation Emergencies

A designated area for wildfire evacuation emergencies is an outdoor area where residents could survive the flaming front of a wildfire. Using a designated area for wildfire evacuation emergencies during a wildfire is **the worst-case scenario**. The goal of first responders and residents is to conduct a safe and effective evacuation.

GFR has identified several locations to create designated areas for wildfire evacuation emergencies. They are committed to maintaining these sites to prevent fuel loads from accumulating over time.

> During a wildfire incident, ONLY first responders will direct vehicles in the direction of a designated area for wildfire evacuation emergencies and determine the number of vehicles and individuals that can safely shelter in each location.

Effective Treatment Design

Creating designated area for wildfire evacuation emergencies involves removing all seedlings, saplings, shrubs, and overstory trees and removing all slash created by thinning. Maintenance includes annually mowing grasses and forbs and regularly removing all seedlings and tall shrubs that reestablish following treatment.

The size of an adequate designated area for wildfire evacuation emergencies depends on the height of surrounding vegetation, slope, windspeed, burning conditions, and the number of individuals and vehicles using the location (Table 5e.1). Windspeed is impossible to predict before an incident, so planning for the worst-case scenario is important. Taller vegetation can support longer flame lengths that emit more radiant heat, and steeper slopes and higher wind speeds result in faster-moving fires and greater exposure to convective heat. Each person using a designated area for wildfire evacuation emergencies needs about 50 ft^2 of space, and vehicles need substantially more area (Campbell and others 2017). Required size estimates are not available for personal vehicles, but wildland fire engines require about 300 ft^2 of space in safety zones (Campbell and others 2017).

Table 5e.1. Safe separation distances are calculated as 8 * Δ * vegetation height, with values of Δ depending on percent slope and windspeeds based on research by Butler (2019). If measurements of vegetation height are in feet, the calculated safe separation distance is in feet. The safe separation distance between surrounding vegetation and designated areas for wildfire evacuation emergencies increases with (1) increasing vegetation height due to greater release of radiant heat from flames consuming taller vegetation, (2) increasing windspeed and slope due to greater exposure to convective heat, and (3) increasing severity of burning conditions due to the overall receptivity of fuels to ignition and sustained combustion.

Δ		Slope %				Burning Conditions
		0	15	30	>40	
Wind (mph)	0	0.8	1	1	2	Low
		1	1	1.5	2	Moderate
		1	1.5	1.5	3	Extreme
	10	1.5	2	3	4	Low
		2	2	4	6	Moderate
		2	2.5	5	6	Extreme
	>20	2.5	3	4	6	Low
		3	3	5	7	Moderate
		3	4	5	10	Extreme

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).

Aerial LiDAR (Light Detection and Ranging): A remote sensing method that uses light in the form of a pulsed laser emitted from low-flying aircraft to measure variable distances to the ground. Output data provides a 3-D representation of the ground and surface features, including vegetation, homes, powerlines, etc. (Andersen and others 2005).

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 2021).

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 bulk density (CBD): The density of available canopy fuels in a stand (the mass of available canopy fuel per canopy volume unit). Typical units are either kg/m^3 or lb/ft^3. Stands with higher CBD have a higher likelihood of active crown fire (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 height: The average height of the top of the vegetated canopy (NWCG 2019).

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

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

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 2021).

Defensible space: The natural and landscaped area around a structure that has been modified and maintained to reduce fire danger by treating, clearing, and reducing the abundance of natural and manmade fuels. Defensible space reduces the risk that fire will spread from surrounding vegetation to the structure, and it enhances firefighter access and safety. The Colorado State Forest Service defines three zones of defensible space: zone 1 (0 to 5 feet from a home), zone 2 (0 to 30 feet from a home), and zone 3 (30 to 100 feet from a home). The presence of defensible space can increase the likelihood that firefighters will be able to defend a home (CSFS 2021).

Designated areas for wildfire evacuation emergencies: An outdoor area where residents might survive a wildfire if they are unable to safely evacuate. The size of an adequate designated area for wildfire evacuation emergencies depends on the height of surrounding vegetation, slope, windspeed, burning conditions, and the number of individuals and vehicles using the location (Butler 2019).

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 and others 2018).

Embers: Small, hot, and carbonaceous particles. Embers are similar to firebrands, but the term "firebrand" specifically denotes a small, hot, and carbonaceous particle that is airborne and carried for some distance in an airstream (Babrauskas 2018).

Energy Release Component (ERC): The computed total heat release per unit area (British thermal units per square foot) within the flaming front at the head of a moving fire based on moisture content of the various fuels present, both live and dead. ERC is a composite fuel moisture value that reflects the contribution of all live and dead fuels to potential fire intensity (NWCG 2018b).

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 and others (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 and others 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). We use the term "roadway fuelbreak" for fuelbreaks built along roadways.

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).

Gorge: A narrow, deep valley with nearly vertical, rocky walls, smaller than a canyon, and more steep-sided than a ravine (NRCS 2017).

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 and increases the chance that firefighters can safely stay and defend a home.

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).

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/.

Long-range spotting: When large glowing firebrands are carried high into the convection column and fall out downwind beyond the main fire, starting new fires. The distance used to differentiate short-range and long-range spotting varies among sources. NWCG (2018b) classifies long-range spotting as firebrands that travel more than 0.25 miles and ignite new fires, whereas Beverly and others (2010) use a threshold of 0.06 to 0.3 miles. We use the Beverly and others (2010) definition in this CWPP. 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 and others 2016).

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 and others 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, creation of fuelbreaks or barriers around critical or sensitive sites or resources, vegetation 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).

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. 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 2021).

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 fuelbreak: 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: Fuelbreaks built 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).

Short-range spotting: When firebrands, flaming sparks, or embers are carried by surface winds and start new fires beyond the zone of direct ignition by the main fire (NWCG 2018b). The distance used to differentiate short-range and long-range spotting varies among sources. NWCG (2018b) classifies short-range spotting as firebrands that travel less than 0.25 miles and ignite new fires, whereas Beverly and others (2010) use a threshold of 0.06 miles. We use the Beverly and others (2010) definition in this CWPP. 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 and others 2016).

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 a firebrand (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. Spotting is classified as short-range or long-range spotting (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 2021).

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 (CalFire 2014). 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): The area where structures and development meet with wildland fuels and vegetation. WUI is subdivided into intermix, areas where housing and wildland vegetation intermingle, and interface, areas where housing is in the vicinity of larger areas of dense wildland vegetation (Martinuzzi and others 2015).

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Appendix A. Genesee Fire Protection District Resident Survey Summary

Survey respondents

In August and September 2020, the Forest Stewards Guild surveyed residents in the Genesee Fire Protection District (GFPD) to gauge their knowledge of wildfire and assess their concerns. Questions developed by the Wildfire Research group (WiRē) were instrumental in conducting the survey. We received 306 completed surveys representing approximately 10% of residents in the GFPD. About 70% of respondents live in the Genesee Foundation and 15% in the Genesee Village Homeowner's Association (HOA). Several residents from Chimney Creek 1 and 2, 1st Ridge and 2nd Ridge Townhomes, Genesee Ridge, and Genesee Estates also responded, as well as one business owner from the business district in the northwestern corner of the GFPD.

Most survey respondents are full-time homeowners living in single-family homes, and 12% live in multi-family dwellings. Ninety percent of survey respondents have been in the community for greater than 2 years, with half of respondents living in the GFPD for over 10 years.

Resident knowledge and concerns about wildfire risk

Most residents feel they understand the level of wildfire risk in the GFPD and understand factors that impact fire behavior (Figure A.1). Residents are primarily concerned about limited evacuation capacity, loss of insurance coverage, damage to property, and loss of life in the case of a wildfire (Figure A.2).

About 70% of residents think there is at least a 50% chance that their home would be destroyed or severely damaged if a wildfire spreads to their property (Figure A.3). Residents believe fire risk is high for several reasons (Figure A.4):

- There are many trees and dried grasses and conifer litter near homes and in open spaces across the community.
- They or their neighbors have not mitigated hazards.
- Homes have combustible building materials.
- Homes are located at the top of ridges and along steep slopes.
- Driveways are narrow and inaccessible to fire engines.
- Climate change is increasing the occurrence of severe fire weather conditions.

Resident quote: *We are originally from Washington State (Central Washington) and experienced many wildfires from nearby dry-land wheat fields and sagebrush fired. We learned to be prepared for wildland fire during certain times of the years and to mitigate around house and outdoor areas. We keep trees trimmed, pinecones and needles picked up, and have gravel riprap around the house and garage.*

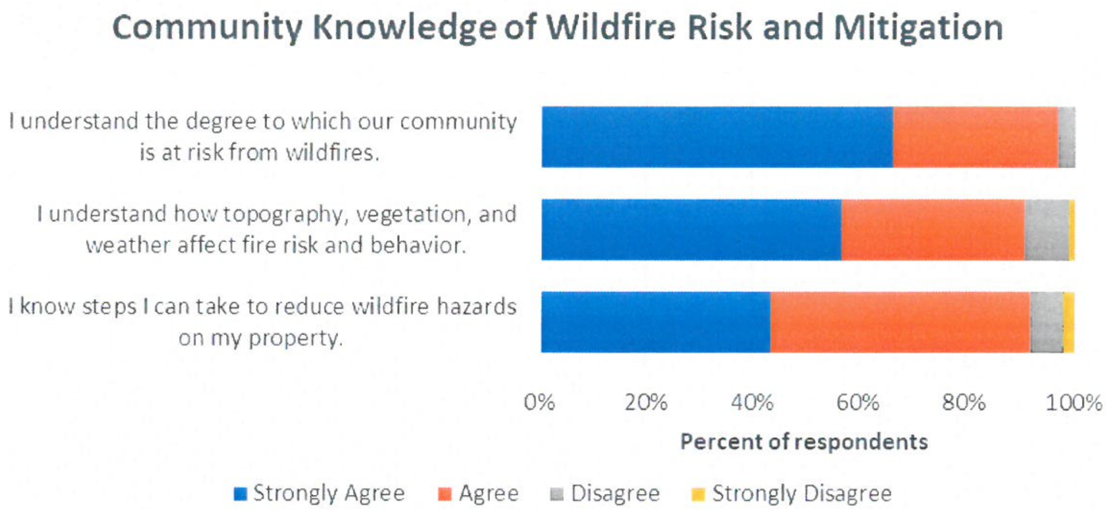


Figure A.1. Residents in the Genesee Fire Protection District are generally familiar with the wildfire risk in their community and factors influencing fire behavior. They are less familiar with steps they can take to reduce wildfire hazards on their property.

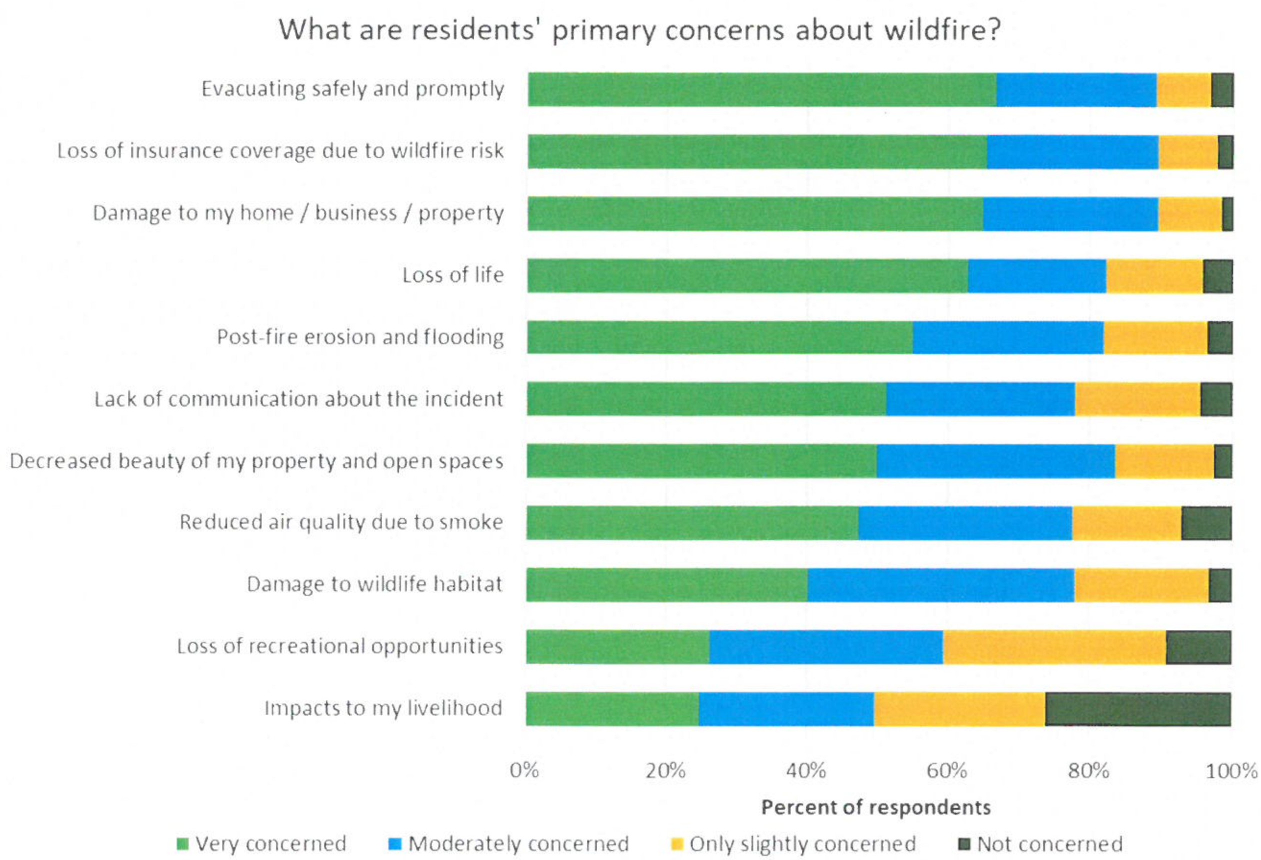


Figure A.2. Residents are primarily concerned about safe evacuations, loss of insurance coverage, damage to property, and loss of life in the case of a wildfire in the Genesee Fire Protection District.

Figure A.3. Many residents in the Genesee Fire Protection District think there is greater than a 50% chance that their home or business could be destroyed or severely damaged in a wildfire.

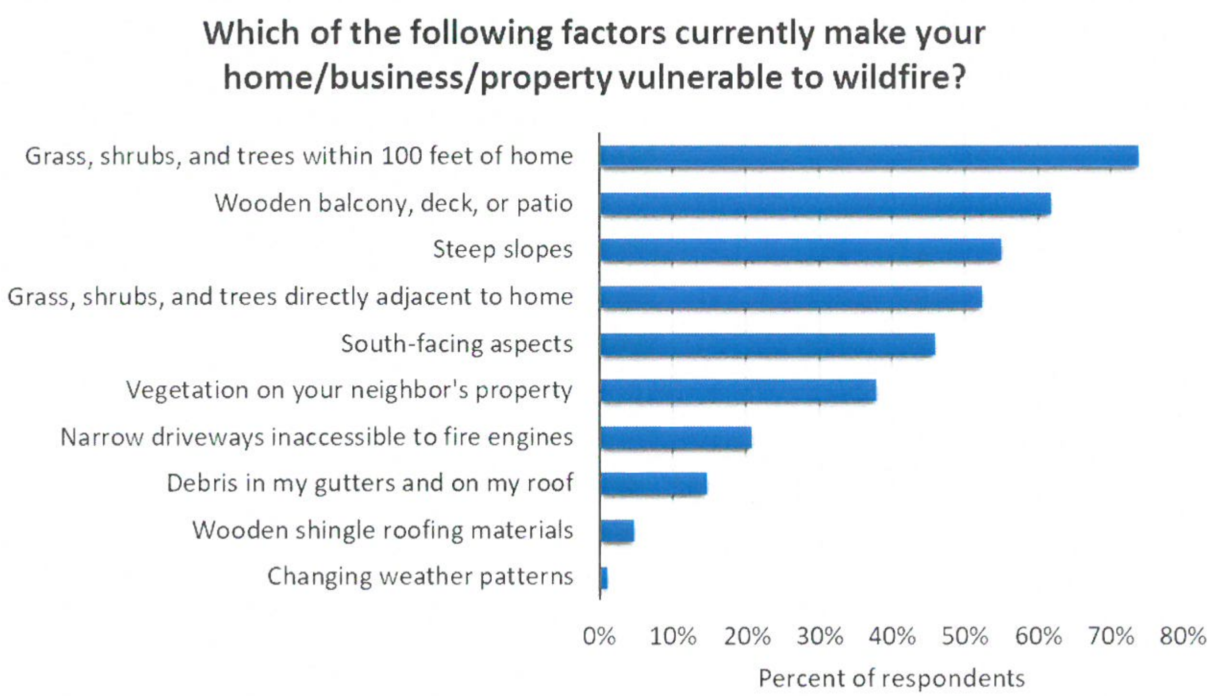


Figure A.4. Residents are aware of numerous factors making their properties vulnerable to wildfire.

Residents report lack of defensible space and flammable housing materials as their highest risk factors. About 20% of respondents recognize that narrow driveways make their properties inaccessible to engines for wildland firefighting.

Some respondents perceive a lower probability of home loss due to the abundance of fire hydrants in the GFPD and their proximity to the GFR Station. Hydrants and firefighters can do a lot to save homes, but residents must also do their part to create defensible space and harden homes.

Some respondents believe that since their homes have not yet burned, it is unlikely they will burn in the future. Other respondents feel it would be hard for wildfire to reach the interior of the GFPD. Unfortunately, wildfire risk in this area is high, and embers from a wildfire can travel a mile or more and ignite homes. Wildfires that ignite outside the boundaries of the GFPD could easily travel into the community. According to the 2020 Wildfire Risk to Communities analysis by the U.S. Forest Service, populated areas in the GFPD have greater risk than 97% of communities in Colorado in terms of potential damage from wildfires (USFS 2020).

Resident support for wildfire mitigation

Community support for mitigation is high in the GFPD (Figure A.5). Most residents would support tree removal and prescribed burning to reduce wildfire risk along roadways and in open spaces. However, some residents express concern about these practices reducing aesthetic value and endangering homes.

Many residents have undertaken actions to lessen the risk of wildfire around their homes (Figure A.6). Over 80% of survey respondents annually remove debris from their gutter and roof, clear debris from around their homes, and cut trees or remove low limbs near their homes. Almost 60% of residents have replaced their roofs with less flammable materials, but only 2% have replaced siding or decking. Only 1% of residents have created non-flammable barriers around their homes, such as bordering the base of their homes with crushed rock.

Resident quote: *I guess [wildfire] mitigation might be akin to what we see with Covid-19 and wearing masks—the impact on the community as a whole is dependent on ALL of us to do our part. Even one diligence lapse or non-compliant person can cause serious risk to others.*

Only 17% of residents have installed screens to block embers. During many wildland fires, 50 to 90% of homes ignite due to embers rather than radiant heat (Babrauskas 2018; Gropp 2019). Residents can reduce their risk dramatically by making it harder for embers to ignite their homes, for example, by installing screens over vents and eaves, replacing flammable decking, and moving firewood away from structures (Syphard and Keeley 2019).

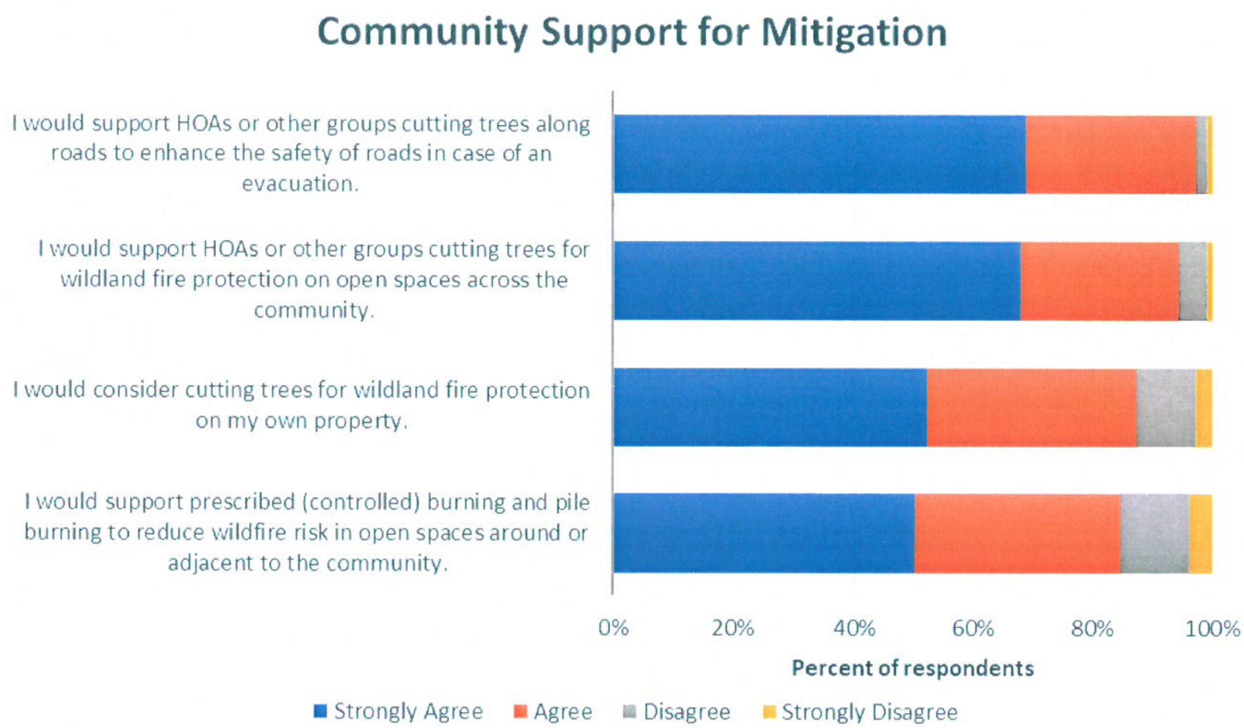


Figure A.5. Many residents are supportive of mitigation measures to reduce wildfire hazards across their community.

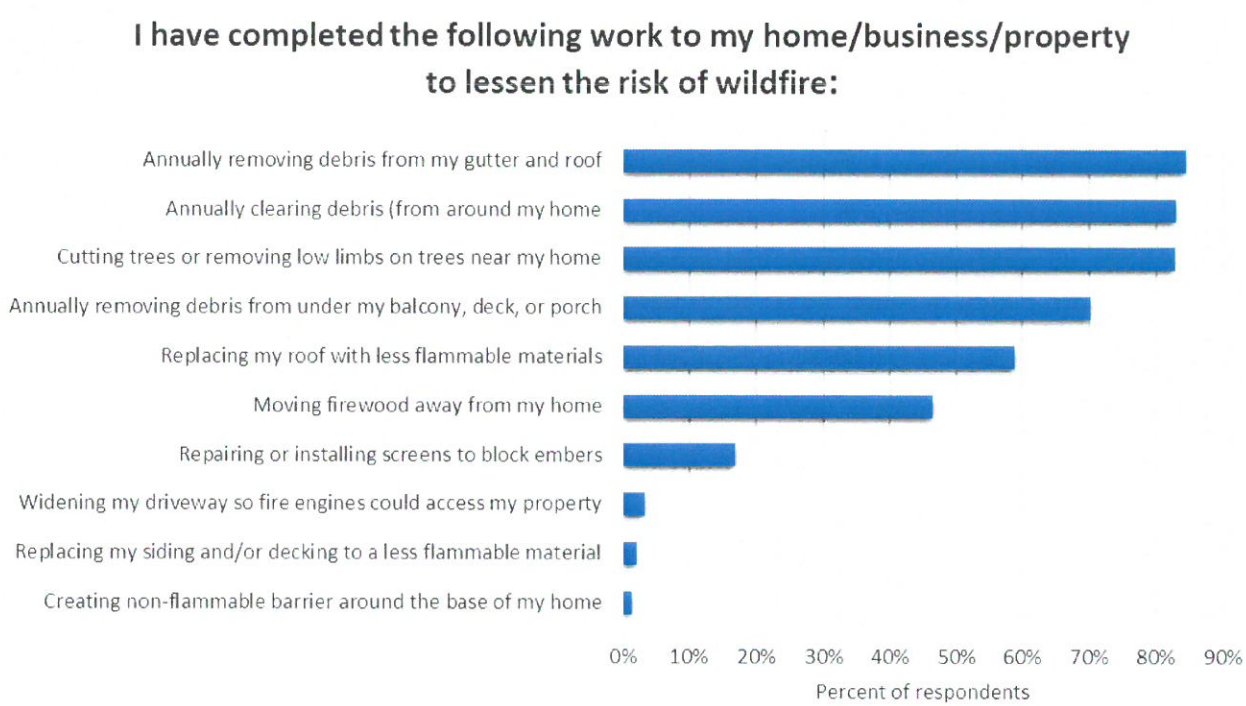


Figure A.6. Many residents in the Genesee Fire Protection District have undertaken efforts to mitigate wildfire risk around their homes.

Barriers to wildfire mitigation and potential solutions

Several barriers prevent residents from undertaking actions to reduce wildfire risk on their property (Figure A.7). Almost a half of residents identified the desire to keep trees near homes for aesthetic reasons, shading, or privacy screening as a barrier to the creation of defensible space. Community fieldtrips to homes with admirable defensible space might assuage the concerns of residents that mitigation work degrades the beauty of the community.

Lack of knowledge about effective mitigation measures was another top barrier in the GFPD (Figure A.7). Newer residents feel particularly unfamiliar with practical steps they can take to reduce wildfire hazards.

Educational opportunities could enable additional mitigation actions by residents in the GFPD (Figure A.8). Over 65% of respondents are interested in presentations on wildfire behavior and risk, trainings on ways to reduce wildfire hazards, and one-on-one consultations about wildfire hazards on individual properties (Figure A.9). Most residents receive information on wildfire mitigation from their HOA and GFR, so it is important for these organizations to continue reaching out and educating residents.

Resident quote: *My largest concern is the beauty of the community. I feel that most of us moved here to be closer to and live within nature. We have factored fire risk into our lives. I am worried that most mitigation destroys what endears us to this community. Please teach me that there are ways to preserve the beauty of the neighborhood, while making it safer.*

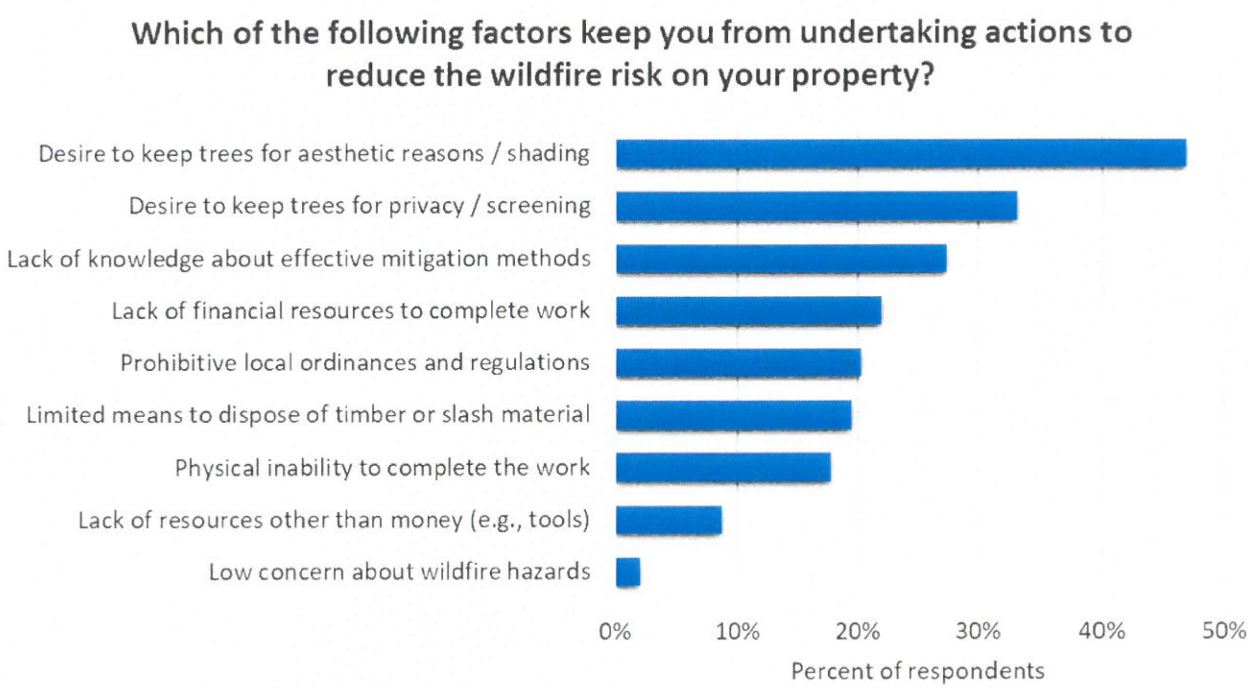


Figure A.7. The desire to keep trees near homes for aesthetic reasons, shading, or privacy screening and lack of information are the top barriers to mitigation work by residents of the Genesee Fire Protection District.

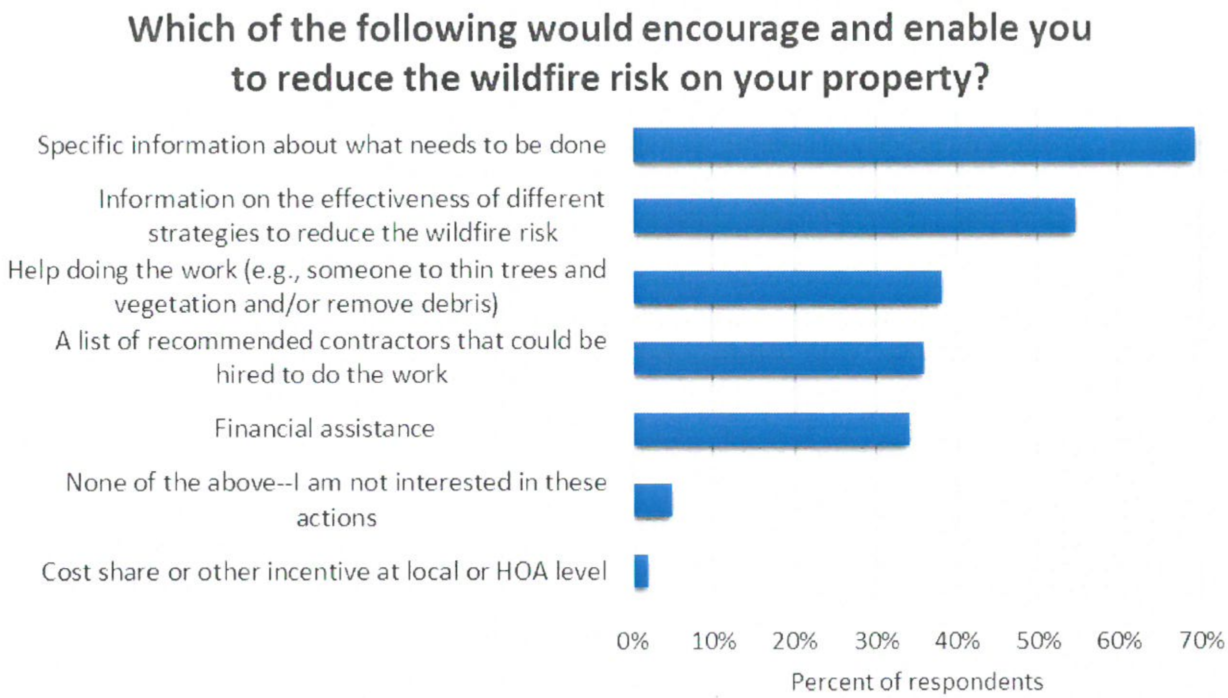


Figure A.8. Training and education can inspire additional risk reduction measures across the Genesee Fire Protection District.

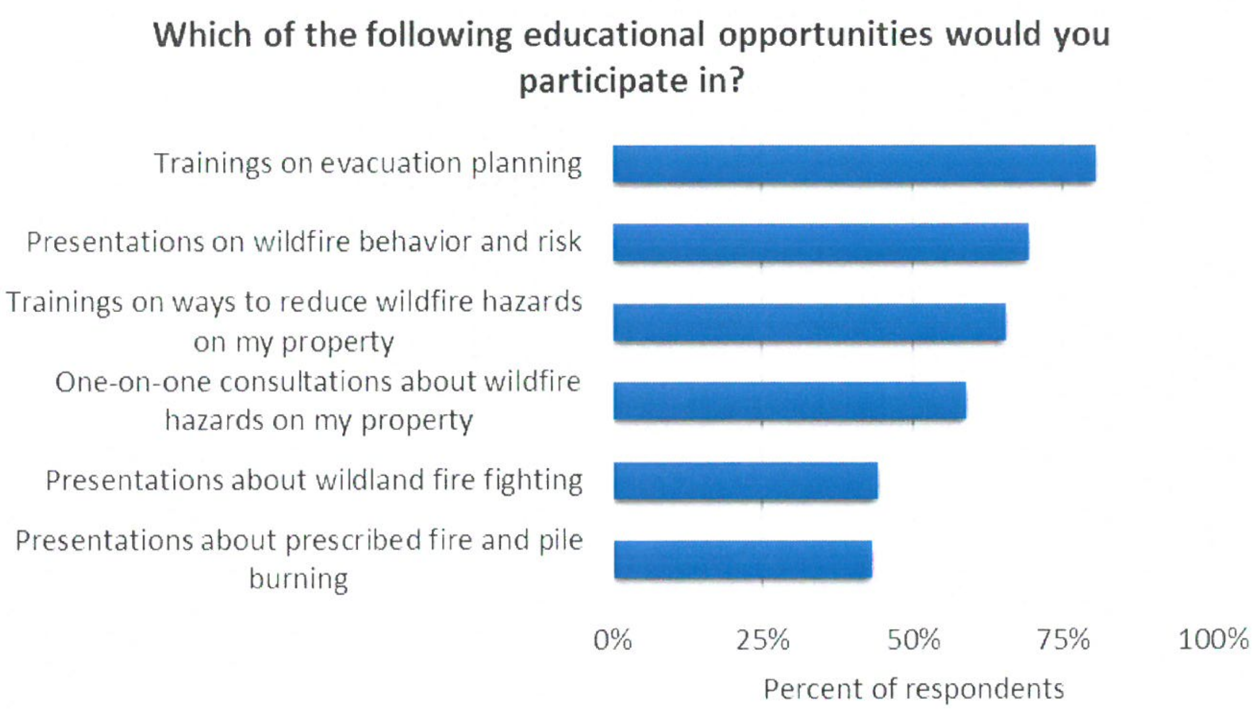


Figure A.9. Residents are interested in a variety of educational and training opportunities about emergency response, wildfire behavior and risk, and wildfire mitigation.

Some survey respondents report they created defensible space and undertook home hardening, but they are concerned about high hazards on their neighbors' properties and HOA open space. It is imperative that residents across the GFPD reduce hazardous fuels and harden their homes. Neighbors committed to addressing wildfire concerns can work with GFR and their HOAs to educate their community about the benefits of defensible space and home hardening. Residents can inspire action through neighborhood ambassador programs (Wildfire Adapted Partnership 2018). About 50% of respondents are willing to encourage their neighbors to reduce hazards on and around their property (Figure A.10).

A couple respondents shared they had completed mitigation projects but were not maintaining their defensible space. The lack of maintenance decreases the effectiveness of their mitigation work and increases their risk. Removing flammable debris from gutters, roofs, decks, and around homes, mowing tall grass near homes, and inspecting covers over vents should be annual activities. Pruning shrubs and low limbs from trees needs to occur as vegetation regrows after initial treatment. These are low-cost and relatively simple measures that can increase the likelihood of homes surviving wildfires. Information on contractors, support removing woody material from properties, and financial incentives could spur additional mitigation actions and maintenance across the GFPD (Figure A.8).

About 20% of respondents feel like HOA regulations and other local ordinances limit their ability to address wildfire risks on and around their properties (Figure A.7). Limitations include HOA regulations on siding types and an involved process to authorize tree removal. To help address these issues, residents can serve on HOA working teams and speak with HOA leadership to support community-wide action around wildfire mitigation. About 45% of respondents indicated willingness to influence community guidance on wildfire mitigation.

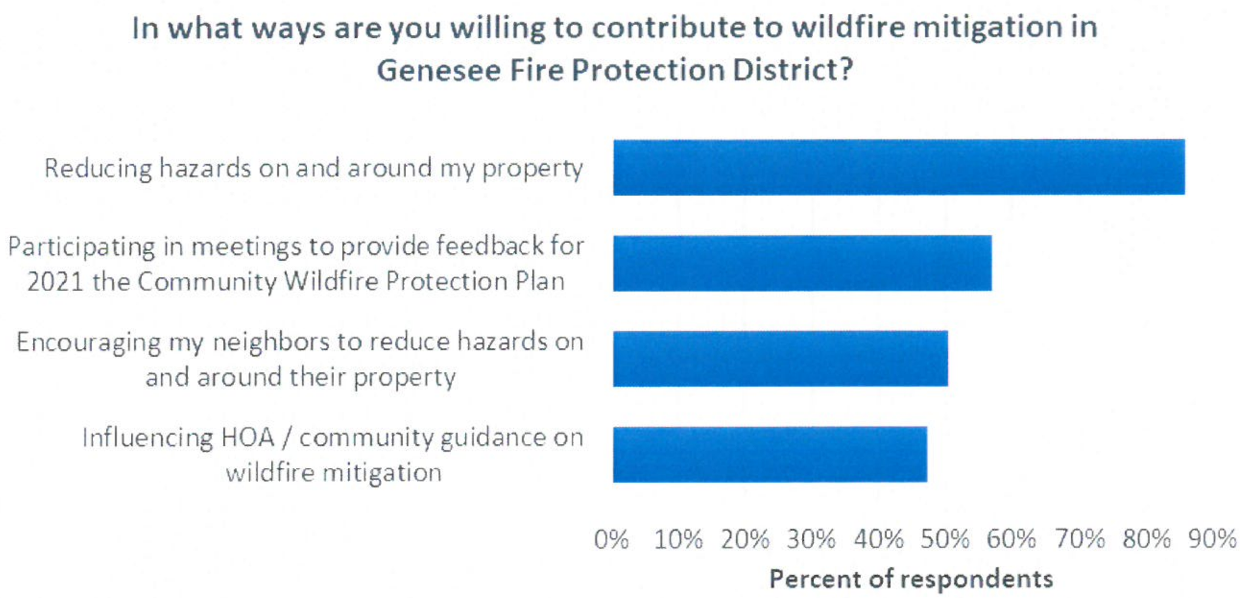


Figure A.10. Many residents in the Genesee Fire Protection District are willing to contribute to wildfire mitigation by addressing hazards on their property and engaging in activities across the community.

Evacuation concerns and solutions

Residents' top concern about wildfires in the GFPD is limited evacuation capacity (Figure A.2). Residents expressed the greatest interest in training on evacuation planning (Figure A.9). Residents are concerned about the lack of evacuation routes in the GFPD, not receiving timely notice of wildfire evacuations, and feeling unprepared to leave their home within 20 minutes (Figure A.11). Some residents are concerned about family members or neighbors with physical limitations who might struggle to evacuate, and some residents are concerned about school-aged children that might be home alone during evacuations.

Resident quote: *The roads in and out in Genesee Village are 2 lanes only with limited access points to I-70. Would all residents attempt to leave the area, I can see a terrible mess—limited access for emergency vehicles and parents unable to enter the area to get their children either from home/babysitters or from school. The area contains many families where both parents work - and children are on their own or in the care of others - this area of the plan [CWPP] requires a great deal of work!*

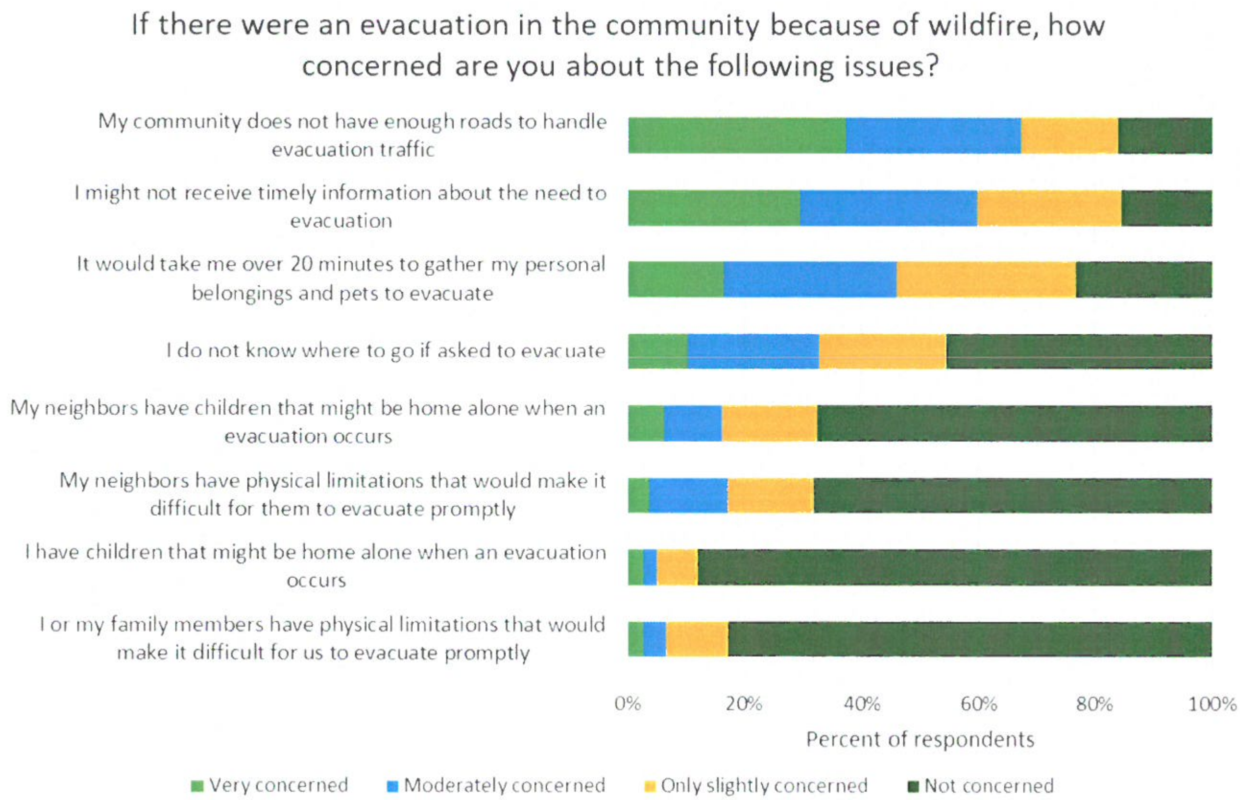


Figure A.11. Residents in the Genesee Fire Protection District are most concerned about the lack of evacuation routes, not receiving timely notice of wildfire evacuations, and feeling unprepared to leave their home within 20 minutes.

Reliable technology to provide warnings and information about evacuations is the most important factor that would make residents feel confident in their ability to evacuate during a wildfire (Figure A.12). Some residents expressed concerns about cellphone coverage in the area, so assessing coverage and addressing issues might be an important step. Educating residents about the purpose and reliability of CodeRED could also address concerns about timely updates during evacuations.

CodeRED participation in the GFPD is already high, with over 80% of residents opted into the program (Figure A.13). GFR, HOAs, and neighbors should actively extend awareness about CodeRED to the 11% of residents that are unaware of the program. Residents of the Genesee Village HOA, Genesee Estates, and Chimney Creek 1 and 2 HOAs have lower participation and awareness rates than residents of the Genesee Foundation.

CodeRED is the reverse 911 system used by Jefferson County Communications Center Authority (JeffCom) to contact residents during emergencies, including during wildfire evacuations. Residents' landlines are automatically registered unless their phone uses VoIP (voice-over internet protocol). Residents can register their cell phones and email addresses on the CodeRED website.

Over half of respondents expressed support for community sirens, signs to indicate evacuation routes, designated and maintained areas where people could potentially survive wildfires, and removal of vegetation along roadways. Over 40% of residents also support district-wide evacuation drills.

Residents in the GFPD can make vast improvements in their own personal evacuation planning and readiness. About 65% of residents have evacuation plans, but only 25% have go-bags packed and ready in the case of an evacuation (Figure A.14). Go-bags are an important aspect of evacuation preparedness. Visit the Rotary Wildfire Ready website to learn about preparing go-bags.

Figure A.12. Digital technology to provide warnings and information about evacuations was the top factor that would make residents feel confident in their ability to evacuate during a wildfire.

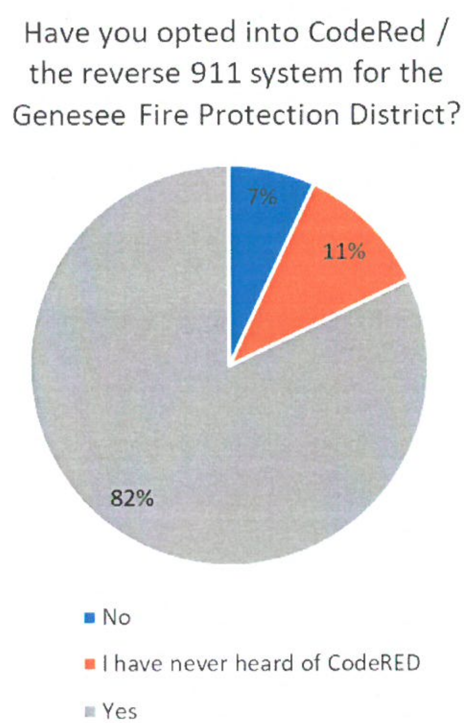
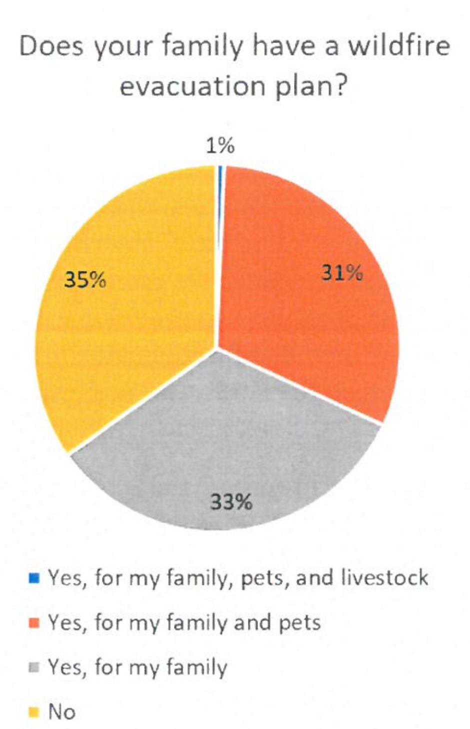


Figure A.13. Most residents are enrolled in CodeRED to receive evacuation notices from Jefferson County Communications Center Authority (JeffCom), but additional education can expand participation to residents unfamiliar with the program.



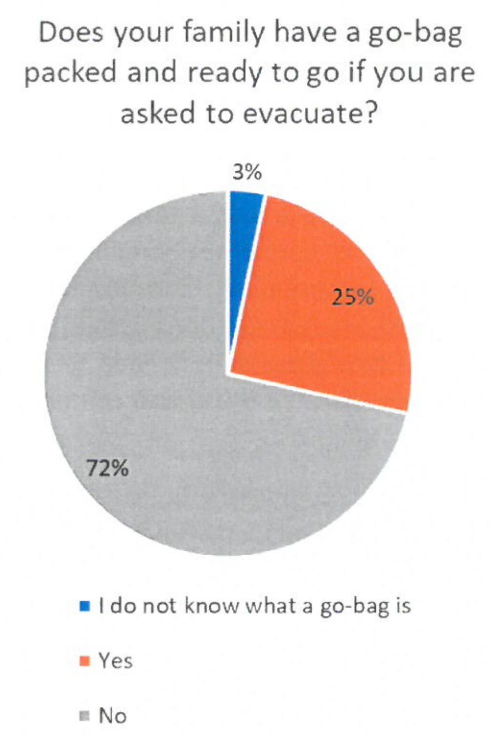


Figure A.14. Many residents have wildfire evacuation plans (left), but fewer have go-bags packed and ready to go (right). Ideally all families would have evacuation plans and go-backs because of the high fire risk in the Genesee Fire Protection District.

Appendix B. Modeling Methodology

Fire Behavior Analysis

Modeling Fire Behavior with FlamMap

We used FlamMap to model flame length, crown fire activity, potential fire sizes, and conditional burn probability. 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 1,000 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 20 times larger than the GFPD and centered on the GFPD to capture the landscape-scale movement of fire.

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). We provide model specifications for our analyses in Table B.1.

Estimating Fuel Conditions from LiDAR

Based on field observations, we determined that raw data from the 2016 LANDFIRE remap[9] did not accurately represent forested vs. non-forested vegetation types or distinguish interspersed open space from low-density housing development within the GFPD. To address these deficiencies, we utilized aerial LiDAR[10] data collected for Jefferson County in 2014 to develop improved estimates of canopy fuel loads. Aerial LiDAR provides accurate and efficient measurements of three-dimensional forest structure over extensive areas (Andersen and others 2005). We predicted vegetation type and fuel models with the same associations used by LANDFIRE, but the integration of high-resolution LiDAR data allowed us to better distinguish forested vs. non-forested area and undeveloped open space from low-density development.

To develop estimates of canopy cover and canopy height, we used the R software and the lidR package (Roussel 2021) and the 3D Analyst extension for ArcGIS. We closely followed the methodology of Peterson and others (2015) and Reeves and others (2009) for this analysis. We used only first return pulses, which is a standard practice for forestry applications of LiDAR data, and we normalized heights using the triangular irregular network algorithm. We used point cloud statistics and visual inspection to identify erroneous returns in the LiDAR data, and we filtered out powerlines, telecommunication towers, and cliffs. We identified and removed buildings from the point cloud data using the "Classify LAS Building" tool in ArcGIS.

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[9] 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. More information about the program is available online at https://www.landfire.gov/.

[10] Aerial LiDAR, which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser emitted from low-flying aircraft to measure variable distances to the Earth. Output data provides a 3-D representation of the ground and surface features, including vegetation, homes, powerlines, etc.

We used forest inventory data from the Genesee Foundation Open Space Manager to develop a relationship between tree height and crown width (crown width (meters) = 1.5047 * tree height (meters) ^ 0.4723; $R^2 = 0.3745$), and we used this equation to determine variable-sized windows for individual tree detection and tree crown delineation in lidR. We used a minimum tree height of 2 m following Peterson and others (2015) and a minimum tree crown area of 6.5 m^2 based on the general distribution of tree inventory data for the Genesee Foundation. Following Peterson and others (2015), we created a canopy height raster by finding the 99^{th} percentile height of points classified as trees in 30-meter x 30-meter areas, and we created a canopy cover raster by determining the cover of the vertical projection of tree crowns in 30-meter x 30-meter areas.

We followed rules used by LANDFIRE products (Reeves and others 2009) to create canopy fuel input layers for fire behavior modeling. Any area with canopy height of 0 was assigned a canopy cover value of 0 and vice versa. Areas with canopy cover less than 10% were classified as non-forested and assigned a canopy height of 0. We quality controlled the LANDFIRE 2014 existing vegetation type (EVT) data by identifying areas where our LiDAR-based estimates of canopy cover were less than 10% but the LANDFIRE EVT was a forest type, and we identified areas where our LiDAR-based estimates of canopy cover were greater than 10% but the LANDFIRE EVT was a non-forest type. We assigned the misclassified areas to the nearest appropriate EVT.

We utilized the National Land Cover Dataset to identify areas that were developed and a rasterized version of the OpenStreetMap dataset to identify areas that were dominated by major roads. We identified areas that were open water or rivers with the National Land Cover Dataset and National Hydrologic Dataset.

We utilized LANDFIRE rules to assign fuel behavior models to each pixel based on EVT, canopy cover, and canopy height. We used the set of 40 fuel models developed by Scott and Burgan (2005) (Figure B.1). We utilized regression equations developed by the LANDFIRE team to predict canopy base height for each pixel based on canopy height, canopy cover, and EVT-specific regression coefficients, and we used the equation outlined in Reeves et al. (2009) to calculate canopy bulk density.

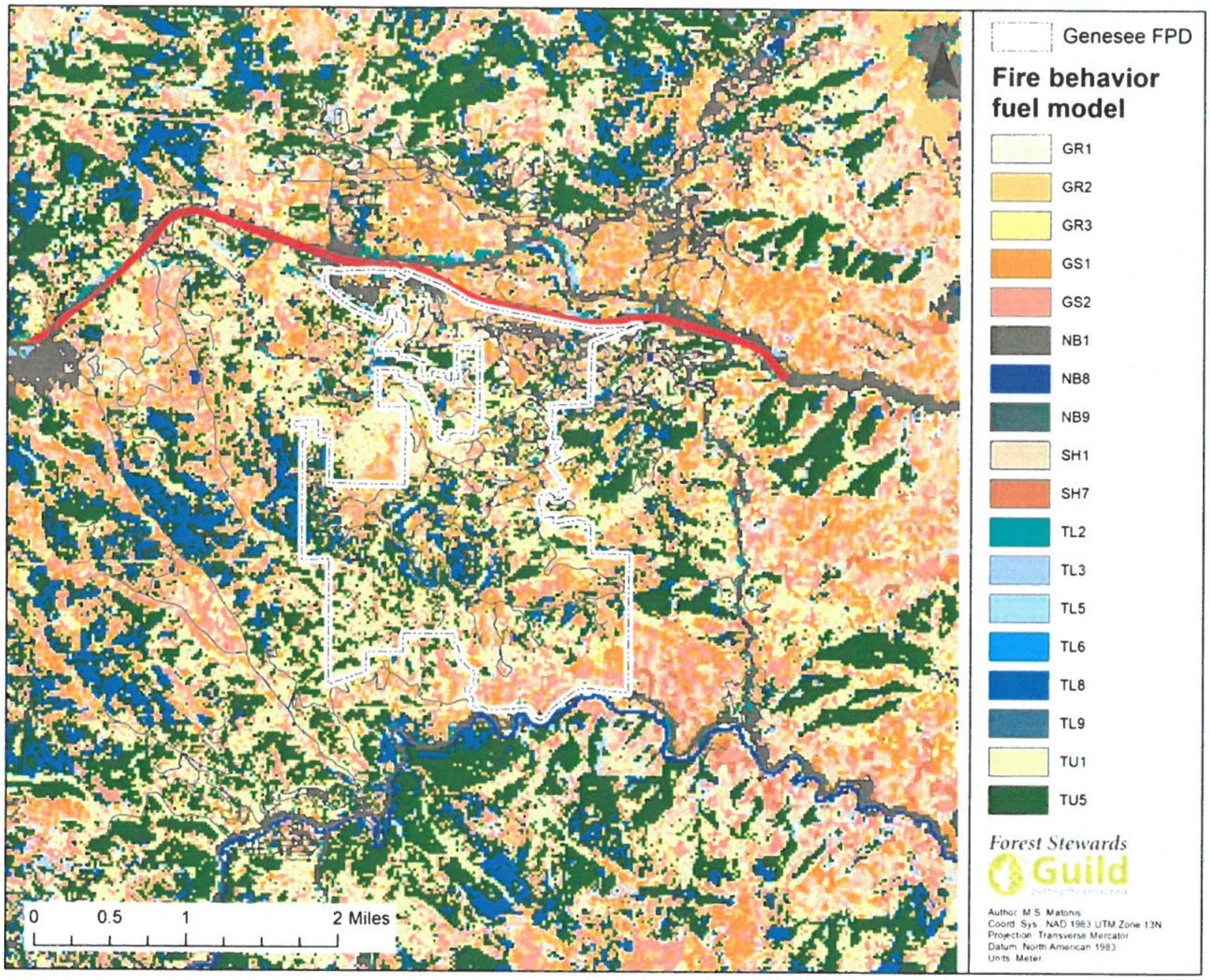


Figure B.1. Fire behavior fuel models within the Genesee Fire Protection District and the surrounding area. We made custom modifications to LANDFIRE 2014 data based on estimates of canopy cover from LiDAR to help differentiate non-forested and forested areas. NB = non-burnable, GR = grass-dominated, GS = grass-shrub, SH = shrub, TL = timber litter, and TU = timber understory fuel models. See Scott and Burgan (2005) for a description of each fuel model.

Table B.1. Model specifications used for fire behavior analyses with FlamMap for the 2021 Genesee Fire Protection District CWPP.

Model specification	Value
Crown fire calculation method	Scott/Reinhardt (2001)
Wind options	Gridded winds
Wind grid resolution	60 meters
Number of random ignitions	1000*
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, 90th, and 97th fire weather conditions.

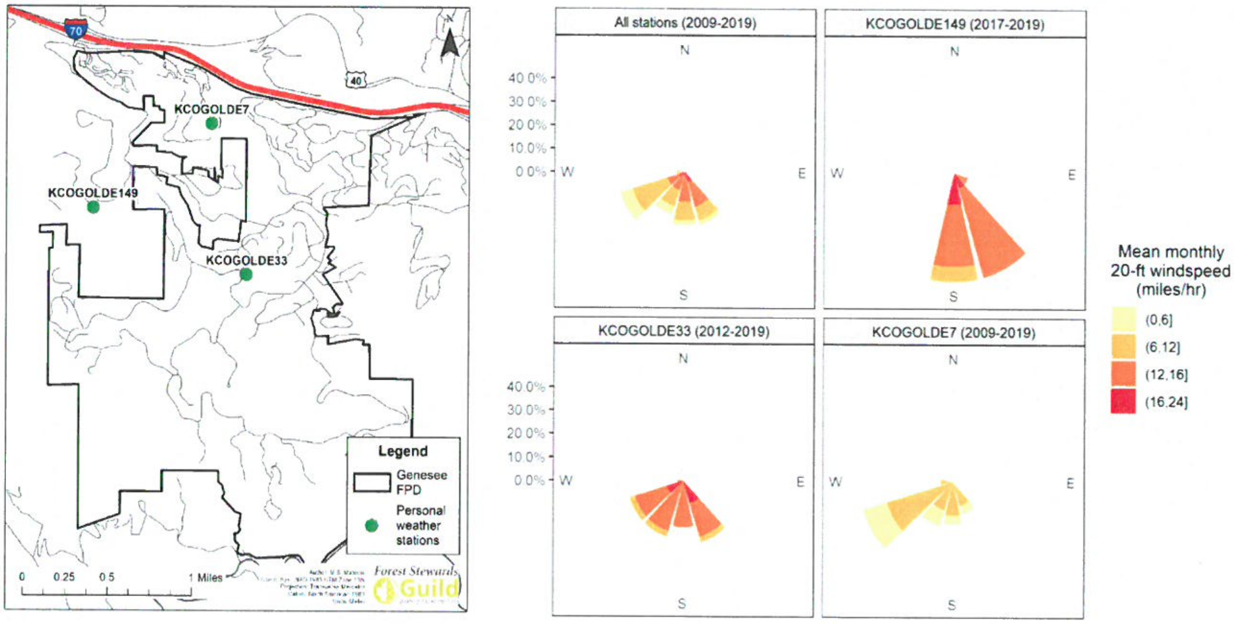
Wind Estimates

Winds across the Front Range of Colorado are unpredictable and can be extremely gusty in mountainous areas. Local firefighters informed us that wind directions at the Lookout Mountain RAWS station, which is north of I-70, are often different from winds in the GFPD. We utilized wind observations from three personal weather stations located across the GFPD as available through Weather Underground (https://www.wunderground.com/). These weather stations reported winds predominantly blowing from the west-southwest and south-southeast. Average monthly windspeeds at the ground level were 1 to 5 mph, and average monthly gusts were 8 to 34 mph between June and October 2009 to 2019.

Windspeeds from personal weather stations are measured a few feet above the ground, but fire behavior models require 20-foot windspeeds, which are defined as sustained wind over a 10-minute period at 20 feet above the dominant vegetation. The wind adjustment factor to convert 20-foot windspeeds to midflame windspeeds is 0.2 for fully sheltered fuels in open stands (NWCG 2021). Vegetation and friction slow down windspeeds closer to ground level. The adjustment factor to convert ground-level winds to 20-foot windspeeds is 5, the inverse of 0.2.

We modeled 20-foot windspeeds of 17 mph for 60th percentile fire weather conditions, 18 mph for 90th percentile fire weather conditions, and 25 mph for 97th percentile fire weather conditions. Wind speeds of 25 mph qualify as red flag warnings when occurring with low relative humidity and dry fuels (Table 1c.1). We modeled potential fire spread under winds blowing out of the south-southeast (158°) and blowing out of the west-southwest (248°); predictions of flame length and crown fire activity using FlamMap are not dependent on wind direction, only wind speed.

Figure B.2. Locations of three personal weather stations in the GFPD (left) and distribution of windspeeds and wind directions (right). Ground-level windspeeds were converted to 20-foot windspeeds following guidance from the National Wildfire Coordinating Group for fully sheltered fuels in open stands. Data was accessed from Weather Underground (https://www.wunderground.com/).



Evacuation Analysis

Modeling Evacuation with ArcCASPER

We modeled evacuation time and roadway congestion using ArcCASPER (Shahabi and Wilson 2014). 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 50. 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.

Delineating Alternate Evacuation Routes

We used a digital topographic map with contour lines to draw two potential southern egress routes. We used ArcGIS to calculate the grade for each segment of road and adjusted the route until most of the road met road standards in Colorado (Figure B.3). The maximum grade for a local rural road in a mountainous area with a speed limit of 20 mph is 16% according to the Colorado Department of Transportation 2018 roadway design guide.

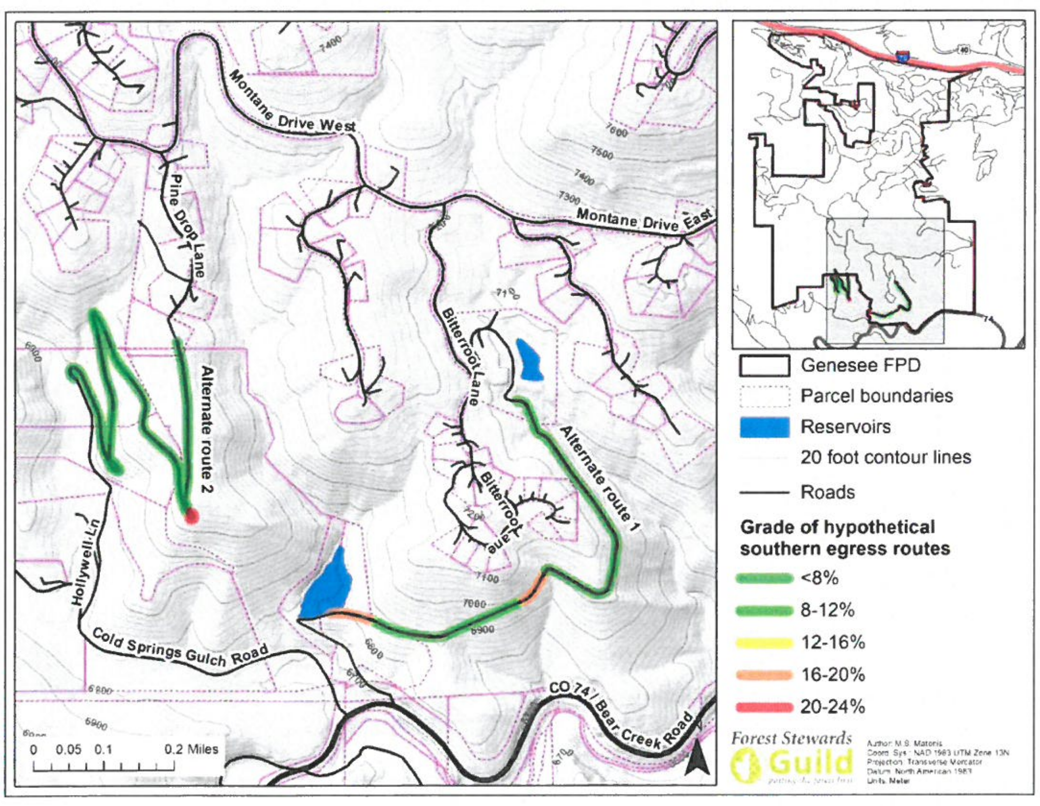


Figure B.3. Hypothetical southern egress routes for the Genesee Fire Protection District.

Designated Areas for Wildfire Evacuation Emergencies

We followed the approach of Campbell and others (2017) to delineate potential designated areas for wildfire evacuation emergencies using LiDAR data. Areas considered for potential locations met the following criteria: (1) non-forested, (2) slopes less than 15%, (3) not on roadways, and (4) within 1/8th mile of roadways. We located individual trees within 30 meters of the edge of potential areas because 30 meters is the threshold we used for radiant heat exposure (Beverly and others 2010). We buffered each tree by its safe separation distance, calculated as 8 * Δ * tree height, where Δ is the wind and slope adjustment factor (Butler 2019; Table 5e.1). The buffer zone around each tree can be thought of as an unsafe zone due to potential radiant and convective heat that would be emitted were that tree to burn during a wildfire. We overlaid the buffered areas around all trees and calculated the number of overlapping "unsafe zones" within each 5 m x 5 m area in potential designated areas for wildfire evacuation emergencies.

Our rating of the relative suitability of designated areas is based on the number of trees with unsafe zones intersecting that location as follows:

- Suitable locations are far enough from all trees.
- Almost suitable locations are overlapped by the unsafe zone of 1 to 10 trees.
- Unsuitable locations are overlapped by the unsafe zone of 11 to 25 trees.
- Very unsuitable locations are overlapped by the unsafe zone of 26 to 100 trees.
- Extremely unsuitable locations are overlapped by the unsafe zone of over 100 trees.

Fuel Treatment Prioritization

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 B.4). 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.

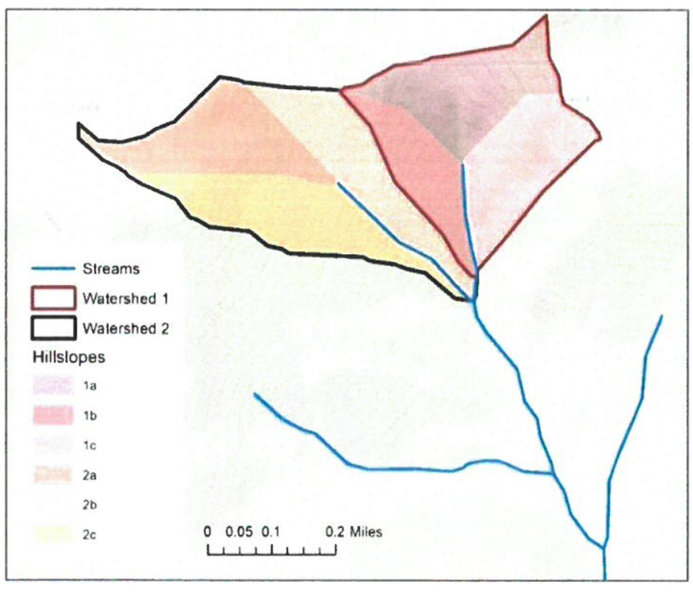


Figure B.4. Depiction of small watersheds and their subdivided hillslopes.

We used 30 m resolution digital elevation models from the U.S. Geological Service, and delineated hillslopes with a critical source area of 12.3 acres (5 hectares) and a minimum source channel length of 330 feet (100 meters), as recommended by Elliot et al. (2016). 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 identified the portions of hillslopes with canopy cover greater than 30% to create forest stands. Areas that were less than 4 acres in size were combined with the largest adjacent stand to result in forest stands ranging in size from 4 to 172 acres—reasonable sizes for forest management projects in the WUI.

We limited prioritization to forest stands containing at least 3.5 acres predicted for active crown fire under 90th percentile fire weather conditions. We developed a prioritization scheme to weight potential treatment units based on predicted fire behavior under 90th percentile fire weather conditions, homes potentially exposed to short-range spotting from the unit, presence of priority roadway treatments, occurrence of previous treatments, and percent slope within the unit (Table B.3).

Some forest stands have high risk of crown fire but are extremely steep and far from roads, and therefore inaccessible to forestry equipment. According to Hunter and others (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 assigned a lower priority to areas that experienced previous treatments in the past 10 years since fuel loads are probably lower in these locations than untreated areas. Based on the distribution of final prioritization scores, we classified units with a value greater than or equal to 33 as first-priority treatments, between 26 to 32 as second-priority treatments, and less than or equal to 25 as third-priority treatments.

We prioritized roadside treatments based on non-survivable conditions (predicted flame lengths >8 feet) under 90th and 97th percentile fire weather conditions and road segments that could become evacuation pinch points (congestion ratio > 5) under a district-wide evacuation order. Areas with non-survivable conditions under 90th percentile fire weather are at greater risk than those with conditions that only become non-survivable under 97th percentile weather because the surrounding vegetation can produce long flame lengths even under less severe (and less uncommon) fire weather conditions. We prioritized treatments following the scheme presented in Table B.4.

Table B.3. Prioritization scheme for ranking potential treatment units to mitigate fire hazards within and adjacent to the GFPD. Fire behavior predictions and number of homes exposed to short-range spotting were weighted higher than the other three prioritization categories.

Prioritization category	First priority (value of 10)	Second priority (value of 5)	Third priority (value of 0)
Percent active crown fire (90th percentile fire weather)	>75% of area	25-75% of area	<25% of area
Average conditional burn probability (90th percentile fire weather and winds out of the west-southwest)	>4%	2-4%	<2%
Number of homes exposed to short-range spotting from unit (90th percentile fire weather)	>20 homes	1-20 homes	0 homes
Prioritization category	**First priority (value of 5)**	**Second priority (value of 3)**	**Third priority (value of 0)**
Contains priority roadways	1st or 2nd priority roadways	3rd priority roadways	None
Percent treated from 2010-2019	<10% of area	10-50% of area	>50% of area
Percent inoperable (slopes >50%)	<10% of area	10-33% of area	>33% of area

Table B.4. Prioritization scheme for ranking potential roadside treatments to mitigate fire hazards along roadways.

Prioritization category	First priority	Second priority	Third priority
Non-survivable conditions (flame lengths >8 feet) under 90th percentile fire weather conditions	✓	✓	
Non-survivable conditions (flame lengths >8 feet) under 97th percentile fire weather conditions	✓	✓	✓
Evacuation pinch points (congestion ratio >5)	✓		

APPENDIX C. ADDITIONAL FIRE BEHAVIOR PREDICTIONS

We modeled wildfire behavior for the GFPD under 60th, 90th, and 97th percentile fire weather conditions (Table 3b.1). Throughout the CWPP we focus on fire behavior predictions under severe fire weather, the 90th and 97th percentile conditions, because these conditions cause the most concern for large fire growth and risks to lives and property. Here we present fire behavior predictions under 60th percentile fire weather conditions for comparison.

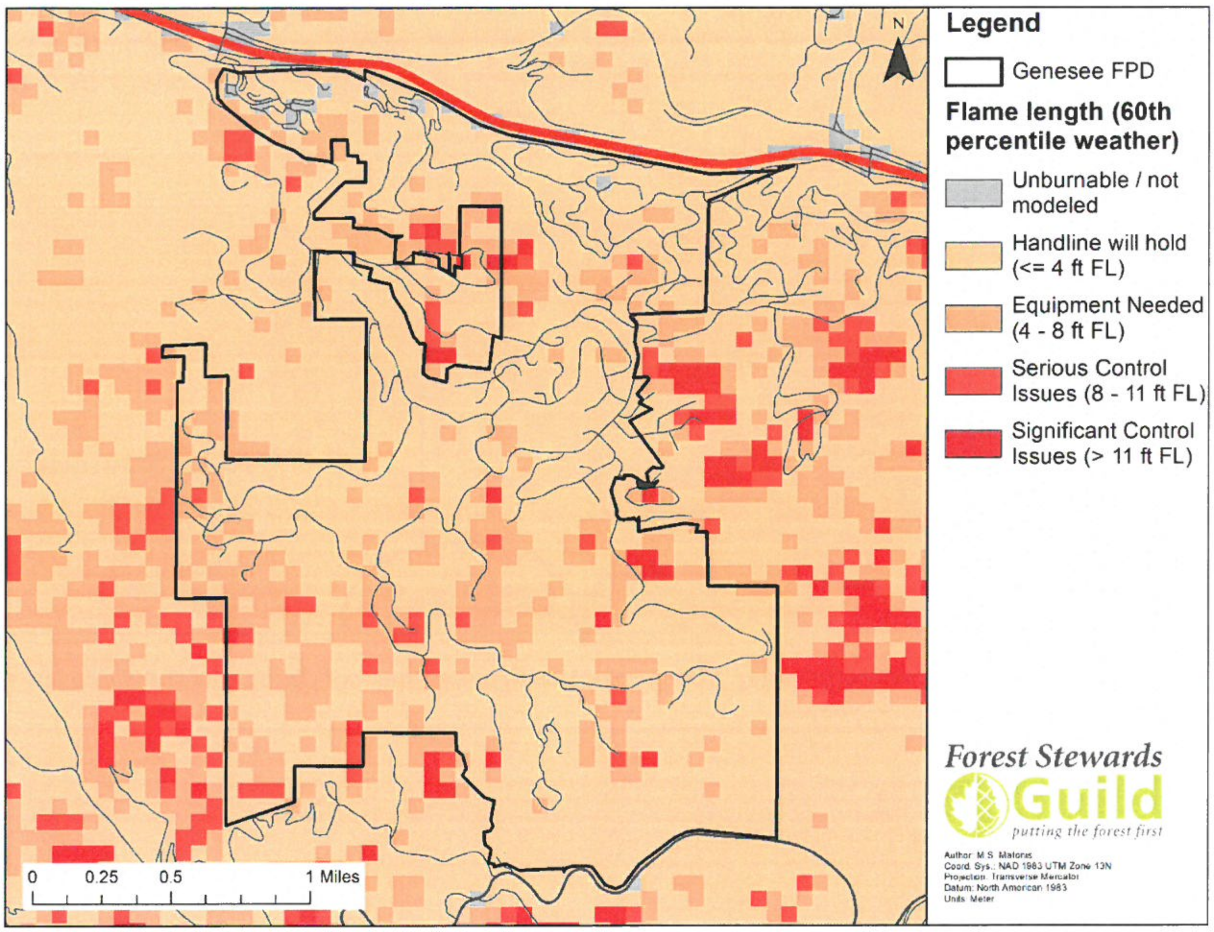


Figure C.1. Flame lengths in the Genesee Fire Protection District under 60th percentile fire weather conditions, categorized by the Haul Chart (Table 3b.2).

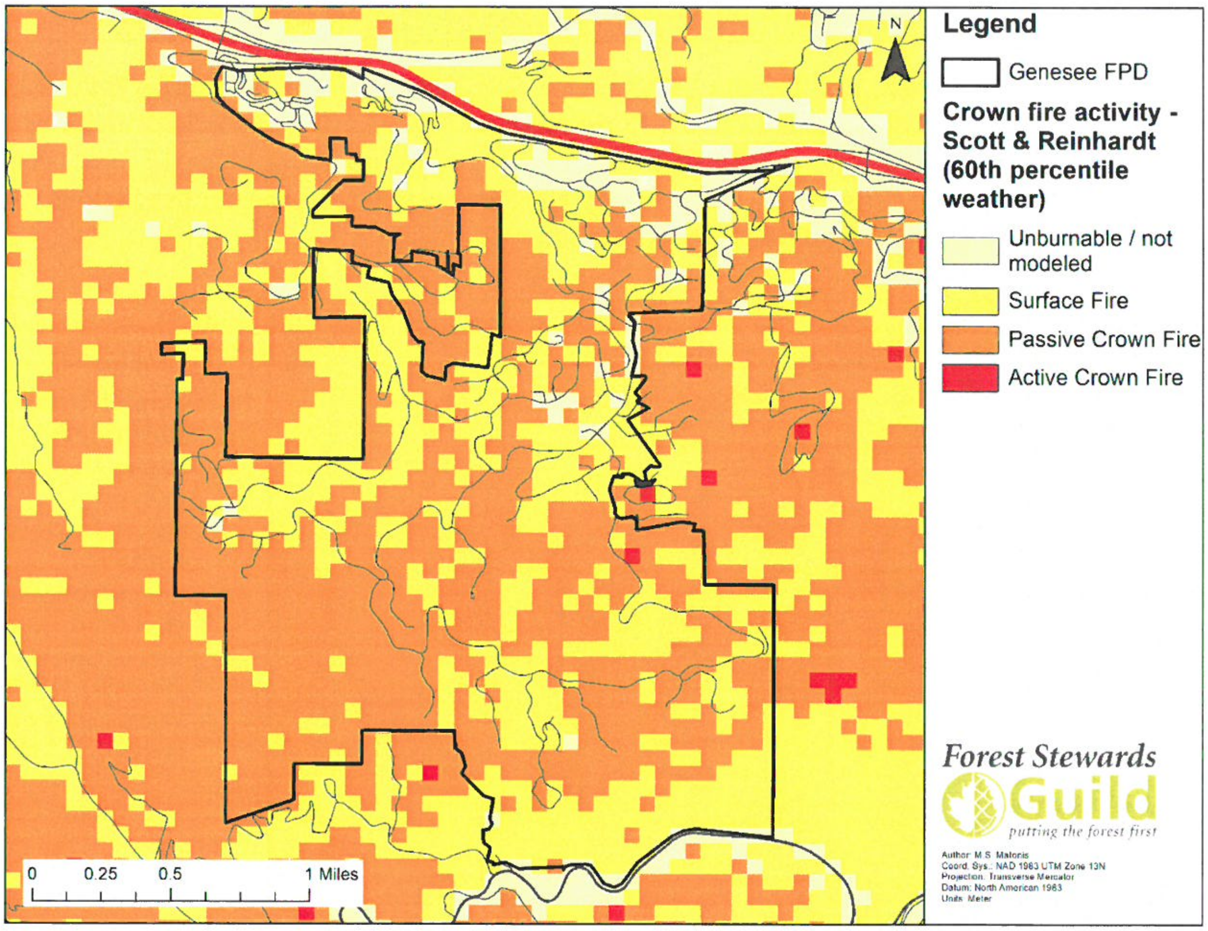


Figure C.2. Crown fire activity under 60th percentile fire weather conditions in the Genesee Fire Protection District.

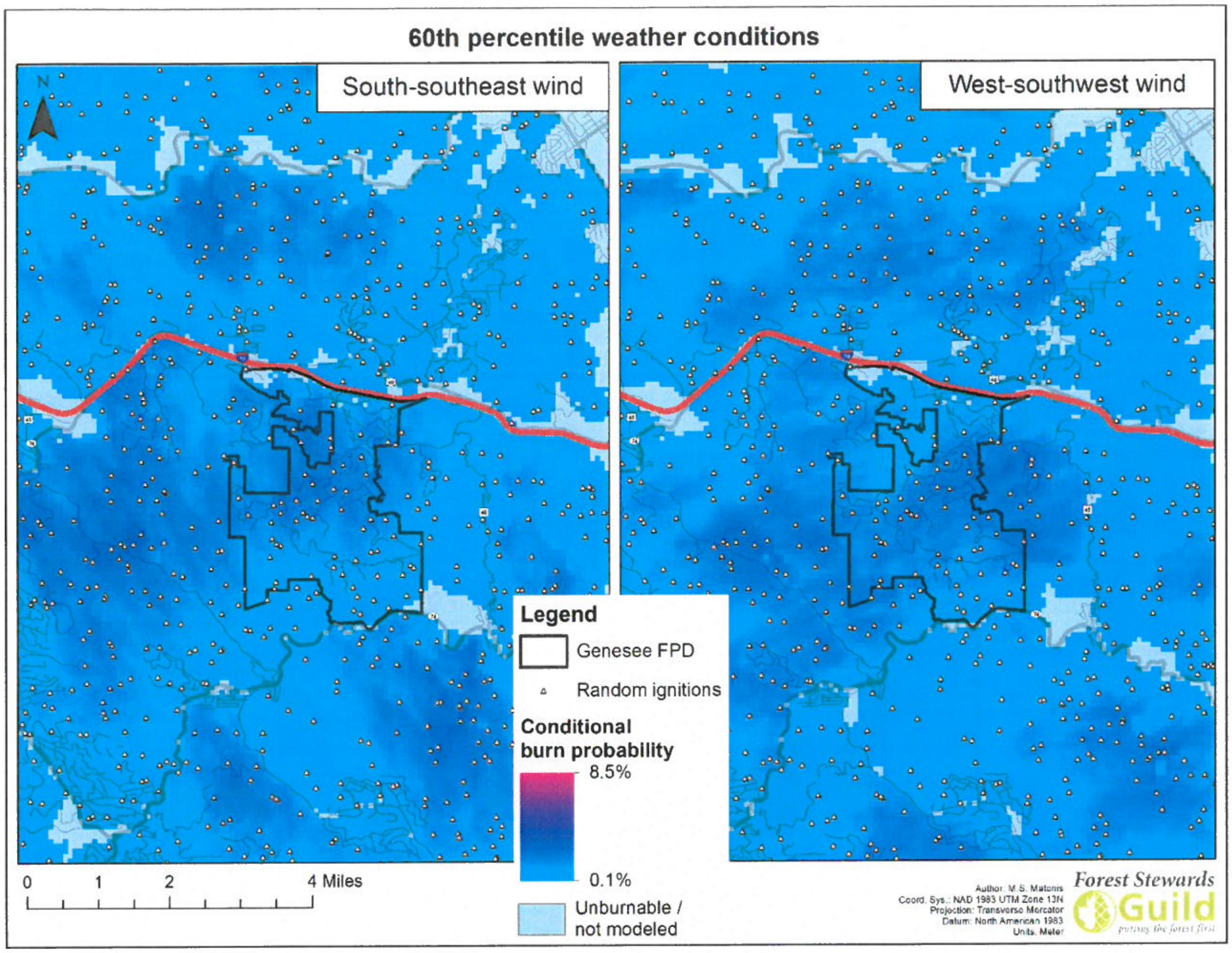


Figure C.3. Conditional burn probability under 60th percentile fire weather conditions. Wildfire spread was simulated for 4-hours without suppression activities from 1,000 random ignition locations across an area 20 times larger than and centered on the GFPD.

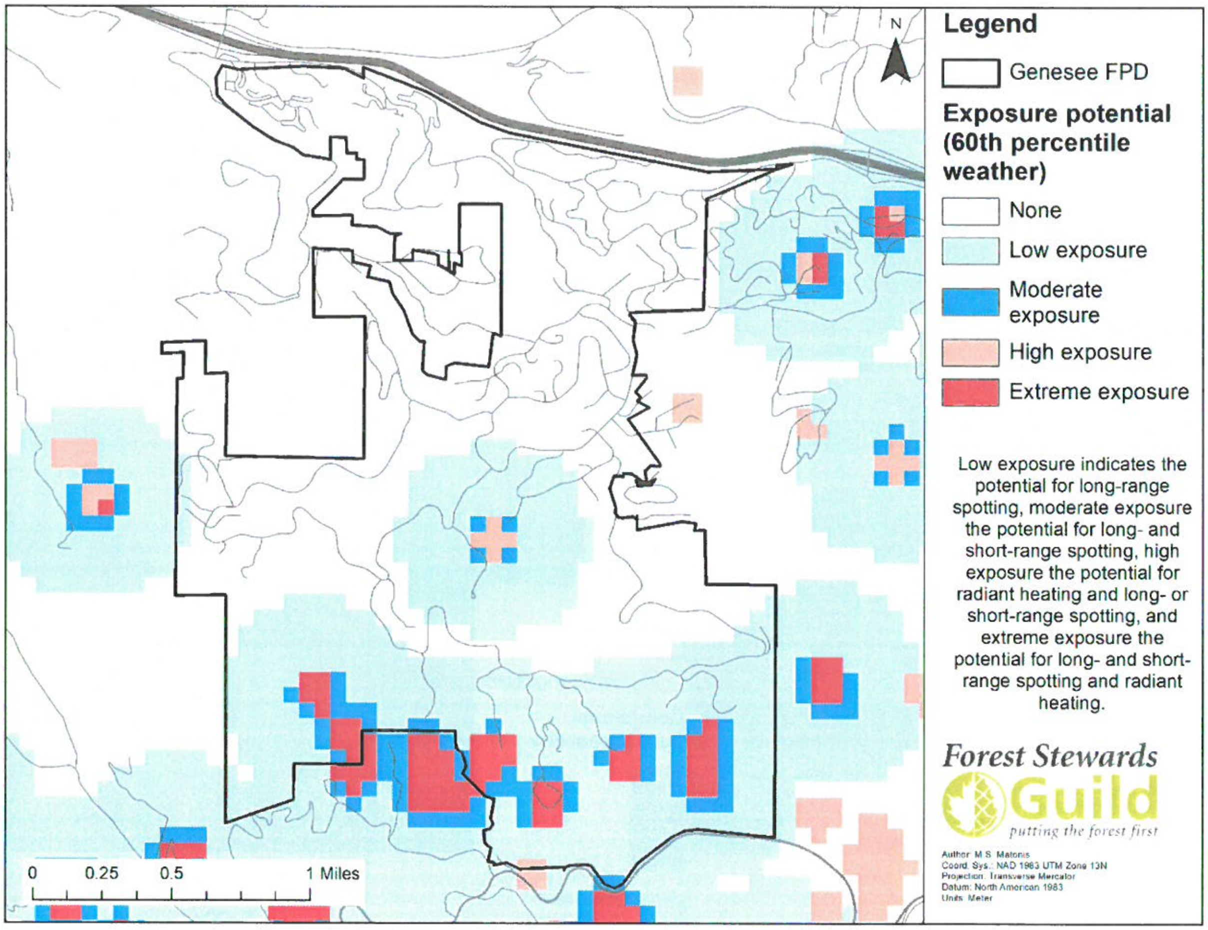


Figure C.4. Exposure to short-and-long range embers and radiant heat under 60th percentile fire weather conditions in the Genesee Fire Protection District.

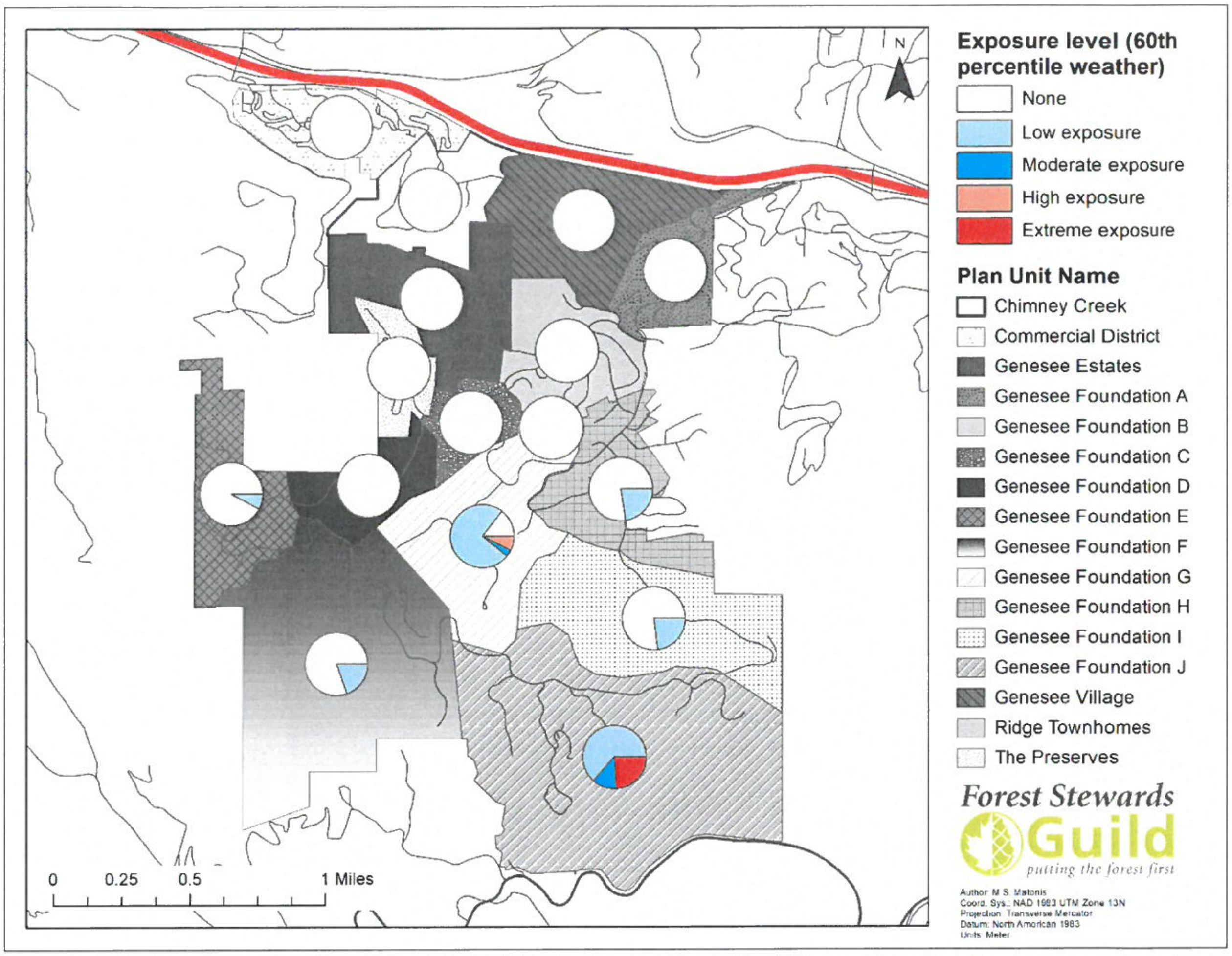


Figure C.5. Percentage of homes within CWPP plan units with different levels of exposure to embers and radiant heat under 60th percentile fire weather conditions. In most plan units, no structures had exposure to radiant heat or short- and long-range spotting under more mild fire weather conditions.

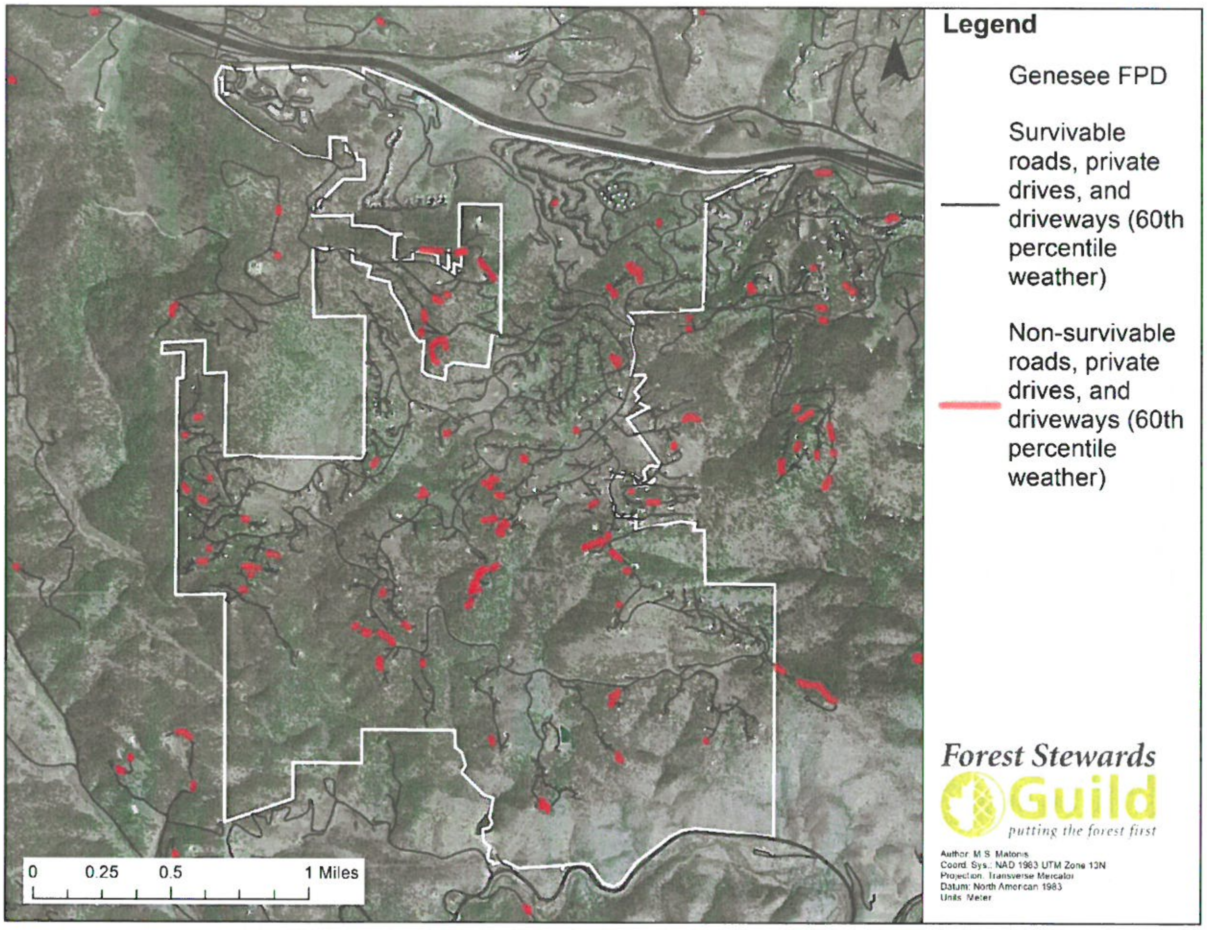


Figure C.6. Under 60th percentile fire weather conditions, 4% of the 56 miles of roads, private drives, and driveways in the Genesee Fire Protection District could potentially experience non-survivable conditions during wildfires (i.e., flame lengths over 8 feet).

APPENDIX D. PLAN UNIT HAZARD ASSESSMENTS

We assessed hazards in four categories across Community Wildfire Protection Plan (CWPP) plan units (Figure 3a.1): fire risk, fire suppression challenges, evacuation hazards, and home ignition zone hazards. Our assessment was based on predictions of fire behavior, radiant heat and spotting potential, roadway survivability, and evacuation time, as well as an on-the-ground assessment of each plan unit using a modified version of the NFPA Wildfire Hazard Severity Form Checklist (NFPA 299 / 1144). We also utilized road data collected by Shandian Wildfire Consulting and Fire Whirl Services Inc. in 2009 for the GFPD.

A. Fire Risk	Points
1. Flame length[1]	
<4 feet	4
4-6 feet	8
>6 feet	12
2. Crown fire activity (unitless)[1]	
<1.4	4
1.4-1.7	8
>1.7	12
3. Conditional burn probability[1]	
<3%	4
3-3.5%	8
>3.5%	12
4. Additional risk factors	
Mid-slope homes	0 - 2
Homes on ridge tops	0 - 2
Saddles / ravines / chimneys within unit	0 - 4
Frequent lightning	0 - 2
Nearby railroads	0 - 2
Many campfires	0 - 2
Frequent ag / debris / wood stove burning	0 - 2
Utilities (gas / electric) placement	
All underground	0
Mixed	3
All aboveground	5
A. Total points possible	**57**

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

B. Fire Suppression Challenges	Points
1. Hydrants	
Hydrants available near homes	0
Mixed	5
No hydrants available	10
2. Estimated response time[2]	
<10 minutes	0
≥10 minutes	2
3. Distance to dip site / draft water[3]	
<1 mile	0
≥1 mile	2
4. Private drive and driveway width	
<25% less than 20 feet wide	0
25-75% less than 20 feet wide	3
>75% less than 20 feet wide	5
5. Private drive and driveway length	
<40% over 300 feet long	0
≥40% over 300 feet long	2
6. Turnarounds absent (% roads/driveways)	
<20% of roads/private drives/driveways	0
20-50% of roads/private drives/driveways	3
>50% of roads/private drives/driveways	5
7. All-season road condition (main roads)	
Surfaced, grade ≤5%	0
Surfaced, grade >5%	1
Non-surfaced, grade ≤5%	1
Non-surfaced, grade >5%	3
Other than all-season	4
8. Street signs	
Present (4 in. in size and reflectorized)	0
Mixed	3
Absent	5
B. Total points possible	**35**

[2] Time to drive from the GFR fire station to the center of the plan unit along the shortest possible route.

[3] Distance from plan unit centroid to nearest dip site as the crow flies

C. Evacuation Hazards	Points
1. Mean household evacuation time[4]	
<60 minutes	0
60-119 minutes	2
120-179 minutes	5
180-239 minutes	10
>=240 minutes	15
2. Non-survivable roads—90th percentile conditions	
<2%	0
2-10%	2
11-20%	4
>20%	5
C. Total points possible	**20**

[4] Estimates from ArcCASPER assuming 2 vehicles departing per residency and all addresses within the Fire Protection District receiving simultaneous evacuation notices.

D. Home Ignition Zone Hazards	Points
1. Roof construction material	
Class A roof (metal, tile)	0
Class B roof (composite)	3
Class C roof (wood shingle)	15
Non-rated	25
2. Siding / deck	
Noncombustible siding/ deck	0
Mixed	5
Combustible siding and deck	10
3. Radius of defensible space around buildings	
>100 feet	1
71 -100 feet	3
51 -70 feet	7
30-50 feet	10
<30 feet	15
4. Wooden fences	
Not present	0
Present but uncommon	1
Relatively common	2
D. Total points possible	**52**

Hazard Rating Scale

We developed a rating scale specifically for the Genesee Fire Protection District (GFPD) based on the range of values observed across the community (Table D.1). The purpose of the assessment is to compare relative hazards within the community and is not suitable for comparing the GFPD to other communities.

Table D.1. Scale to assign relative hazard ratings (low, moderate, high, and extreme) to plan units in the Genesee Fire Protection District.

	Points			Relative hazard rating			
Hazard category	**Max. possible**	**Min. in GFPD**	**Max. in GFPD**	**Low**	**Moderate**	**High**	**Extreme**
A. Fire risk	57	16	44	<20	20-29	30-39	≥40
B. Fire suppression challenges	35	3	22	<5	5-9	10-19	≥20
C. Evacuation hazards	20	5	20	<6	6-10	11-15	≥16
D. Home ignition zone hazards	52	5	25	<6	6-10	11-19	≥20
Overall risk	164	30	91	<50	50-69	70-79	≥80

SIGNATURES AND RECORD OF DISTRIBUTION

This Community Wildfire Protection Plan (CWPP) was developed in response to the Healthy Forest Restoration Act of 2003 and complies with CWPP standards set forth by the Colorado State Forest Service in 2009. The CWPP is a collaborative effort to guide our wildfire protection. Where possible, we intend to apply the recommended practices to improve our community and increase public safety.

This CWPP is a voluntary, recommended plan and imposes no obligations of the signatories. Executing this document in no way obligates the Genesee Fire Protection District to take any action requiring the commitment of funds to accomplish the recommendations presented herein.

The following individuals and organizations were engaged in developing the Genesee Fire Protection District CWPP and approve the 2020 update:

	Date		Date
Jason Puffett, Chief Genesee Fire Rescue	7/6/21	Ryan Babcock, Training Chief Genesee Fire Rescue	7/14/21
Dorie Dalton, Wildland Specialist Genesee Fire Rescue	7/6/21	Nancy Balter, Secretary GFPD Board of Directors	7/6/21
Scott Mefford, President GFPD Board of Directors	7/6/21	Jeff Shrader, Sheriff Jefferson County Sheriff's Office	7/6/21
Nate Beckman, Supervisory Forester Colorado State Forest Service	08/24/21		

RECORD OF DISTRIBUTION

- Hal Grieb, Jefferson County Sherriff's Office, Director of Emergency Management
- Kevin Michalak, Jefferson County Sherriff's Office, Fire Management Officer
- Andy Perri, Denver Mountain Parks, Program Manager
- Garrett Stephens, Jefferson Conservation District, Director
- Steve Murdock, Jefferson County Open Space, NR Team Lead
- Brian Maillett, Genesee Foundation, Open Space Manager