# Application of Wildfire Mitigation to Insured Property Exposure

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# Executive Summary

The recent wildfires across the Western U.S. have created an insurance crisis across several states. Homeowners are facing non-renewals or significantly increasing insurance premium rates, issues that put pressure on State Departments of Insurance and other state policymakers to act. Research by renowned organizations such as the *Insurance Institute for Building and Home Safety* (IBHS) and community mitigation programs such as *National Fire Protection Association's* (NFPA) *Firewise USA® Program* provide guidance on how to create more wildfire resilient communities. However, what is relatively unknown is whether these risk reduction actions are economically worth the effort and cost? Or which features are the most important from a relative investment return perspective?

Catastrophe modeling allows for a probabilistic assessment of wildfire risk, examining key location and community level attributes to determine potential insured property losses. These models calculate risk by looking at a range of factors such as topography, distance to vegetation, slope, and other location-specific information including roof system covering, roof vents, suppression, and accessibility conditions. Critically then, catastrophe models can reflect structure-specific and community level mitigation in loss estimates. This study is designed to demonstrate that learnings from building science research can be reflected in a catastrophe model framework in order to proactively inform decision-making around the reduction of wildfire risk for residential homeowners in wildfire zones.

To quantify the benefits of certain wildfire mitigation features, this study uses the *RMS North America Wildfire Model* to quantify hypothetical loss reduction benefits in nine communities across three Western States: California, Colorado, and Oregon. The simulated reduction in losses are compared to the costs of implementing associated mitigation measures. A straightforward benefit-cost methodology is applied to assess the economic effectiveness of the two overall mitigation strategies modeled – structural mitigation, and vegetation management.

We find that there are opportunities to significantly reduce this risk with the two stated mitigation strategies. Firstly, we show that structural modifications can reduce wildfire risk up to 40%, and structural and vegetation modifications combined can reduce wildfire risk up to 75% when simply moving to a well-built wildfire-resistant structure from a neutral property setting. Moreover, we determine that the losses avoided can be even more significant (e.g. 5 times greater) when compared to a highly flammable structure.

From a benefit-cost perspective, we demonstrate that for a number of the modelled locations, the relative risk reduction, if enabled within insurance products based on wildfire risk-based pricing, would provide economically effective incentives at promoting mitigation with pay-back periods from 10 to 25 years.

This study also concludes that the identification of locations where viable economic incentives are effective is complex, and will require insurance companies to invest in location specific data and new pricing approaches that leverage probabilistic methodologies that also incorporate risk reduction strategies as we have done here.

Finally, the authors emphasize that this study is an illustrative, foundational effort and further detailed research is necessary to illustrate specifically where and how economically effective wildfire mitigation could be applied in the context of insured property exposures. On its own, this study is neither comprehensive nor sufficient to create regulatory policy on this topic. Nonetheless, there is a definite and growing need for the type of analysis we have performed here to help to guide the implementation of wildfire risk reduction actions and to inform the policy discussion for how to make this happen in an economically efficient manner.

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# The Case for Wildfire Mitigation – A Catastrophe Model Application

For homeowners in wildfire prone areas of the United States, as the underlying wildfire risk continues to increase, there are exacerbating pressures on the affordability and availability of homeowner's insurance. As evidence of this insurance dynamic in California, 2019 saw a 31 percent increase in non-renewals by insurance companies state-wide as compared to 2018, with more significant non-renewal increases in higher risk areas in the state, up to 203 percent (CDI, 2020). And this data follows the recent trend since 2010 in California "that homeowners' insurance coverage in the wildland-urban interface (WUI) is increasingly difficult to obtain and, if available, is unaffordable to many that need it." (CDI, 2018. pg. 1). Relatedly, since 2015 California FAIR Plan policies – the state insurer of last resort – have increased by 35 percent state-wide with up to 803 percent increases in higher wildfire risk areas such as the Southern Sierra (CDI, 2020). Continued population and WUI expansion, coupled with increased weather and climate drivers, will continue to aggravate this insurance dynamic.

Decreasing the risk of loss is a direct and likely expedient way to increase the availability and affordability of homeowner's insurance in wildfire-at-risk areas. Mitigating wildfire risk can involve several activities including enhanced building codes; land-use planning; environmental regulation; enhanced infrastructure; adoption of wildfire sensors; fire resistant individual property modifications; and community wide abatement. Understanding the relative value of each of these mitigation measures is critical toward their implementation. In this report we focus specifically on quantifying wildfire avoided losses due to the implementation of individual property modifications and community wide abatement of wildfire risk. By combining the determined avoided losses with costs to implement these activities we can determine the economic efficiency of property and community wildfire mitigation efforts.

Historically wildfire risk scores have been used by insurers to decide whether to renew or write new insurance policies in the WUI. However, they do not consider home & community mitigation efforts (Commission on Catastrophic Wildfire Cost & Recovery, 2018). However, catastrophe (CAT) models have the ability to reflect structure-specific and community level mitigation. Accordingly, we take a CAT modeling approach to quantify the benefits and costs of individual & community wide wildfire mitigation.

We use the *RMS North America Wildfire HD Model* applied to 1,161 individual structures in 9 community locations in the states of California, Oregon, and Colorado. The RMS wildfire model accounts for the latest wildfire mitigation science regarding structural and surrounding ignition zone modifications that can be made to a property and we utilize the modeling framework to quantify their impacts.

With these impacts quantified, a benefit-cost analysis has been completed to show how under some circumstances, wildfire mitigation is not only possible but economically feasible.

# Wildfire Mitigation – Individual and Community Best Practices

The building science behind wildfire mitigation has been an active area of research for several decades. There are many mitigation programs developed and proposed in various areas. At the national level, the most prominent recommendations come from the collaboration between the Insurance Institute for Business and Home Safety (IBHS) and the National Fire Protection Association's (NFPA) Firewise USA® Program.

The following sections describe the physical attributes of homeowner wildfire risk identified by IBHS and the voluntary educational Firewise USA program designed to bring these techniques to the public.

## Insurance Institute for Business and Home Safety (IBHS)

There are three main sources of ignition for structures stemming from the wildfire hazard:

- i) direct — flame in direct contact with a structure or accumulated embers on a structure;
- ii) indirect — flying embers ignite materials close to a home; and
- iii) radiant heat — heat from the fire causes materials to ignite.

A house, its roof, and its surroundings can be configured to defend against these three sources of ignition and hence the ways that a wildfire can attack a structure. By bringing the current state of science to bear, IBHS has identified eight critical parts of a home and its surroundings.

- Fuel management – Defensible space, combustibles around a home (home ignition zone)
- Fences
- Decks
- Building shape
- Walls
- Roofs
- Roof vents
- Eaves & overhangs

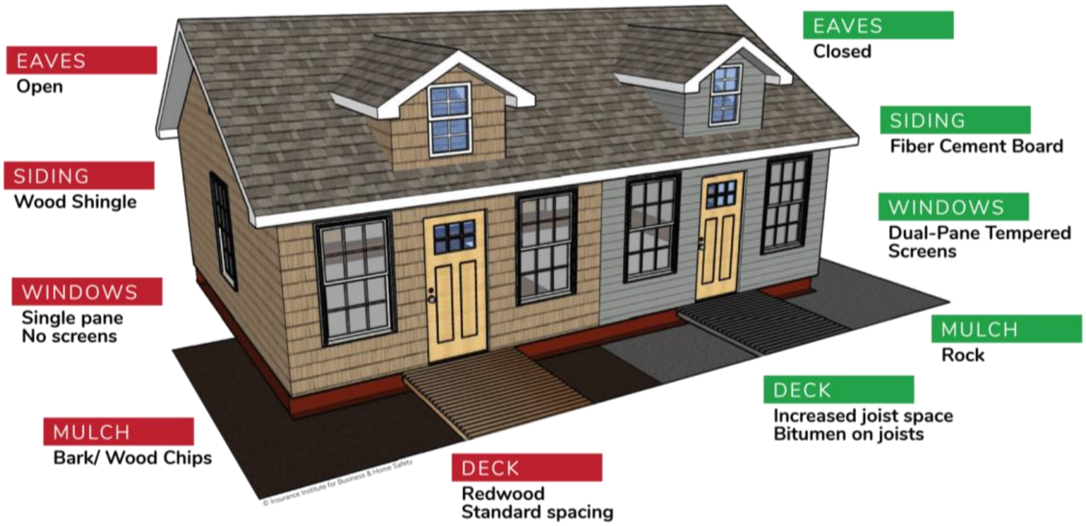
The vulnerability of a home or business can be reduced by adapting to the threat of wildfire for each of these eight components through making better material and building choices for each.

From these eight, the most critical actions for wildfire protection are **the roof, the defensible space/home ignition zone, decks, and vents.** This is the starting line for homeowners to reduce their risk and increase the chances for a home to survive should a wildfire threaten. This set of actions must be addressed and maintained before any other steps can have a meaningful impact.

- ROOF: A noncombustible roof covering and assembly is the first line of defense against ember attack during a wildfire. The roof material must have a fire rating from the Underwriters Laboratories testing program (Class A, B, and C). IBHS encourages homeowners to use a product or full roofing assembly that has a Class A rating when re-roofing. Nearly all asphalt shingles currently on the market have a stand-alone Class A rating. Approximately 75% of homes in the United States have asphalt shingle roofs.
- HOME IGNITION ZONE: This is the five- foot area extending outward from a home, sometimes referred to as the noncombustible zone[1]. The area is essential to stopping fire from spreading to a structure and stopping embers from igniting anything that may be immediately next to a home. The best practice is to avoid anything that can burn, but when used with gravel or rock ground cover/mulch, fire-resistant plants can help slow fire from spreading or reduce the intensity of fire in this area. Diligent maintenance of this area is vital
- DECKS: Decks are a common feature of suburban homes but unfortunately can be a vulnerable element that allows intense fire to spread quickly to a home. It is critical to keep areas underneath elevated decks clear of yard debris, firewood, and anything else that could ignite. Research has shown that fire can become very intense if the deck ignites and can easily spread toward the home. This also exposes the home not only to extreme heat, but also direct flame contact and burning embers from the deck itself. This area must also be vigilantly maintained for it to be effective.
- VENTS: Roof vents, gable vents, and crawl space vents are small but critical pieces of a home. During wildfires, wind-driven embers can easily enter a home though vents and ignite materials. A simple and cost-effective mitigation strategy is to ensure all vents have 1/8th inch or finer noncombustible (i.e. metal) mesh covering them. This will keep the larger, more energetic embers from entering. While maintenance is needed to keep vents clear of any debris, this is an easy but critical step in combating an ember storm

[1] [1] We note that NFPA defines the home ignition zone as the home itself and everything around it within 100 to 200 feet. NFPA has recently broken out the home ignition zone into sub-zones – the immediate zone is the five foot area; intermediate is 5-30 feet; extended zone is 30-100 feet (or more).

**Figure 1: Comparison of Good (Green) and Bad (Red) House features to reduce Wildfire risk.**




Source: IBHS

The wildfires of 2017–2018 across California were a stark reminder of what can happen when the ingredients for significant wildfires come together. There remains no better example of the damaging and deadly potential of wildfire than the Camp Fire of 2018. The 2017 and 2018 wildfires caused over $33 billion in losses and put damages on par with those from landfalling hurricanes and severe storms. IBHS analysed post-event data collected by CalFire from the fires of 2017-2018 to determine what factors are most critical to the damage level to the building. Looking at three important fires including Atlas, Thomas, and Tubbs, the five building and surrounding home features with the most relative importance were:

- Topography
- Vegetative clearance (i.e. defensible space)
- Roof material
- Siding material
- Vents / screens.

However, from these five factors, IBHS scientists found that only topography and defensible space were consistent predictors of home damage level. Other attributes of a home and its property varied in their level of importance from fire to fire. This suggests the need for a system of mitigation steps to be taken to protect a home.

And although defensible space was an important characteristic of homes that survived, well-maintained defensible space did not guarantee survivability in this fire. It was clear in some instances that rapid fire spread, under ideal conditions, defeated even well-maintained defensible space. Furthermore, some actions cannot be effectively applied in suburban communities because homes are closely spaced, or landscape designs have not historically considered the threat from wildfires.

In addition to steps property owners can take to protect their homes, actions at the neighborhood and community level can improve resilience for everyone. Because of the way wildfires spread, in some cases, a neighbor's actions or inactions could determine whether surrounding homes survive. In a closely spaced suburban environment, maintaining good defensible space must be a community-wide effort. Actions taken by neighbors are just as important as those taken by an individual property owner.

Homeowners associations (HOAs) also can play a large role in helping scale-up mitigation protections for individual homes. HOAs can develop and enforce architectural rules that are in alignment with the steps necessary to reduce the neighbourhood's vulnerability to fire, or less formally, provide forums for homeowners to share best practices. In addition, enforcement of maintenance practices is often easier at the small community scale. However, HOAs can also be a hindrance by restricting the use of building materials and landscaping that may be more fire resistant. Homeowners should be encouraged to share best-practices with their associations and explore serving on neighborhood boards. These actions at the community scale can also help reduce the need for firefighter intervention and allow these critical resources to be focused on containing a potential catastrophic wildfire.

## National Fire Protection Association (NFPA) Firewise USA® Program

Initiatives such as NFPA's Firewise USA recognition program help strengthen the survivability of homes and neighbourhoods with hands-on efforts to reduce ignition risks and maintain buildings and landscapes with fire in mind. It is a voluntary program that provides a framework to help neighbours get organized, find direction, and act to increase the ignition resistance of their homes and community. The focus of this program is showing how we can stop the transition from the wildland fire to the W/UI fire and create ignition-resistant communities.

When individual homes ignite or a single wildland ignition occurs, local fire agencies' standard operating procedures (SOPs) are very effective. The success rate in containing these ignitions is routinely in the 98%-99% range. When ignitions occur in dense fuels (whether structural or vegetative) during periods of severe fire conditions, numerous homes may become involved. Rapidly spreading fire cannot be stopped and our suppression efforts are dramatically reduced. The world sees the resulting "wildland/urban fire disaster" on the evening news.

Standard fire suppression operations are largely ineffective against the most severe wildland fire behavior, driven by high winds and producing huge flames, along with intense heat and showering firebrands. The effectiveness of well-equipped fire departments is hampered to perform even the simplest task, like placing a hose stream on a flaming house. Often, during these situations fire fighters must "fall back" to implement their own necessary life safety procedures. Stopping the transition of a fire from natural fuels to built fuels (i.e. buildings) significantly reduces the likelihood of a disaster.

The Firewise USA® Recognition program is administered by the non-profit National Fire Protection Association (NFPA) and is co-sponsored by the USDA Forest Service, the U.S. Department of the Interior, and the National Association of State Foresters.

NFPA, as a non-profit that reaches out to consumers and the fire service, has partnered with the USDA Forest Service since 1986 on cooperative agreements to help reach the public with wildfire safety information and knowledge to reduce losses to life and property from wildfire. Firewise USA® was developed in acknowledgement that private residents often lacked knowledge about how to prepare homes and neighbourhoods to resist wildfire ignition, and that the fire service and government agencies could not require activity on private property. The program seeks to educate residents to help them realize their ownership of the risk and provides a path for them to take practical, science-based steps to reducing their individual and collective risk.

Started in 2002, the original pilot had 12 sites, 9 of which are still active. As of October 2020, there are 1782 active sites in 42 states. 55 percent of all participating sites are in the top 5 states of California, Colorado, Oregon, Washington, and Arizona. There are several steps to achieving national recognition:

- Completing a written wildfire risk assessment is the first step in becoming a nationally recognized Firewise USA® site. The community wildfire risk assessment is typically completed with the assistance of state forestry staff, local fire department, or a designated partner.
- Form a board/committee comprised of residents and other applicable wildfire stakeholders. This group will collaborate on developing the site's risk reduction priorities and they will develop a multiyear action plan based on the assessment, along with overseeing the completion of the annual renewal requirements. The board or committee can involve just homeowners or sometimes local fire staff
- Action plans are a prioritized list of risk reduction projects developed by the participant's board/ committee for their site. Plans include recommended home ignition zone projects, educational activities, and other stakeholder outreach efforts that the site will strive to complete annually or over multiple years.
- At a minimum, each site is required to invest the equivalent value of one volunteer hour per dwelling unit in risk reduction actions annually. A wide range of qualifying actions and expenditures (contractor costs, rental equipment, resident activities, grants, etc.) comprise the overall investment totals.
- Applicants begin the overall process by creating a site profile at: www.portal.firewise.org. The application is eligible for submission when the overall criteria is completed. State liaisons (assigned from state forestry agencies) approve applications with final processing completed by the National Fire Protection Association (NFPA).

The community wildfire risk assessment is an important step in the Firewise USA® recognition process. It is a tool to help residents and their community members understand their wildfire risk and engage them in risk reduction efforts.

The community wildfire risk assessment methodology that NFPA recommends speaks to the general conditions of the overall Firewise USA® site and does not provide details on each individual dwelling. The assessment should focus on:

- Vulnerability of homes to embers, surface fire, and crown fire
- Condition of the structures themselves
- Immediate hazards within the Home Ignition Zone on individual properties
- Concerns presented by common/open space areas or adjacent public lands

The assessment also considers factors that impact risk and influence fire behavior or structure ignitability:

- Structural characteristics (such as roofing, siding, and decks)
- Vegetation types
- Slope and aspect (direction a community faces - north, south, east, or west)
- Housing density

The recommendations provided by the completed assessment will be the board/committee's primary tool in determining action priorities within the site's boundaries, documented in their action plan. The Firewise USA® program requires assessments be updated at a minimum of every five years, and action plans be updated every three years.

# Study Methodology

This study is a benefit-cost study based on notional risk assessments at sample communities in three states. The benefits of individual risk reduction are quantified using a catastrophe model which simulates millions of possible wildfire scenarios that could occur in the immediate future. The benefits are expressed as an average annual loss reduction. Costs associated with implementing one or more of the wildfire mitigation techniques in this study are referenced from published research studies. Finally, the benefit-cost ratio is developed by converting future loss reduction benefits into a present value and comparing them to mitigation costs.

This section describes the catastrophe model used in this study – the RMS North America Wildfire model - and the design of the study locations and mitigation scenarios investigated.

## RMS North America Wildfire HD Model

Recent catastrophe events have highlighted the need across the (re)insurance industry for a new generation of quantification tools for wildfire risk. To that end, the RMS North America Wildfire HD Models have been developed to enable effective underwriting, portfolio management, and risk transfer use cases across the industry.

The four basic components of a catastrophe model are: hazard, exposure, vulnerability, and loss as depicted in Figure 2:

**Figure 2: Basic Component of a Catastrophe Model.**


Catastrophe models use synthetic events representing thousands of years of potential events to create analytics that can be used by the insurance industry. First, the model determines the risk of the hazard phenomenon, which in the case of a wildfire is characterized by heat, ember, and smoke hazard components. Next, the model characterizes the exposure by determining how many properties are at risk from the wildfire heat, ember, and smoke hazards.

The vulnerability module then quantifies the physical impact of the wildfire hazard phenomenon on the exposure at risk. Vulnerability is typically characterized as a mean damage ratio given a hazard level. Based on this measure of vulnerability, the financial loss to the property exposure is evaluated. Direct financial losses include the cost to repair and/or replace a structure, and also the anticipated increase in cost of material and workforce due to the demand surge in the aftermath of a major disaster.

The simulated losses for each event are then passed to a financial module which allocates loses to various parties in the risk transfer process – homeowners, insurers, and re-insurers (if applicable).

More specifically, the *RMS North America Wildfire Models* includes ground-up and temporal simulations of building-level losses per coverage and sub-peril, and includes:

- A simulation-based framework that enables millions of realizations of wildfire losses across thousands of simulated years
- A probabilistic approach to model the ignition and spread of wildfires, in addition to their associated ember and smoke footprints
- High-resolution geospatial data to resolve the high-gradient nature of the peril due to topography, fuel (type of vegetation), and weather parameter variations
- Multi-parameter vulnerability distributions to enable greater risk differentiation and reflect the behavior of wildfire claims in a realistic manner
- Flexible financial modeling to handle diverse temporal (hours clause) and spatial (distance clause) policy terms

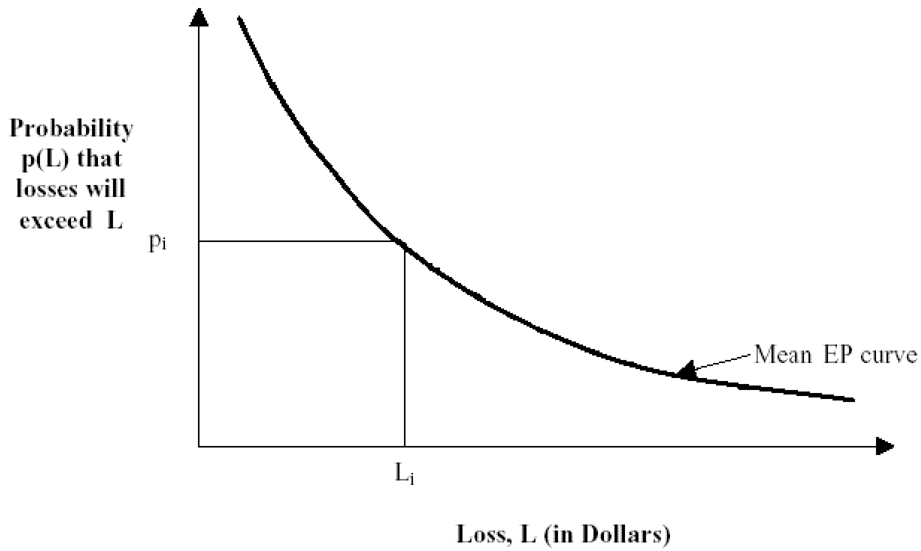
RMS derived the methodologies used in developing the wildfire model components in collaboration with researchers and experts in different areas of specialty including historical fire incidents datasets, fire occurrence modeling, fire spread, and damage mitigation. The model includes a comprehensive range of stochastic wildfire events, accounting for fire, ember, and smoke risk, over a wide geographic extent, at high resolution. The wildfire vulnerability module supports a comprehensive range of risk classes, which were calibrated using extensive claims data. In addition, the financial options enable users to explore sensitivity of loss results to various modeling assumptions.

## Cat Model Ouptut: Exceedance Probability and Average Annual Loss

The stochastic event sent from the model can be sorted in such a way as to create an exceedance probability (EP) curve. This curve provides the probability of surpassing any loss level, expressing this probability in the form of a return period. Return periods are calculated by sorting the occurrence and yearly losses to create occurrence (OEP) and aggregate (AEP) curves, respectively. These curves are often used to look up key return period losses, such as 1 in 100 or 1 in 250, to help with solvency, rating agency evaluation, and reinsurance purchasing decisions.

For a given portfolio or structure at risk, an EP curve is a graphical representation of the probability $p$ that a certain level of loss $X will be surpassed. The x-axis measures the loss in dollars and the y-axis depicts the annual probability that losses will exceed a particular level. Figure 3 depicts a hypothetical mean EP curve where for a specific loss $L_i$, the likelihood that losses will exceed $L_i$ is given by $p_i$.

**Figure 3: Example of Mean Exceedance Probability Curve**




(Source: Czajkowski et al., 2012)

The overall expected loss for the entire set of events, denoted as the average annual loss (AAL) is the sum of the expected losses of each of the individual events for a given year. The AAL is calculated by summing the product of each event loss and its corresponding frequency for all events in the stochastic set (here we model 50,000 events) for any specific location/building, account, or portfolio. It is graphically represented as the area underneath the EP curve.

Average Annual Loss (AAL), the averaging of all potential yearly losses into one average number, is one of the most frequently used outputs of the model. The AAL is calculated by summing the product of each event loss and its corresponding frequency for all events in the stochastic set for any specific location/building, account, or portfolio.

Risk reduction measures typically decrease the vulnerability and therefore reduce the expected loss. Graphically, mitigation shifts the EP curve down and to the left and therefore reduces the AAL value (i.e. decreases the area under the curve) as depicted in Figure 4.

Consequently, we express the benefits to mitigation in terms of average annual losses and loss cost – a normalized loss metric, which is defined as the average annual loss per $1000 of coverage (i.e., AAL / Total Insured Value x $1000).

For the three site locations in each state we first present the AAL from a neutral setting where there is no mitigation credit or penalty accounted for (to be describe below), and then represent the benefits to mitigation – structural and vegetation – as differences from this initial neutral AAL perspective.

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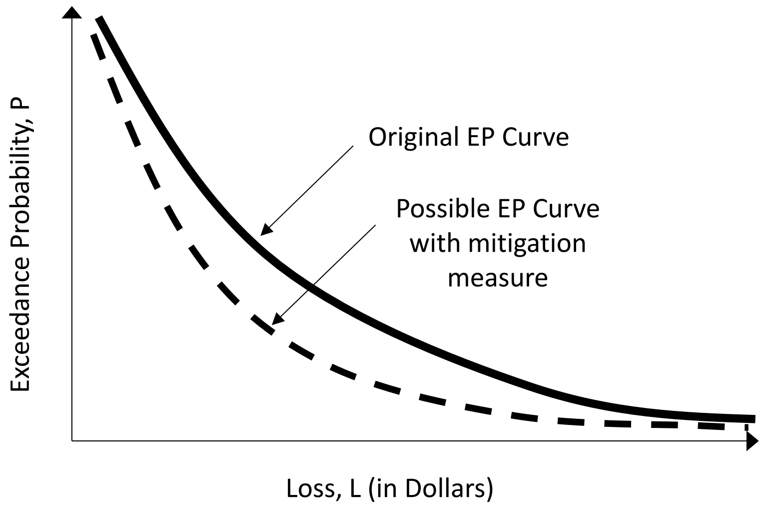
**Figure 4: Exceedance Probability (EP) curve showing potential benefits of disaster risk reduction**




## Vulnerability and Structure Secondary Modifiers

As presented in the earlier section on wildfire mitigation best practices, recent work in the building science disciplines have shown that the factors most critical to the survivability of a structure include the site hazard parameters that affect localized hazard intensity as well as the various structural characteristics of the home such as roofing, siding, and decks. These wildfire mitigation aspects can be accounted for – their value and/or presence/lack of presence – in the RMS wildfire model hazard, exposure, and ultimately vulnerability components through exposure secondary modifier and site hazard data as we describe below.

The RMS North America Wildfire HD Models express damage to insured properties through vulnerability functions, also known as vulnerability curves or damage curves. Wildfire vulnerability functions consider the combined effect of probability of ignition to a structure when faced with radiant heat, flames, and embers, as well as the conditional damage once a structure is ignited. The model includes separate vulnerability functions for each hazard (i.e., direct flame and radiant heat, embers, and smoke). The model combines damage ratios for heat and ember to output the fire risk for every location. For analyses that include fire and smoke, the model combines damage from both sub-perils to determine the overall damage for each individual coverage (structure, contents, or business interruption).

An important aspect of modeling wildfire losses is recognizing that there is a possibility of structures surviving *within* the fire footprint as shown in Figure 5. Finding ways to increase the likelihood of survival is the whole point of adopting mitigation measures.

**Figure 5: Example of Partially Damaged Structure following Wildfire**

In the RMS North America Wildfire HD Models, damage curves for heat, ember and smoke represent the average vulnerability of a class of buildings for a specific combination of primary characteristics. The vulnerability of any individual building relative to others in that group depends on site-specific details as well as localized wildfire characteristics that can significantly alter the ignition probability as well as conditional damage. Users can model this variation in expected performance of individual buildings using secondary modifiers.

The North America Wildfire HD Models support 15 wildfire-specific secondary modifiers (Table 1) which affect loss estimates when the user specifies all the primary building characteristics (occupancy type, construction class, year built, and number of stories). Many of these modifiers (e.g., roof cover and roof shape) are commonly collected on homeowners policies and are used for risk assessment in other perils such as hurricane and hail. Others, such as slope setback and roof vents, may not be readily available at the point of underwriting but are commonly recorded during physical inspection of the property.

With heightened awareness of wildfire risk after recent catastrophe events and new research on roof materials, fire retardant gels, and suppression tactics, wildfire-resistant mitigation practices are now more commonplace. Thus, modeled secondary modifiers offer a convenient way to reflect location-level view of wildfire risk. We apply ten of these modifiers (described below) in our wildfire mitigation analysis.

**Table 1: Mitigation Factors available in RMS Wildfire model.**

| Secondary Modifier | Description | Number of Options |
|---|---|---|
| Roof System Covering | ▪ The flammability of roof cover is an important factor in structure ignitions. Users can specify either a roof cover material type, from which the model infers a typical flammability class or specify a fire rating class based on UL (Underwriter Laboratories) or FM (Factory Mutual Global) classifications | 15 |
| Roof Shape | ▪ Roof Slope affects a building susceptibility to flames and radiant heat. It also affects the likelihood of embers to accumulate on the roof. | 9 |
| Roof Age or Condition | ▪ Older roofs are more susceptible to ignition due to degradation of roof material and lower resistivity to heat and embers. | 5 |
| Roof Vents | ▪ Roof vents allow embers and smoke to infiltrate the structure causing ignitions and, smoke damage.<br>▪ Wildfire resistive vents have been tested by research institutions such as IBHS and contain baffles impeding the direct flow of embers, or 1/8-inch diameter (or smaller) mesh screens, or both.<br>▪ Most exterior vents do not typically meet the "wildfire-resistant" classification. For example, large vents on the broad side of gabled roof structures are very vulnerable to ember attack. In addition, venting with no (or missing) louvers without the presence of screens are the most vulnerable. | 6 |
| Ember Accumulators | ▪ Ember accumulators are areas on the building's roof and envelope that allow or encourage wind-borne embers to pile up and cause ignition of other combustible objects. These building features include inside corners, junctions between horizontal surfaces, and depressions such as stairwells. | 4 |
| Suppression | ▪ Captures likelihood of localized suppression at the property based on specific measures that are either active (private fire protection) or passive (exterior sprinklers) | 4 |
| Sprinkler Presence | ▪ Presence of interior sprinklers only can have some impact on reducing loss if the structure ignites. Note dedicated **exterior** sprinkler systems intended for wildfire applications are accounted for within the Suppression modifier. | 3 |
| Construction Quality | ▪ Obvious signs of degradation can increase susceptibility to ember attacks. | 3 |
| Slope Setback | ▪ Minimal (or no) setback includes homes built directly on slopes with sloped foundation or homes (and/or decks attached to structures) partially supported by elevated piers downslope.<br>▪ For homes built on slope or at top of slope, adequate structure set back is a minimum of 15 ft for single story and 30 ft for two-story; extended fuel modification (removing or modifying vegetation to minimize fire spread) on down-slope area approximately 150 ft from top of slope. | |
| Wall Cladding Type | ▪ The flammability of wall cladding is an important factor in structure ignitions.<br>▪ Specify a wall cladding material type from which model infers a typical flammability class. Research demonstrates that the risk of structure ignitions from ember attack is substantially lower for siding that terminates at least a foot above ground. | 13 |

| Secondary Modifier | Description | Number of Options |
| --- | --- | --- |
| Residential Appurtenant Structures | ▪ Residential appurtenant structures refer to fences, carports, and screened enclosures that can readily ignite.<br>▪ When appurtenant structures are generally over 10 feet away from the main building, the model applies a credit. | 16 |
| Patio Deck | ▪ Wooden deck patios on the exterior are a common source of structure ignitions from heat and embers during a wildfire. | 5 |
| Opening Heat Resistance | ▪ Research shows that double pane glazing is more likely to resist radiant heat effects in a wildfire. | 7 |
| Accessibility Condition | ▪ Ability of fire fighters to access the area within the vicinity of the structure can significantly affect the likelihood of structure survival in a wildfire.<br>▪ Communities that have implemented wildfire mitigation activities such as those suggest by NPFA Firewise USA® can be captured with an option in this secondary modifier. | 5 |

## Site Hazard Data – Fuel Type, Slope, Distance to Vegetation

The RMS North America Wildfire HD Models contains 72 million events each with a heat, ember, and a smoke footprint. Research has shown that local conditions in the immediate vicinity of a structure including fuel type, slope, and distance to vegetation are critical for estimating the likelihood of ignition during a wildfire from the combined effect of radiant heat, flames, and embers. In particular, the effect of heat footprints is highly dependent on these local conditions at a site.

The RMS wildfire model contains site hazard model-default values from the hazard lookup that users can override with location-level inputs on one or more of the landscape parameters to better reflect in-situ conditions. This is the primary mechanism for capturing the risk reduction associated with developing and maintaining a defensible space as described by IBHS above.

Users may provide local fuel type, slope, or distance to vegetation based on inspections done before or after binding a policy.

- Fuel Type - For instance, if there are changes in fuel landscape due to urbanization of land, clearing of a defensible space, or recently experienced wildfire, users can override the default fuel type to a value more representative of the current state of vegetation.
- Slope - In a similar vein, slope values in the geohazard layer reflect the average across a 50-m cell. However, the slope of terrain within a cell can vary, particularly at sites where properties are located, due to presence of hills or road cutbacks.
- Distance to Vegetation – this is how defensible space is captured in the model. Default distance to vegetation values are provided by RMS databases at a resolution of 50 m. These default values represent an average across a 50-m URG cell. As users collect high-fidelity data on defensible space around property risks, they can override model-default values with site-specific distance to

vegetation input, which can significantly impact the composite hazard index and resulting modeled losses.

The RMS model has 26 different fuel type classifications. For purposes of our analysis on 9 site locations in California, Oregon, and Colorado (to be described below), nine of these fuel type classifications are utilized in the wildfire model application as described in Table 2.

For this notional study, default values provided by the underlying hazard layer have been used although conditions within these communities may actually be different.

**Table 2: Fuel Classes in RMS Wildfire Model used in study**

| RMS Ranked Fuel Value | Description |
|---|---|
| 10 | Grass – Short |
| 20 | Grass – Timber understory |
| 40 | Shrubs – Chaparral |
| 50 | Shrubs – Brush |
| 60 | Shrubs – Dominant brush, hardwood slash |
| 80 | Timber – Needle and leaf litter only |
| 90 | Timber – Hardwood litter and occasional dead-down material |
| 100 | Timber / Slash |
| 101 | Urban (non-burnable) |

## Study Locations

This study is a notional study of hypothetical risks spread throughout selected communities. In each state of California, Oregon, and Colorado we selected three site locations (i.e., community) that were relatively geographically proximate, but varied in their inherent wildfire risk being either high or medium wildfire risk. Furthermore, one of the three sites selected in each state is a current Firewise USA® site. In total, 1,161 locations were chosen across 9 communities as described in the following sections.

Within each community, the hypothetical homes are spread uniformly at 1 km intervals across the community, and a notional total insured value (TIV) appropriate to that community is assigned uniformly. Because the area of each community is different, the number of notional structures in each community is different, but the focus of this study is on the relative performance of homes under wildfire risk scenarios within each community. Note that comparisons between communities are possible through normalization of the data.

Total Insured Value for each structure is the sum of building value replacement cost, content value replacement cost, and one year of coverage for additional living expenses. These values are obtained from an RMS database on industry exposure and represent typical values as of 2018. Total Insured Value ranges from $325 thousand in Colorado City in Colorado to about $1.5 million in Cordillera, Colorado.

Every structure in this study is assigned the same set of primary characteristics which may or may not exist within the selected communities. Specifically, this study assumes the following:

- Construction class = wood frame.
- Occupancy = single-family residential.
- Number of stories = 1 story.
- Year of construction = year 2000; and
- Floor area = 2000 square feet.

## California Communities

The three selected communities in California are provided in Table 3 and shown in Figure 6. These communities are all in Northern California as illustrated below (Figure 6) with Upper Deerwood being the Firewise community and Berry Creek and Oroville the non-Firewise communities which are close to the city of Paradise which was the location of 2018 Camp Fire.

As you can also see from the aerial view figures shown in Figure 7 to Figure 9, Upper Deerwood and Berry Creek are located in more wooded-type locations with Oroville more of a suburban location.

Across all three communities in California, there are a total of 284 structures included in our analysis – 67 in Upper Deerwood[2], 98 in Berry Creek, and 119 in Oroville. Notional Total Insured Values assumed for each community range from about $550 thousand to $790 thousand.

From the below table (Table 4) in terms of fuel type composition we see that Upper Deerwood has 66% of its structures in grass or shrubs, 25% in timber, and 9% urban fuel types. Berry Creek has 7% of its structures in grass or shrubs and 93% in timber fuel types. The Oroville suburb is a more urbanized development pattern with only 10% of its structures in grass or shrubs, 3% in timber, and 87% in urban fuel types.

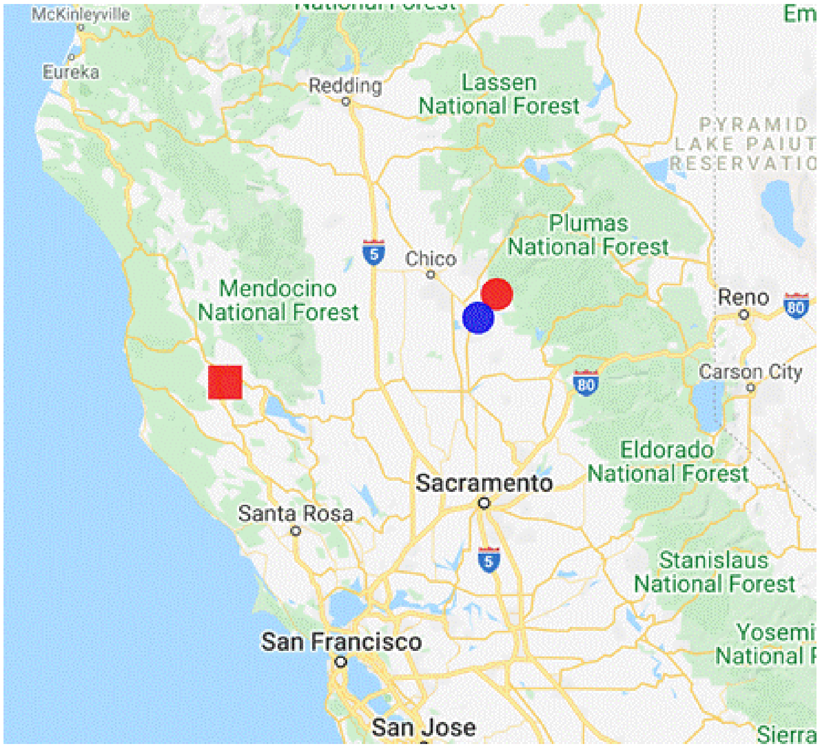
Only the urban locations in Upper Deerwood and Oroville have 160 feet or more of distance to the nearest vegetation, all others are assigned a distance to vegetation of 5 feet.

**Table 3: California communities selected for study**

| Community Name | Latitude | Longitude | Number of Locations | Firewise | Risk | Notinoal Insured Value | Map |
|---|---|---|---|---|---|---|---|
| Upper Deerwood | 39.18873 | -123.17 | 67 | Yes | High Risk | $789,573 | Red Square |
| Berry Creek | 39.63443 | -121.405 | 98 | No | High Risk | $558,650 | Red Circle |
| Oroville | 39.51285 | -121.536 | 119 | No | Medium Risk | $593,820 | Blue Circle |

[2] According to the 2019 Firewise Renewal Application there are 35 dwelling units in Upper Deerwood Site Location

**Figure 6: Map of locations of California Communities in Study**




(map source: https://mobisoftinfotech.com/tools/plot-multiple-points-on-map/)

**Figure 7: Upper Deerwood sub-division community, aerial view**

**Figure 8: Berry Creek community, aerial view**


**Figure 9: Oroville sub-division community; aerial view**

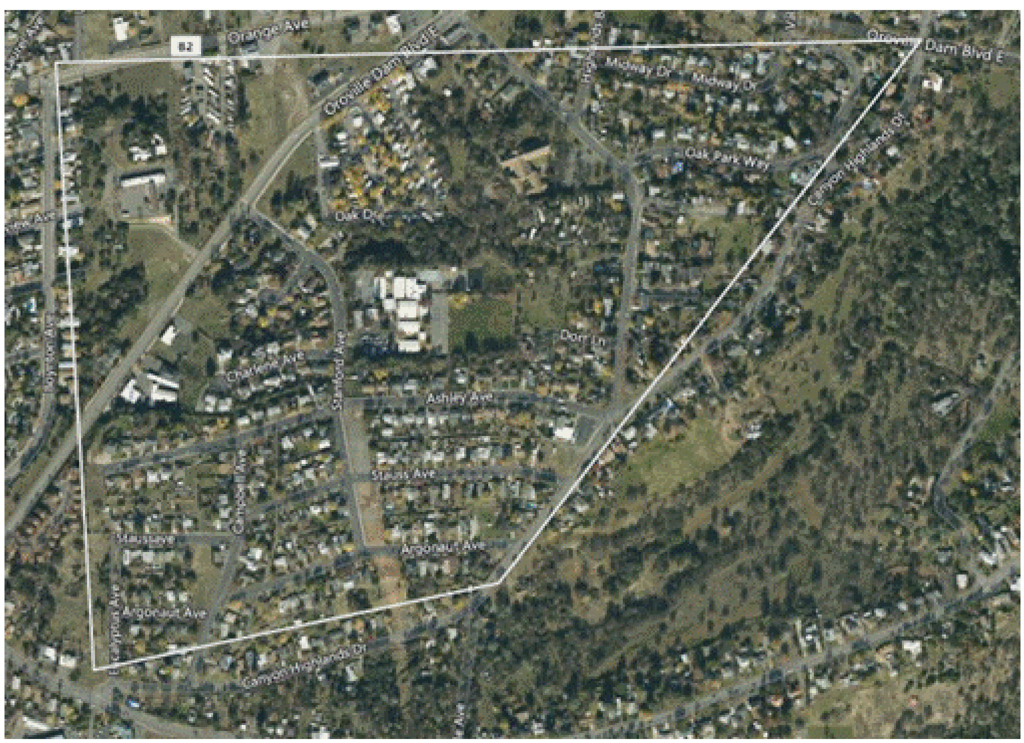


**Table 4: Distribution of Fuel Types within Communities, California**

| Fuel Type | | Upper Deerwood | Berry Creek | Oroville |
|---|---|---|---|---|
| 10 | Grass – Short | 45% | - | 1% |
| 20 | Grass – Timber understory | 18% | 5% | 8% |
| 40 | Shrubs – Chaparral | - | 1% | - |
| 50 | Shrubs – Brush | 3% | - | 1% |
| 60 | Shrubs – Dominant brush, hardwood slash | - | 1% | - |
| 80 | Timber – Needle and leaf litter only | 1% | 10% | - |
| 90 | Timber – Hardwood litter and occasional dead-down material | 18% | 39% | 3% |
| 100 | Timber / Slash | 6% | 44% | - |
| 101 | Urban (non-burnable) | 9% | - | 87% |
| | **Total** | **100%** | **100%** | **100%** |

## Oregon Communities

The three selected communities in Oregon are shown in Table 5 and shown in Figure 10. The Firewise community of Shadow Hills is located in the Southern Part of the state near to the Rogue River-Siskiyou National Forest, Brookings is in the Southwest corner of the state near to the California border, and Sweet Home being Southeast of Corvallis.

As you can see from the individual aerial view community maps (Figure 11, Figure 12, and Figure 13), Shadow Hills is in more wooded-type location, Brookings a mix of wooded and urban, and Sweet Home more of a suburban location.

Across all three communities in Oregon, there are a total of 309 structures included in our analysis – 157 in Shadow Hills[3], 79 in Brookings, and 73 in Sweet Home. Notional Total Insured Values assumed for each community range from about $380 thousand to $510 thousand.

In Table 6, in terms of fuel type composition we see that Shadow Hills has 34% of its structures in grass or shrubs, 60% in timber, and 6% urban fuel types. Brookings has 9% of its structures in shrubs, 23% in timber, and 68% in urban fuel types. Sweet Home has 4% of its structures in grass and 96% in urban fuel types.

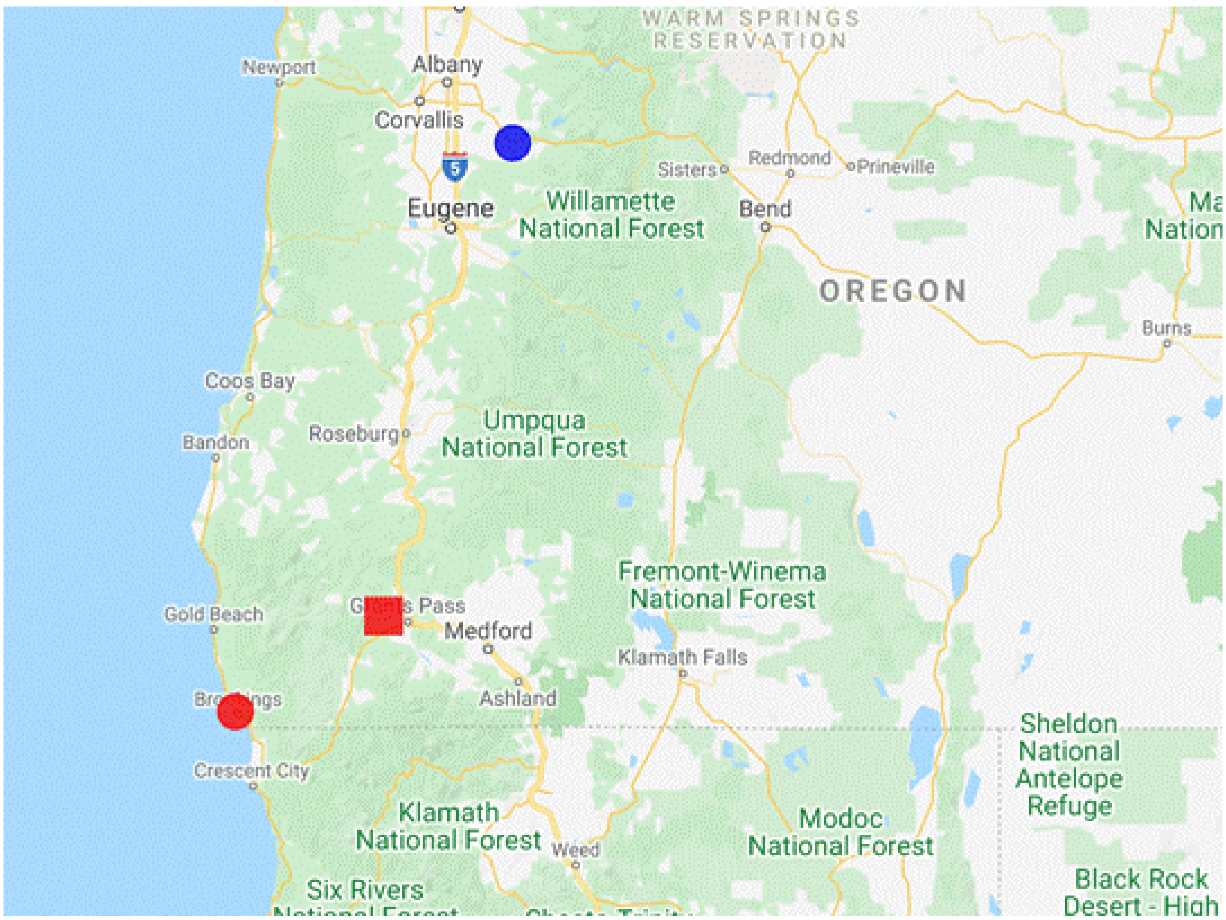
.

[3] From the Firewise Risk Assessment there are 12 dwelling units in their official Firewise community

**Table 5: Oregon communities selected for study**

| Community Name | Latitude | Longitude | Number of Locations | Firewise | Risk | Notional Insured Value | Map |
|---|---|---|---|---|---|---|---|
| Shadow Hills | 42.46689 | -123.467 | 157 | Yes | High Risk | $450,081 | Red Square |
| Brookings | 42.0633 | -124.295 | 79 | No | High Risk | $510,661 | Red Circle |
| Sweet Home | 44.39191 | -122.738 | 73 | No | Medium Risk | $378,665 | Blue Circle |

**Figure 10: Map showing locations of Oregon communites in Study**




(map source: https://mobisoftinfotech.com/tools/plot-multiple-points-on-map/)

**Figure 11: Aerial view of Shadow Hills, Oregon**


**Figure 12: Aerial view of Brookings, Oregon**

**Figure 13: Aerial view of Sweet Home, Oregon**


**Table 6: Distribution of Fuel Type within Communities, Oregon**

| Fuel Type | | Shadow Hills | Brookings | Sweet Home |
|---|---|---|---|---|
| 10 | Grass – Short | 3% | | 3% |
| 20 | Grass – Timber understory | 4% | | 1% |
| 40 | Shrubs – Chaparral | | | |
| 50 | Shrubs – Brush | 28% | 9% | |
| 60 | Shrubs – Dominant brush, hardwood slash | | | |
| 80 | Timber – Needle and leaf litter only | 2% | 8% | |
| 90 | Timber – Hardwood litter and occasional dead-down material | 25% | 15% | |
| 100 | Timber / Slash | 32% | | |
| 101 | Urban (non-burnable) | 6% | 68% | 96% |
| | **Total** | **100%** | **100%** | **100%** |

## Colorado Communities

The three selected communities in Colorado are provided in Table 7 and shown in Figure 14. The Firewise community of Cordillera is in the White River National Forest West of Denver;  Boulder Valley is West of Boulder in the Rocky Mountains; and Colorado City is Southwest of Pueblo in the Southern part of the state.

As you can also see from the aerial view maps in Figure 15 to Figure 17, Cordillera and Boulder Valley are in more wooded-type locations with Colorado City more of a suburban location.

Across all three communities in Colorado, there are a total of 568 structures included in our analysis – 341 in Cordillera[4], 85 in Boulder Valley, and 142 in Colorado City. Notional Total Insured Values assumed for each community range from about $325 thousand to $ 1.5 million.

In Table 8, in terms of fuel type composition we see that Cordillera has 64% of its structures in grass or shrubs, 31% in timber, and 5% urban fuel types.  Boulder Valley has 28% of its structures in grass or shrubs and 72% in timber.  Colorado City has 66% of its structures in grass and shrubs and 34% in urban fuel types.

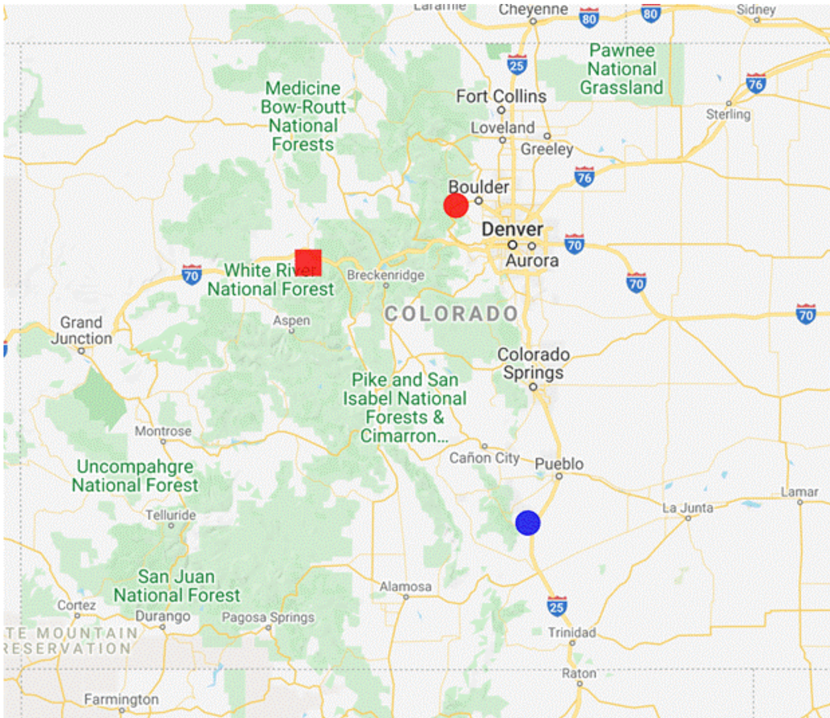
Only the urban locations in Cordillera and Colorado City have 160 feet of distance to the nearest vegetation, all others are assigned a distance of 5 feet.

**Table 7: Colorado communites selected for study**

| Community_Name | Latitude | Longitude | Number of Locations | Firewise | Risk | Notional Insured Value | Map |
|---|---|---|---|---|---|---|---|
| Cordillera | 39.62237 | -106.674 | 341 | Yes | High Risk | $ 1,489,947 | Red Square |
| Boulder Valley | 39.98445 | -105.458 | 85 | No | High Risk | $ 559,443 | Red Circle |
| Colorado City | 37.95177 | -104.86 | 142 | No | Medium Risk | $ 325,414 | Blue Circle |

[4] According to the 2019 Firewise application there are a total of 586 dwelling units in Cordillera.

**Figure 14: Maps of locations of Colorado communities in study**




(map source: https://mobisoftinfotech.com/tools/plot-multiple-points-on-map/)

**Figure 15: Aerial view of Cordillera, CO community**

**Figure 16: Aerial view of Boulder Valley, CO community**


**Figure 17: Aerial View of Colorado City, CO community**

**Table 8: Distribution of Fuel Type within Communites, Colorado**

| Fuel Type | | Cordillera | Boulder Valley | Colorado City |
|---|---|---|---|---|
| 10 | Grass – Short | 49% | | 21% |
| 20 | Grass – Timber understory | 5% | 1% | 8% |
| 40 | Shrubs – Chaparral | | | |
| 50 | Shrubs – Brush | 6% | 27% | 27% |
| 60 | Shrubs – Dominant brush, hardwood slash | 4% | | 9% |
| 80 | Timber – Needle and leaf litter only | 15% | 46% | |
| 90 | Timber – Hardwood litter and occasional dead-down material | 12% | 6% | |
| 100 | Timber / Slash | 4% | 20% | |
| 101 | Urban (non-burnable) | 5% | | 35% |
| | **Total** | **100%** | **100%** | **100%** |

# Mitigation Scenarios

To assess the benefits to wildfire mitigation, we employ the RMS wildfire model on the 1,161 total structures that comprise our 9 site locations in California, Oregon, and Colorado.

For each structure in the selected site locations we perform five separate mitigation case runs of the model through site hazard and secondary modifier model selections that adjust the RMS vulnerability curves. We start with a neutral setting where all structural secondary modifiers are set to 0 = “unknown” such that there is no credit or penalty provided for the structural secondary modifier characteristics. Also, in the neutral setting the vegetation distance is taken as-is from the model-default distance to vegetation values which represent an average across a 50-m URG cell. As discussed in the location overview above, only the urban locations have distance to vegetation of 160 feet or more in this neutral setting, all other locations are determined to be at 5 feet.

Then two structural mitigation scenarios are applied, and then two additional vegetation management scenarios are applied so representative ranges of risk can be determined for the hypothetical community.

## Structural Mitigation Scenarios

As described earlier, the RMS model includes several wildfire-specific secondary modifiers to capture the impact of additional building characteristics and mitigation measures on structure ignition and damage potential. As with other RMS peril models, the wildfire-specific secondary modifiers adjust the base heat, ember, and smoke vulnerability curves using credits and penalties for mean damage ratios. Through insights from detailed claims analyses and collaboration with research organizations such as the IBHS, RMS developed credit and penalty ranges for each modifier, which depend on specific building characteristics. Mean damage ration (MDR) credits and penalties in the model typically differ by occupancy group, construction class, number of stories, and hazard intensity. But as discussed above, we have normalized the primary characteristics of occupancy group, construction class, and number of stories for our analysis to allow for the MDR credits and penalties for the selected secondary modifiers to only vary by hazard intensity.

We perform two structural mitigation cases where we apply both structural maximum credits and structural maximum penalties by adjusting the associated secondary modifiers simultaneously for each structure. The options set for these secondary modifier adjustments are shown in Table 9 for each of the ten secondary modifiers discussed earlier that impact wildfire risk – roof system covering, roof shape, roof age, roof vents, ember accumulators, suppression, wall cladding, patio deck, opening heat resistance, and accessibility.

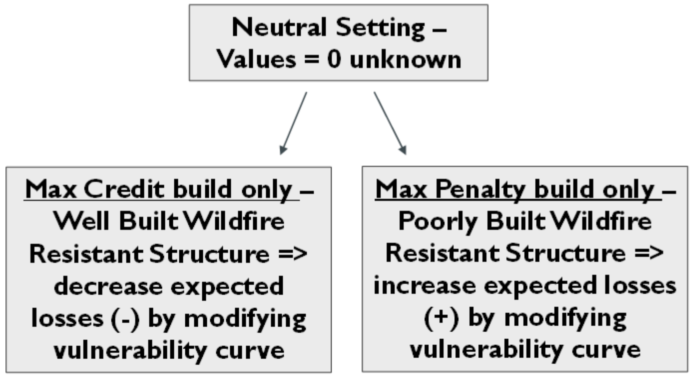
**Table 9: Attributes used for the two Mitigation Cases**

| Variable | Max Credit Build Only | Max Penalty Build Only |
|---|---|---|
| Roof System Covering | 2 - Metal sheathing with concealed fasteners | 6 - Wood shakes |
| Roof Shape | 2 - Flat roof without parapets | 5 - Gable roof |
| Roof Age/Condition | 1 – 0 to 5 years | 4 - Obvious signs of deterioration and distress |
| Roof Vents | 2 – None | 5 - Wildfire Vulnerable Vents |
| Ember Accumulators | 1 - None to few | 3 – Abundant |
| Suppression | 1 - Active Suppression | 3 – None |
| Wall Cladding Type | 9 – Stucco | 3 –Wood |
| Patio Deck | 1 - No deck present | 2- Wood decking |
| Opening Heat Resistance | 6 - All openings compliant with WUI code | 1 - Single-pane windows and glass door |
| Accessibility | 1 - Community designed or retrofit to be wildfire resistant / shelter-in-place | 4 - Remote location with limited water supply and single access road |

In essence, in comparison to a neutral structure we create a well-built wildfire resistant structure vs. a poorly constructed wildfire resistant structure as shown in Figure 18. For example, a well-built wildfire resistant structure has a flat metal roof that is less than 5 years of age, no ember accumulators, stucco walls, no wooden deck, openings that are WUI code compliant and is located in an active suppression community that is also designed or retrofitted to be wildfire resistant / shelter-in-place. Conversely, a poorly-constructed wildfire resistant structure has a gable shape wood shake roof that is quite aged and deteriorating, has wildfire vulnerable vents with abundant ember accumulators, wood cladding, wood decking, single-pane windows and is located non-active suppression community that is a remote location with limited water supply and a single access road.

Note, the accessibility secondary modifier is only applied to structures in our three Firewise communities. The well-built wildfire mitigation structure decreases expected losses and the poorly built wildfire structures increases expected losses.

**Figure 18: Relationship of Structure Credit / Penalty Scenarios relative to Neutral Scenario**

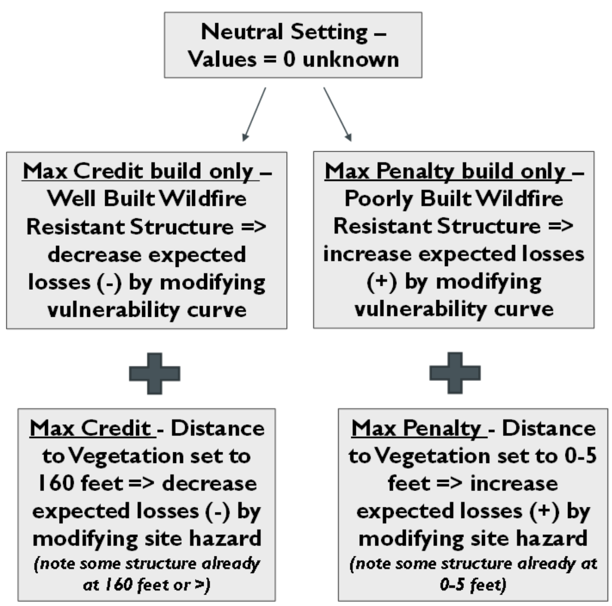



## Vegetation Management Mitigation Scenarios

In addition to the structural credits and penalties, we also apply two vegetation mitigation cases where we apply both distance to vegetation maximum credits and distance to vegetation maximum penalties by adjusting the distance to vegetation data to 160 feet for the credit and 0 to 5 feet for the penalty respectively. For example, if from the neutral setting the vegetation distance is 0 to 5 feet representing an average across a 50-m cell that was collected for the structure and site, this is adjusted to 160 feet for the maximum credit. Likewise, if from the neutral setting the vegetation distance is 160 feet or greater representing an average across a 50-m cell, this is adjusted to 0 to 5 feet for the maximum penalty.

The vegetation credit scenario is only applied in addition to the structural credit, and the vegetation penalty is only applied in addition to the structural penalty as per Figure 19:.

**Figure 19: Relationship of Structure Credit / Penalty Scenarios and Vegetation Mitigation relative to Neutral Scenario**



# Wildfire Mitigation Benefits

The following sections present the results of the catastrophe model simulations for the 5 mitigation scenarios described above. Commentary and analysis that put these results in context with prevailing insurance rates are presented by state and community.

## California Community Mitigation Benefits

### Comparison to Prevailing Insurance Premiums - California

For our three California communities of Upper Deerwood (67 structures), Berry Creek (98 structures), and Oroville (119 structures), the mean AAL across all structures in each community is $3,169, $637, and $35 respectively when all secondary modifiers have been set to the neutral setting. Therefore, on average, the wildfire risk in Upper Deerwood is 5 times greater than the wildfire risk in Berry Creek, and 90 times greater than the wildfire risk in Oroville.

As noted earlier, local conditions in the immediate vicinity of a structure including the fuel type are critical for estimating the likelihood of ignition during a wildfire. In Figure 20 we present the mean AAL by fuel type per community. In Upper Deerwood, AAL ranges from $1,971 for urban fuel type (9% of total structures) to $4,929 for timber/slash fuel type (6% of total structures). In Berry Creek, AAL ranges from $332 for grass-timber understory fuel type (5% of total structures) to $872 for timber/slash fuel type (44% of total structures). And finally, in Oroville AAL ranges from $18 for shrubs-brush fuel type (1% of total structures) to $47 for timber-hardwood litter fuel type (3% of total structures).

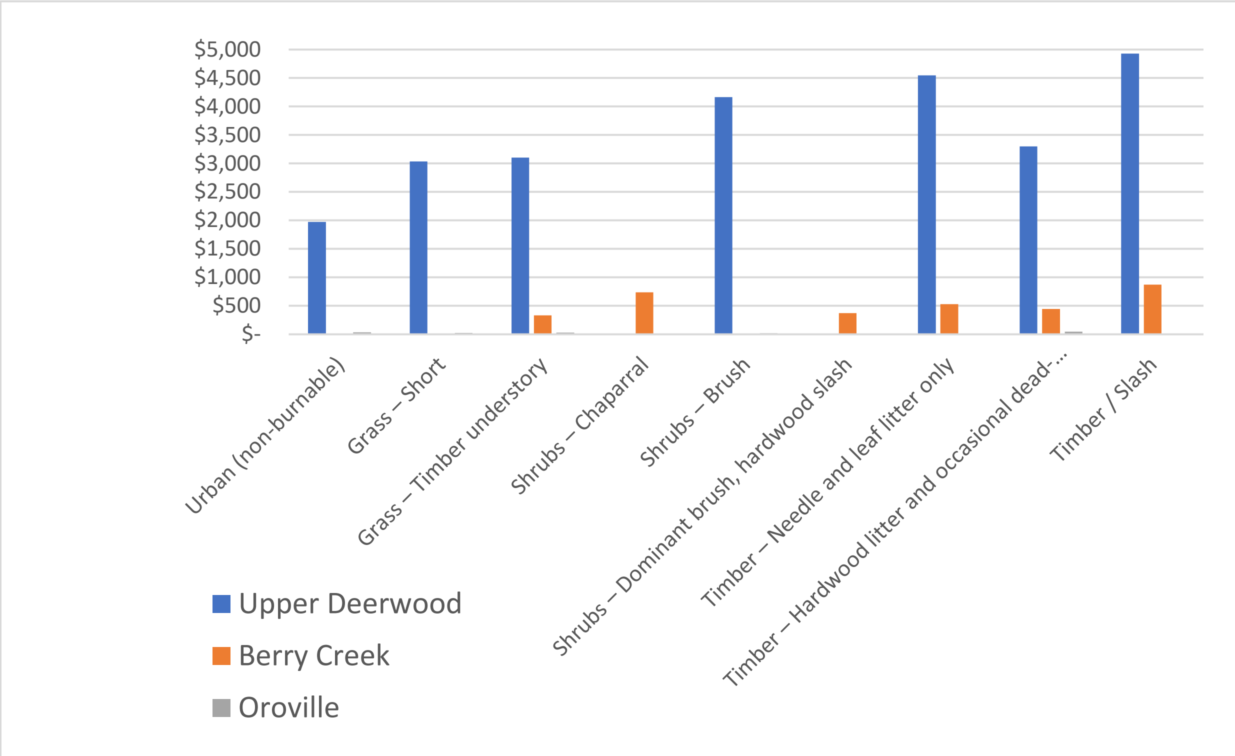
These determined AALs represent an unloaded premium for wildfire risk only. For relative comparison purposes, we pulled the California 2017 NAIC state-wide premium data in Table 10. In 2017, California HO-3 average premium values were $1,643 and California HO-5 average premium values were $2,595, both for exposure values $500,000 and over. These are the nearest NAIC premium values matching to our California communities modeled structure total insured value that ranges from $558,650 to $789,573.

**Table 10: California Average Premium and Loss Cost for expsoure values $500,000 or more (NAIC 2017)**

| Policy Type | Average Premium | Loss Cost ($ / $1000) |
|---|---|---|
| HO-3 | $1,643 | $3.29 |
| HO-5 | $2,595 | $5.19 |

Source (NAIC Premiums); Loss Cost = Premium / $500,000 * $1000

**Figure 20: Average Annual Loss by Fuel Type for three communites in California**




Thus, our determined wildfire AAL value per fuel type as a percentage of the California NAIC H0-3 state-wide average premium are: 120% to 300% in Upper Deerwood; 20% to 53% in Berry Creek; and 1% to 3% in Oroville. Of course, these NAIC premium values do account for more than just wildfire risk; they will cover other perils and also variable and fixed expenses. While it is unknown how much of the existing California 2017 premium accounts for wildfire risk, clearly our determined wildfire risk AAL represents a significant percentage of existing premiums in two of the three California communities.

For further comparative purposes we also collected 2017 and 2018 FAIR plan premiums and it is presented below. While we are able to collect FAIR plan premium data for comparative geographic areas utilizing zip codes, we are not able to collect it by the amount of coverage as is done with the NAIC data (e.g., $500,000 and over). From this information we see that FAIR plan premiums in our study areas – again not accounting for coverage amounts – are only greater than the NAIC state-wide data in Oroville ($1659 vs. $1643). Again, we can conclude that our determined wildfire risk AAL represents a significant percentage of existing FAIR plan premiums in two of the three California communities

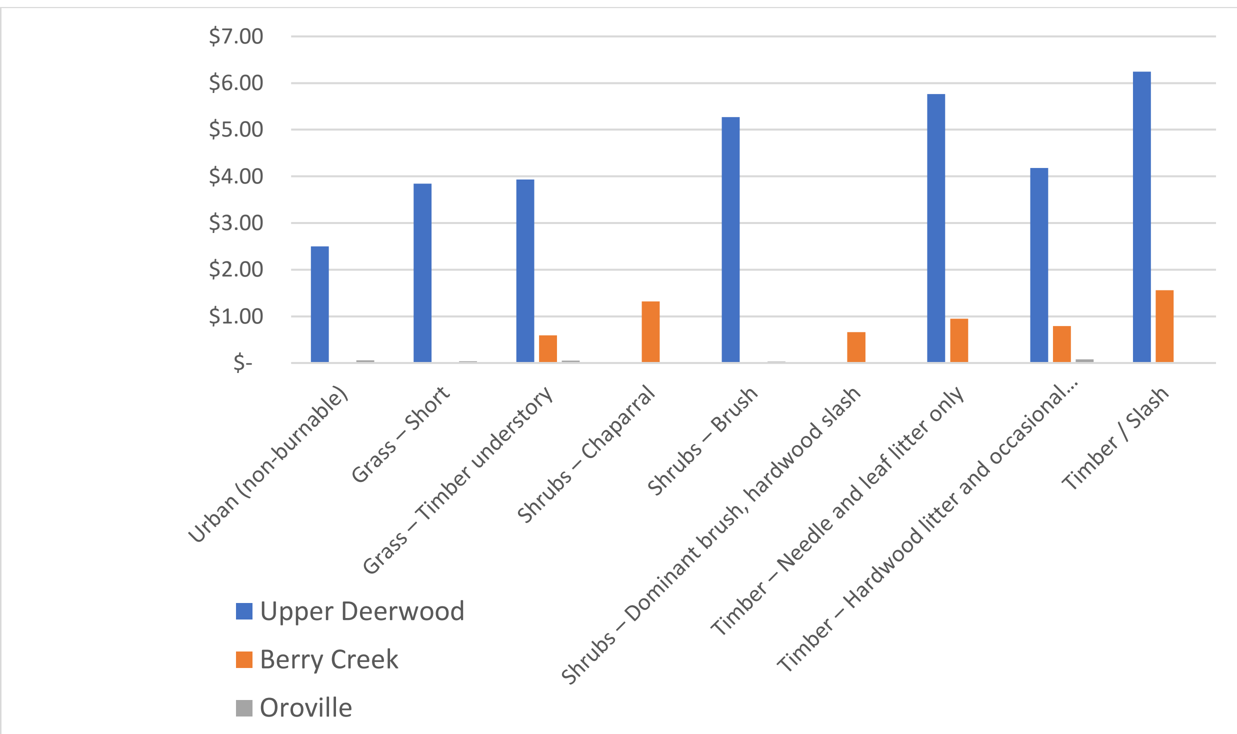
**Table 11: Califonia FAIR Plan Average Premium for Selected Zip Codes**

| | | Dwelling Fire - Owner-Occupied | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2017 | | | 2018 | | |
| ZIP Code | City | Earned Premium | Earned Exposure | Average Premium | Earned Premium | Earned Exposure | Average Premium |
| 95965 | Oroville | $ 18,385 | 11 | $ 1,659 | $ 19,666 | 13 | $ 1,573 |
| 95966 | Oroville | $ 46,585 | 37 | $ 1,253 | $ 62,482 | 48 | $ 1,295 |
| | Oroville | $ 64,970 | 48 | $ 1,347 | $ 82,148 | 61 | $ 1,352 |
| 95916 | Berry Creek | $ 32,813 | 27 | $ 1,204 | $ 37,000 | 30 | $ 1,223 |
| 95482 | Ukiah | $ 21,573 | 16 | $ 1,321 | $ 33,546 | 26 | $ 1,286 |

(Source: California Department of Insurance, personal communication)

All else being equal, AAL will be higher for larger TIV. To account for the TIV impact on our determined AAL we calculate the loss costs per $1000 of insurance coverage which is equal to the (AAL/TIV) * 1000. In Figure 21, we present the mean loss cost per $1000 of coverage by fuel type per community. In Upper Deerwood, loss costs per $1000 of coverage range from $2.50 for urban fuel type (9% of total structures) to $6.24 for timber/slash fuel type (6% of total structures). In Berry Creek, loss costs per $1000 of coverage range from $0.59 for grass-timber understory fuel type (5% of total structures) to $1.56 for timber/slash fuel type (44% of total structures). And in Oroville loss costs per $1000 of coverage range from $0.03 for shrubs-brush fuel type (1% of total structures) to $0.08 for timber-hardwood litter fuel type (3% of total structures).

**Figure 21: Loss Cost per $1000 of Coverage (mean by number of structures)**



Again, for relative comparison purposes, we determined a loss cost per $1000 of coverage from the California 2017 NAIC state-wide premium data (Table 10) . In 2017, California HO-3 loss costs per $1000 coverage were $3.29 and California HO-5 loss costs per $1000 coverage were $5.19, both for exposure values $500,000 and over.

Thus, our determined wildfire loss costs per $1000 of coverage values per fuel type as a percentage of the California NAIC H0-3 state-wide loss costs per $1000 of coverage are: 76% to 190% in Upper Deerwood; 18% to 48% in Berry Creek; and 0.9% to 2.4% in Oroville. While not as large a percentage as the AAL to premium values, again wildfire loss cost per $1000 coverage are still significant in two of the three California communities.

Normalizing associated with Loss Cost means that we can compare risks within and between the communities. In Figure 22 to Figure 24, the variation of the loss costs for each notional location are plotted with the same color ramp in the legend. These plots show that there are variations within the communities that are related to the nearby fuels, local topography, and distance to dense vegetation. These figures show that the level of risk in Oroville is an order of magnitude lower than the other high-risk communities, but the risk is not zero.

## Potential for Extreme Wildfire Losses – California

The EP curve also provides the probability of surpassing any loss level, expressing this probability in the form of a return period. These metrics reveal the potential for very extreme events to wipe out entire communities like the situation in Coffey Park in 2017 or the Camp Fire in 2018. Average Annual Loss metrics can mask this potential because they weight the most extreme scenarios with extremely small likelihood of occurrence. Thus, it is useful to also examine the community EP curve to get a sense of how these ‘tail’ events contribute to the overall risk level.

**Figure 22: Upper Deerwood sub-division community; Aerial view (left) and Loss Cost Map (Right)**

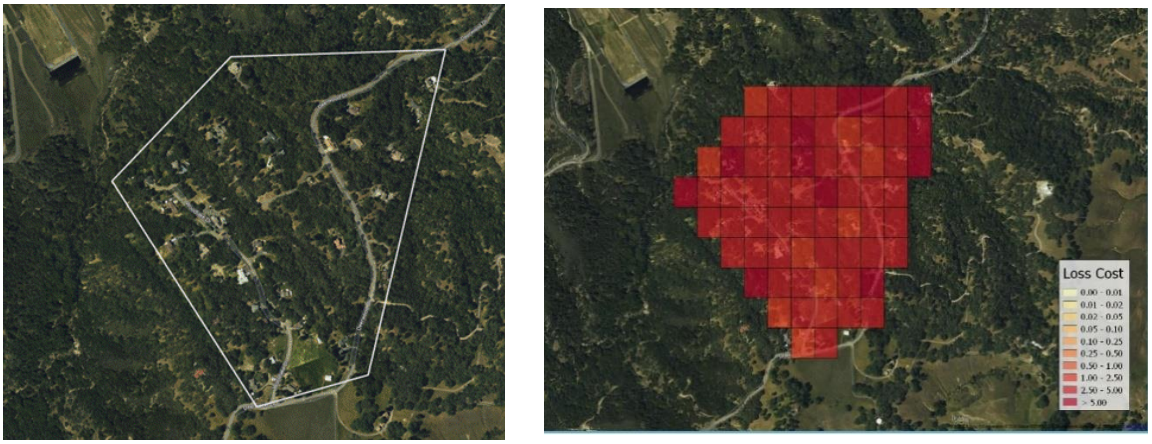



**Figure 23: BerryCreek community; Aerial view (left) and Loss Cost Map (Right)**

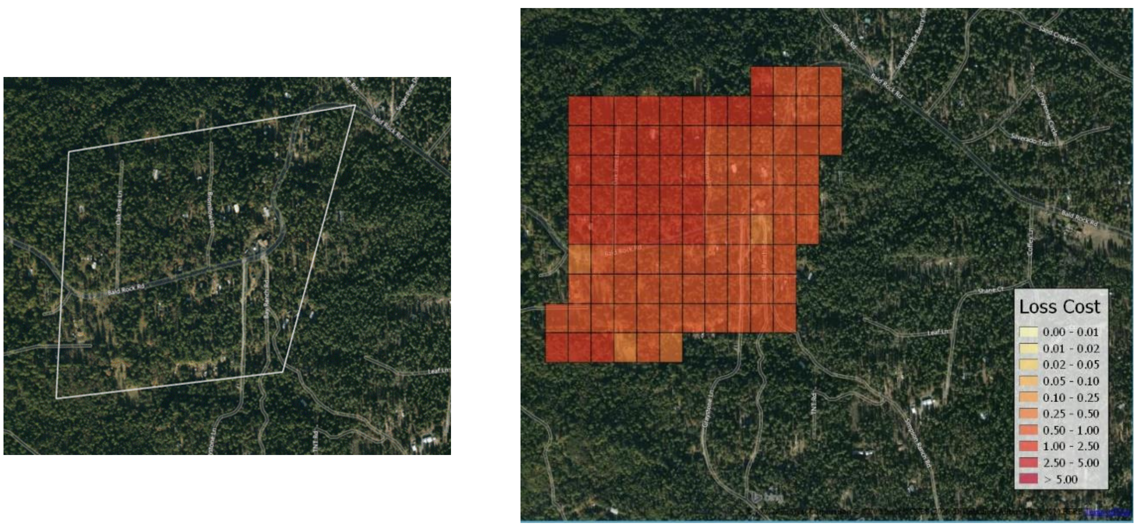
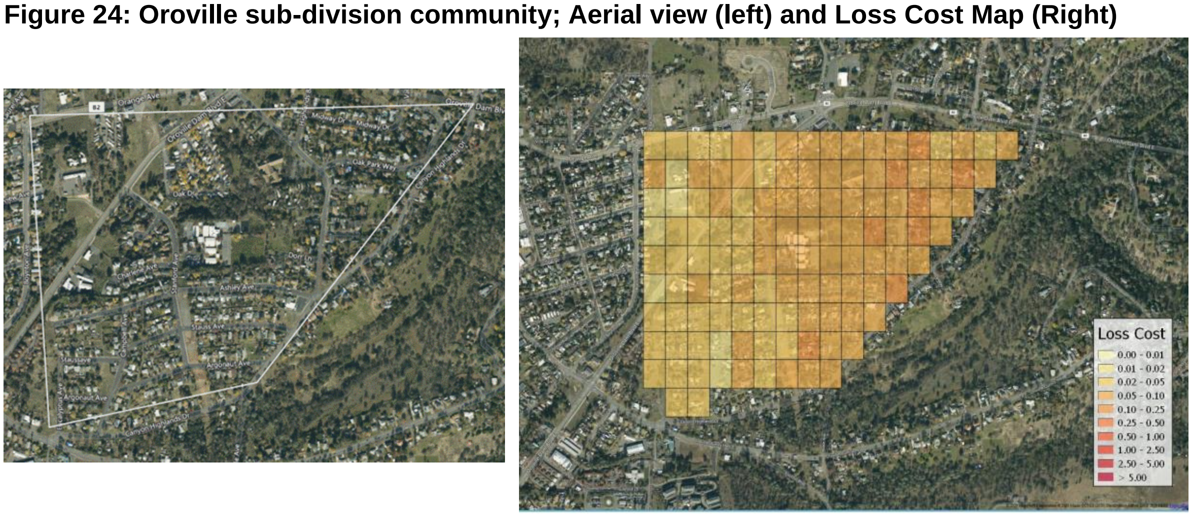



**Figure 24: Oroville sub-division community; Aerial view (left) and Loss Cost Map (Right)**



In the below table we present the various OEP return period (100, 250, 500, 1000 and 10,000 year) mean losses and losses per $1000 of coverage for each of the three California communities. We can see that the mean 1000 year return period loss in Upper Deerwood is approximately 63 percent of a total loss from the $789,573 TIV. Mean 1000 year return period losses are not as relatively high in Berry Creek and Oroville, but significant nonetheless at $119,808 and $1,626 respectively. Importantly, these tail return period losses highlight the potential significant impact of just one event occurring in a community, an aspect that is not as readily apparent from the AAL view of loss.

**Table 12: Study Community Average Return Period (RP) Loss per structure and normalized Return Period Loss per $1000 coverage**

| Community / Return Period | Average RP Loss per Structure | Normalized RP Loss per $1000 Coverage |
|---|---|---|
| **Upper Deerwood (FireWise)** | | |
| 10,000 yr. | $666,777 of $790,000 | 844.48 |
| 1,000 yr. | $498,940 | 631.91 |
| 500 yr. | $424,667 | 537.84 |
| 250 yr. | $325,194 | 411.86 |
| 100 yr. | $86,242 | 109.23 |
| **Berry Creek** | | |
| 10,000 yr. | $243,181 of $558,000 | 435.30 |
| 1,000 yr. | $119,808 of $558 k | 214.46 |
| 500 yr. | $98,544 | 176.40 |
| 250 yr. | $72,431 | 129.65 |
| 100 yr. | $1,941 | 3.47 |
| **Oroville** | | |
| 10,000 yr. | $57,537 of $593,000 | 96.89 |
| 1,000 yr. | $1,626 of $593 k | 2.74 |
| 500 yr. | $921 | 1.55 |
| 250 yr. | $554 | 0.93 |
| 100 yr. | $245 | 0.41 |

## Structural Mitigation Benefits - California

Given our neutral setting AAL results, we determine the structural maximum credit and the structural maximum penalty as differences from these values by adjusting the ten secondary modifiers (roof system covering, roof shape, roof age, roof vents, ember accumulators, suppression, wall cladding, patio deck, opening heat resistance, and accessibility) simultaneously for each structure in each community. The table below presents both the mean AAL percent difference and the mean AAL dollar value difference from the neutral setting results for all fuel types in each community as well as for the overall community.

**Table 13: Credits and Penalties of the Structural Mitigation relative to Neutral Scenario for locations in various fuel classes.**

| Community / Fuel Type | STR Credit (%) | STR Penalty (%) | STR Credit ($) | STR Penalty ($) |
|---|---|---|---|---|
| **Upper Deerwood (Firewise)** | | | | |
| Urban (non-burnable) | -37% | 97% | -$720 | $1,909 |
| Grass – Short | -31% | 81% | -$945 | $2,457 |
| Grass – Timber understory | -29% | 78% | -$890 | $2,411 |
| Shrubs – Brush | -27% | 72% | -$1,121 | $3,015 |
| Timber – Needle and leaf litter only | -18% | 59% | -$822 | $2,685 |
| Timber – Hardwood litter and occasional dead-down material | -27% | 73% | -$893 | $2,398 |
| Timber / Slash | -16% | 50% | -$770 | $2,454 |
| **Community Average** | **-28%** | **76%** | **-$899** | **$2,409** |
| **Berry Creek** | | | | |
| Grass – Timber understory | -37% | 81% | -$121 | $269 |
| Shrubs – Chaparral | -39% | 97% | -$287 | $711 |
| Shrubs – Dominant brush, hardwood slash | -38% | 85% | -$139 | $316 |
| Timber – Needle and leaf litter only | -37% | 95% | -$196 | $505 |
| Timber – Hardwood litter and occasional dead-down material | -38% | 90% | -$168 | $397 |
| Timber / Slash | -33% | 105% | -$289 | $920 |

| Community / Fuel Type | STR Credit (%) | STR Penalty (%) | STR Credit ($) | STR Penalty ($) |
|---|---|---|---|---|
| **Community Average** | **-35%** | **99%** | **-$222** | **$633** |
| **Oroville** | | | | |
| Urban (non-burnable) | -15% | 58% | -$5 | $21 |
| Grass – Short | -21% | 62% | -$5 | $13 |
| Grass – Timber understory | -15% | 58% | -$5 | $18 |
| Shrubs – Brush | -28% | 92% | -$5 | $16 |
| Timber – Hardwood litter and occasional dead-down material | -12% | 55% | -$6 | $26 |
| **Community Average** | **-15%** | **58%** | **-$5** | **$21** |

Looking across all three communities we see that on average structural credits as a percentage difference from the neutral value AALs are significant ranging anywhere from 12 to 39 percent reductions in expected losses depending upon the fuel type. These percent differences are highest in Berry Creek (35% less on average), but certain fuel types in the other communities are comparable such as urban fuel types in Upper Deerwood (37% less on average) and shrubs-brush fuel types in Oroville (28% less on average).

Conversely, poorly built wildfire resistant structures suffer even more significant structural penalties as a percentage difference from the neutral value AALs. For example, Berry Creek penalties across all structure are 99 percent higher on average, whereas Upper Deerwood and Oroville are 76 percent and 58 percent higher on average, respectively. There is not one fuel type in any of our communities that does not incur at least a 50 percent penalty from the neutral value AALs when moving to a poorly built wildfire resistant structure.

Additionally, another way of thinking about these results is not just moving from an assumed CAT modeling neutral setting, but rather from a poorly built wildfire resistant structure to a well-built one. From this perspective, mean community AAL percent differences are 104 percent in Upper Deerwood, 134 percent in Berry Creek, and 73 percent in Oroville. Clearly, from an expected loss percentage reduction perspective substantial differences are achieved from this view for all three communities.

However, while percent differences are a useful measuring stick, the actual dollar value differences these percent differences represent are even more critical for implementing wildfire mitigation measures given the implementation costs. In the below figure (Figure 25) we present the mean AAL dollar value differences for all three communities from the neutral value setting AAL results (mean AAL dollar value differences by fuel type are also presented in Table 13).

**Figure 25: Mean Average Annual Loss Difference from Neutral case ($) by Community, California**


Not surprisingly, we see that the largest AAL dollar value differences incurred from well-built wildfire resistant structures happen where the wildfire risk is greatest in Upper Deerwood. Here, expected losses are on average $899 less from the neutral setting for well-built wildfire resistant structures. Conversely, poorly built wildfire structures in Upper Deerwood have mean AAL increases that are on average $2409 higher than the neutral setting. In total, moving from a poorly built wildfire resistant structure to a well-built one in Upper Deerwood saves on average $3307 annually in wildfire expected losses.

While AAL percent differences in Berry Creek were the largest for all three California communities, expected losses are on average $222 less from the neutral setting and AAL increases $633 more on average as compared to a neutral setting. Overall, moving from a poorly built wildfire resistant structure to a well-built one in Berry Creek saves on average $856 annually in wildfire expected losses. Given the relatively low neutral setting determined AAL in Oroville ($35), moving from a poorly built wildfire resistant structure to a well-built one in Oroville only saves on average $26 annually in wildfire expected losses.

## Structural plus Vegetation Mitigation Benefits – California

In addition to the structural credits and penalties only, we also apply two distance to vegetation mitigation cases where we apply both distance to vegetation maximum credits (160 feet of defensible space) and distance to vegetation maximum penalties (less than 5 feet of defensible space). As described earlier, the vegetation credit is only applied in addition to the structural credit, and the vegetation penalty is only applied in addition to the structural penalty. The table below, Table 14, presents both the mean AAL percent difference and the mean AAL dollar value difference from the neutral setting results for all fuel types in each community as well as for the overall community. Note that in the table, “Veg Credit” values are the combined mitigation loss reductions of a well-built wildfire resistant structure with the additional distance to vegetation mitigation. And similarly, the “Veg Penalty” values are the combined mitigation penalties of a poorly built wildfire resistant structure with the additional distance to vegetation penalty applied. "STR Credits" and "STR Penalty" values are as they were in the Table 13 above.

**Table 14: Credits and Penalties of the Structural and Vegetation Mitigation relative to Neutral Scenario for locations in various fuel classes.**

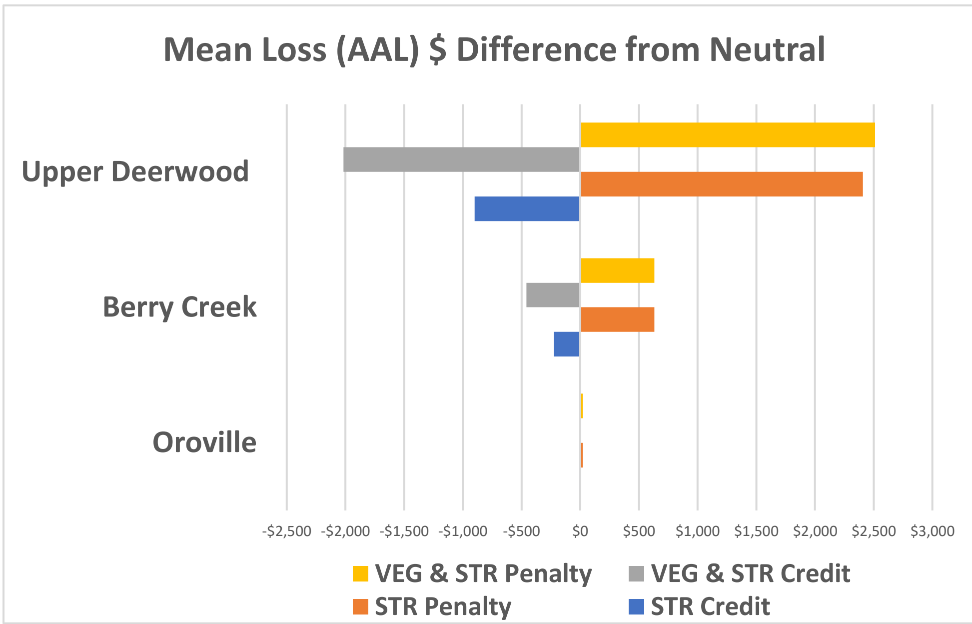
| | VEG Credit | STR Credit | STR Penalty | VEG Penalty | VEG Credit | STR Credit | STR Penalty | VEG Penalty |
|---|---|---|---|---|---|---|---|---|
| Urban (non-burnable) | -39% | -37% | 97% | 155% | -$760 | -$720 | $1,909 | $3,056 |
| Grass – Short | -65% | -31% | 81% | 81% | -$1,973 | -$945 | $2,457 | $2,457 |
| Grass – Timber understory | -64% | -29% | 78% | 78% | -$1,989 | -$890 | $2,411 | $2,411 |
| Shrubs – Brush | -69% | -27% | 72% | 72% | -$2,884 | -$1,121 | $3,015 | $3,015 |
| Timber – Needle and leaf litter only | -76% | -18% | 59% | 59% | -$3,457 | -$822 | $2,685 | $2,685 |
| Timber – Hardwood litter and occasional dead-d | -65% | -27% | 73% | 73% | -$2,151 | -$893 | $2,398 | $2,398 |
| Timber / Slash | -64% | -16% | 50% | 50% | -$3,134 | -$770 | $2,454 | $2,454 |
| **Upper Deerwood** | **-64%** | **-28%** | **76%** | **79%** | **-$2,018** | **-$899** | **$2,409** | **$2,511** |
| | | | | | | | | |
| | | | | | | | | |
| Grass – Timber understory | -52% | -37% | 81% | 81% | -$173 | -$121 | $269 | $269 |
| Shrubs – Chaparral | -72% | -39% | 97% | 97% | -$533 | -$287 | $711 | $711 |
| Shrubs – Dominant brush, hardwood slash | -54% | -38% | 85% | 85% | -$200 | -$139 | $316 | $316 |
| Timber – Needle and leaf litter only | -68% | -37% | 95% | 95% | -$362 | -$196 | $505 | $505 |
| Timber – Hardwood litter and occasional dead-d | -62% | -38% | 90% | 90% | -$274 | -$168 | $397 | $397 |
| Timber / Slash | -78% | -33% | 105% | 105% | -$684 | -$289 | $920 | $920 |
| **Berry Creek** | **-72%** | **-35%** | **99%** | **99%** | **-$459** | **-$222** | **$633** | **$633** |
| | | | | | | | | |
| Urban (non-burnable) | -15% | -15% | 58% | 62% | -$5 | -$5 | $21 | $22 |
| Grass – Short | -21% | -21% | 62% | 62% | -$5 | -$5 | $13 | $13 |
| Grass – Timber understory | -15% | -15% | 58% | 58% | -$5 | -$5 | $18 | $18 |
| Shrubs – Brush | -28% | -28% | 92% | 92% | -$5 | -$5 | $16 | $16 |
| Timber – Hardwood litter and occasional dead-d | -12% | -12% | 55% | 55% | -$6 | -$6 | $26 | $26 |
| **Oroville** | **-15%** | **-15%** | **58%** | **62%** | **-$5** | **-$5** | **$21** | **$22** |

From these results we can ascertain the marginal value provided by the vegetation-based mitigation (i.e., building a defensible space around one's home) in addition to the structural mitigation efforts that have already been afforded to the structure. In Upper Deerwood, the overall combined vegetation and structural percentage AAL reduction is 64 percent, with vegetation mitigation providing an additional 35 percent in mitigation benefits on average at the margin. In Berry Creek, the overall combined vegetation and structural percentage AAL reduction is 72 percent, with vegetation mitigation providing an additional 37 percent in mitigation benefits on average at the margin. However, in Oroville we determine no additional benefit on average in this community since the baseline distance to nearest vegetation is already at 160 feet or more for most homes given that 87 percent of the structures in our analysis are of an urban fuel type.

We can also examine the marginal impact of a vegetation penalty in addition to the structural penalties already in place. In this scenario, our AAL results show that an additional vegetation penalty makes little difference to expected losses. Only in Upper Deerwood was any additional impact determined moving from a 76 percent penalty on average for the poorly built wildfire resistant structure only to 79 percent with the additional poorly maintained distance to vegetation.

Again, while percent differences are a useful measuring stick, the actual dollar value differences these percent differences represent are even more critical for implementing wildfire mitigation measures given the implementation costs. In the below figure (Figure 26) we present the structural and vegetation mitigation mean AAL dollar value differences for all three communities from the neutral value setting AAL results (mean AAL dollar value differences by fuel type are also presented in Table 14).

**Figure 26: Mean Average Annual Loss Difference for Structural and Vegetation Credit/Penalty Scenarios**




Not surprisingly again, we see that the largest AAL dollar value differences incurred from well-built wildfire resistant structures with defensible space happen where the wildfire risk is greatest in Upper Deerwood. Here expected losses are on average $2018 less from the neutral setting with the additional vegetation mitigation representing $1119 of this amount. Conversely, poorly built wildfire structures combined with poorly maintained defensible space in Upper Deerwood have mean AAL increases that are on average $2511 higher than the neutral setting with the vegetation penalty representing only $103 of this amount. In total then moving from a poorly built wildfire resistant structure with poorly maintained defensible space to a well-built one with well-maintained defensible space in Upper Deerwood saves on average $4529 annually in wildfire expected losses.

In Berry Creek expected losses are on average $459 less from the neutral setting with the additional vegetation mitigation representing $237 of this amount. Conversely, poorly built wildfire structures combined with poorly maintained defensible space in Berry Creek have mean AAL increases that are on average $633 higher than the neutral setting with the vegetation penalty not increasing this total amount. In total then moving from a poorly built wildfire resistant structure with poorly maintained defensible space to a well-built one with well-maintained defensible space in Berry Creek saves on average $1092 annually in wildfire expected losses.

In Oroville, there is no meaningful difference in the vegetation mitigation results as compared to the structural only results.

# Oregon Community Mitigation Benefits

## Comparison to Prevailing Insurance Premiums - Oregon

For our 3 Oregon communities of Shadow Hills (157 structures), Brookings (79 structures), and Sweet Home (73 structures), mean AAL across all structures in each community is $310, $1,638, and $1 respectively when all secondary modifiers have been set to the neutral setting. Therefore, on average the wildfire risk in Brookings is 5 times greater than the wildfire risk in Shadow Hills, and 1,638 times greater than the wildfire risk in Sweet Home.

As noted earlier, local conditions in the immediate vicinity of a structure including the fuel type are critical for estimating the likelihood of ignition during a wildfire. In Figure 27 we present the mean AAL by fuel type per community (given the almost non-existent AAL in Sweet Home we only present data for Shadow Hills and Brookings). In Shadow Hills, AAL ranges from $102 for urban fuel type (6% of total structures) to $342 for timber/slash fuel type (33% of total structures). In Brookings, AAL ranges from $1,550 for urban fuel type (68% of total structures) to $2,173 for timber-hardwood litter fuel type (15% of total structures).

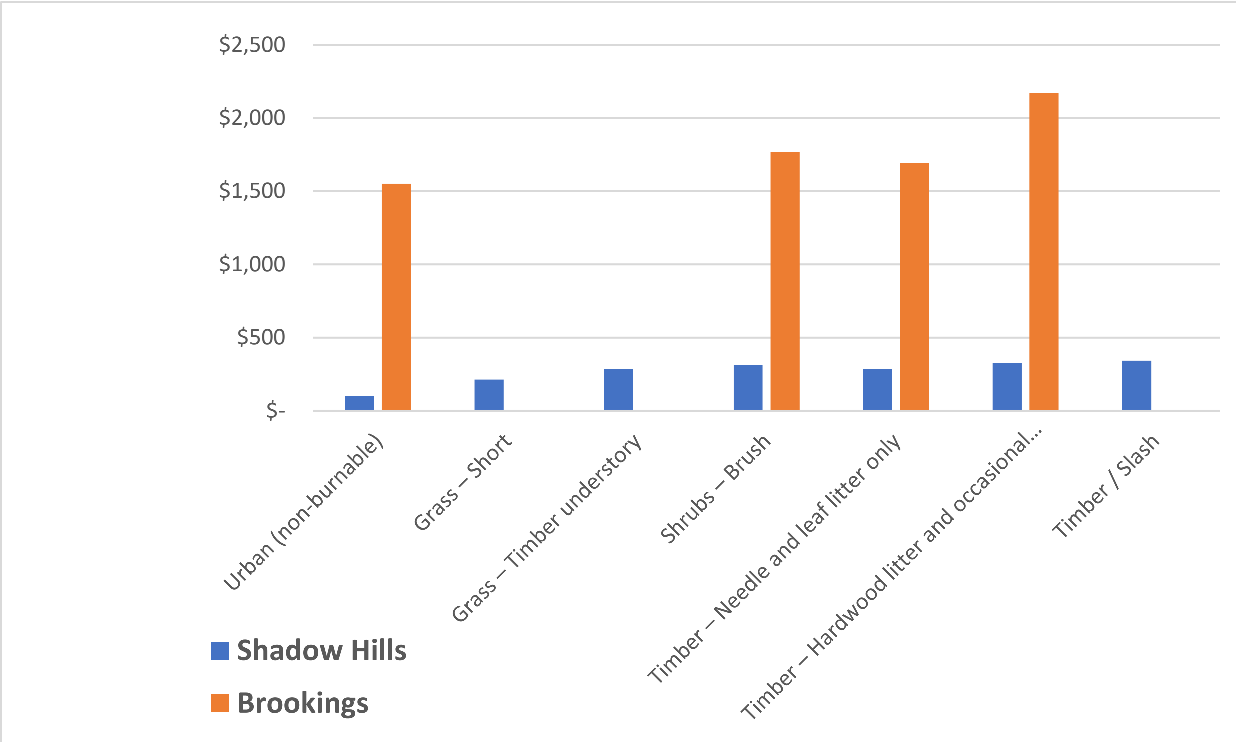
These determined AALs represent an unloaded premium for wildfire risk only. For relative comparison purposes, we pulled the Oregon 2017 NAIC state-wide premium data in Table 15Table 1. In 2017, Oregon HO-3 average premium values were $883 and Oregon HO-5 average premium values were $934, both for exposure values from $400,000 to $499,999. These are the nearest NAIC premium values matching to our Oregon communities modeled structure total insured value that ranges from $378,665 to $510,661.

**Table 15: Oregon Average Premium and Loss Cost for expsoure values $400,000 to $499,000 (NAIC 2017)**

| Policy Type | Average Premium | Loss Cost ($ / $1000) |
|---|---|---|
| HO-3 | $883 | $1.96 |
| HO-5 | $934 | $2.08 |

Source (NAIC Premiums); Loss Cost = Premium / $450,000 * $1000

**Figure 27: Average Annual Loss by Fuel Type for each Community**

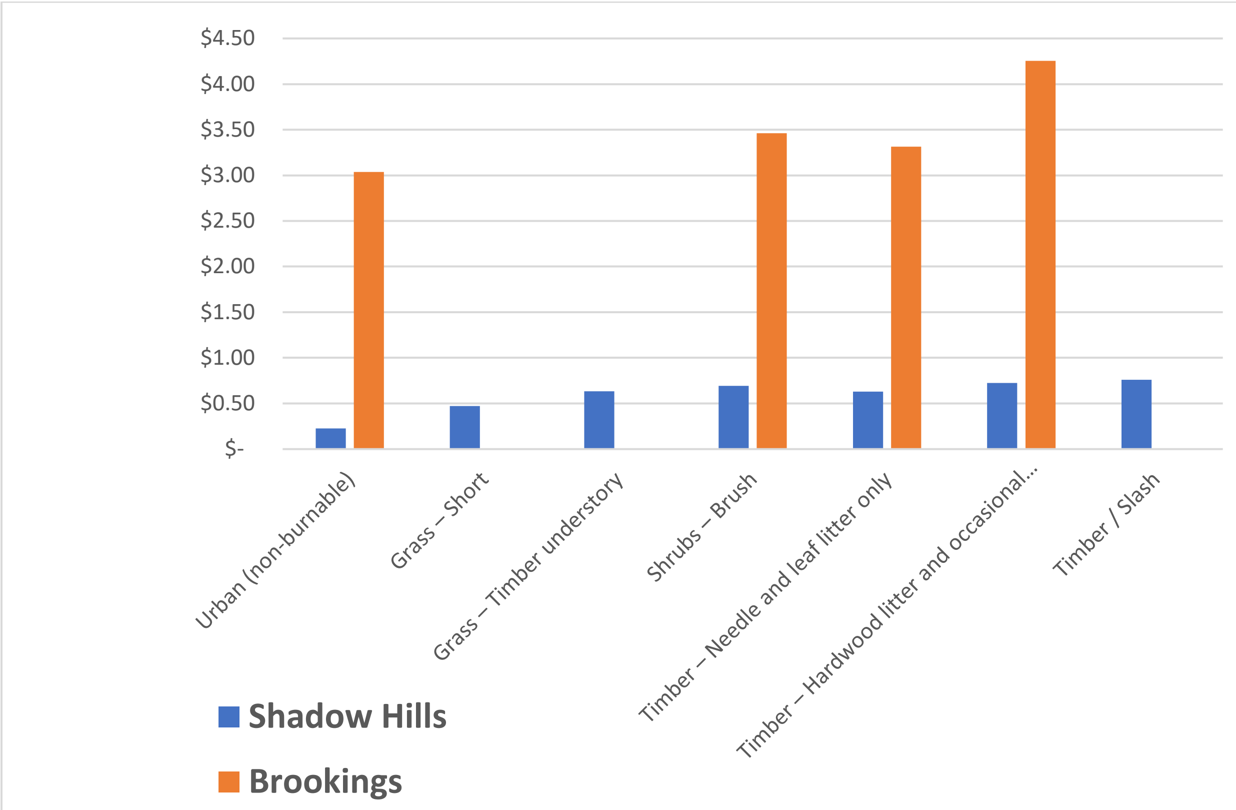



Thus, our determined wildfire AAL value per fuel type as a percentage of the Oregon NAIC H0-3 state-wide average premium are: 12% to 39% in Shadow Hills; and 176% to 246% in Brookings. Of course, these NAIC premium values do account for more than just wildfire risk. While it is unknown how much of the existing Oregon 2017 premium accounts for wildfire risk, clearly our determined wildfire risk AAL represents a significant percentage of existing premiums in two of the three Oregon communities.

All else being equal, AAL will be higher the larger is the TIV. To account for the TIV impact on our determined AAL we calculate the loss costs per $1000 of insurance coverage which is equal to the (AAL/TIV) * 1000. In Figure 28 we present the mean loss cost per $1000 of coverage by fuel type per community. In Shadow Hills, loss costs per $1000 of coverage range from $0.23 for urban fuel type (6% of total structures) to $0.76 for timber/slash fuel type (33% of total structures). In Brookings, loss costs per $1000 of coverage range from $3.04 for urban fuel type (68% of total structures) to $4.25 for timber-hardwood litter fuel type (15% of total structures).

Again, for relative comparison purposes, we determined a loss cost per $1000 of coverage from the Oregon 2017 NAIC state-wide premium data (Table 15). In 2017, Oregon HO-3 loss costs per $1000 coverage were $1.96 and Oregon HO-5 loss costs per $1000 coverage were $2.08, both for exposure values from $400,000 to $499,999.

**Figure 28: Loss Cost per $1000 of Coverage for various Fuel Types for each Community**




Thus, our determined wildfire loss costs per $1000 of coverage values per fuel type as a percentage of the Oregon NAIC H0-3 state-wide loss costs per $1000 of coverage are: 12% to 39% in Shadow Hills; and 155% to 217% in Brookings. While not as large a percentage as the AAL to premium values, again wildfire loss cost per $1000 coverage are still significant in two of the three Oregon communities

Normalizing associated with Loss Cost means that we can compare risks within and between the communities. In Figure 29 to Figure 31, the variation of the loss costs for each notional location are plotted with the same color ramp in the legend. These plots show that there are variations within the communities that are related to the nearby fuels, local topography, and distance to dense vegetation. These figures show that the level of risk in Sweet Home is extremely low, but the risk is not zero.

## Potential for Extreme Wildfire Losses - Oregon

The EP curve also provides the probability of surpassing any loss level, expressing this probability in the form of a return period. Return periods are calculated by sorting the occurrence and yearly losses to create occurrence (OEP) and aggregate (AEP) curves, respectively. These curves are often used to look up key return period losses, such as 1 in 100 or 1 in 250, to help with solvency, rating agency evaluation, and reinsurance purchasing decisions. They can also be used to understand the tail risks of the loss distribution.

**Figure 29: Shawdow Hills sub-division; Aerial view (left) and Loss Cost Map (Right)**

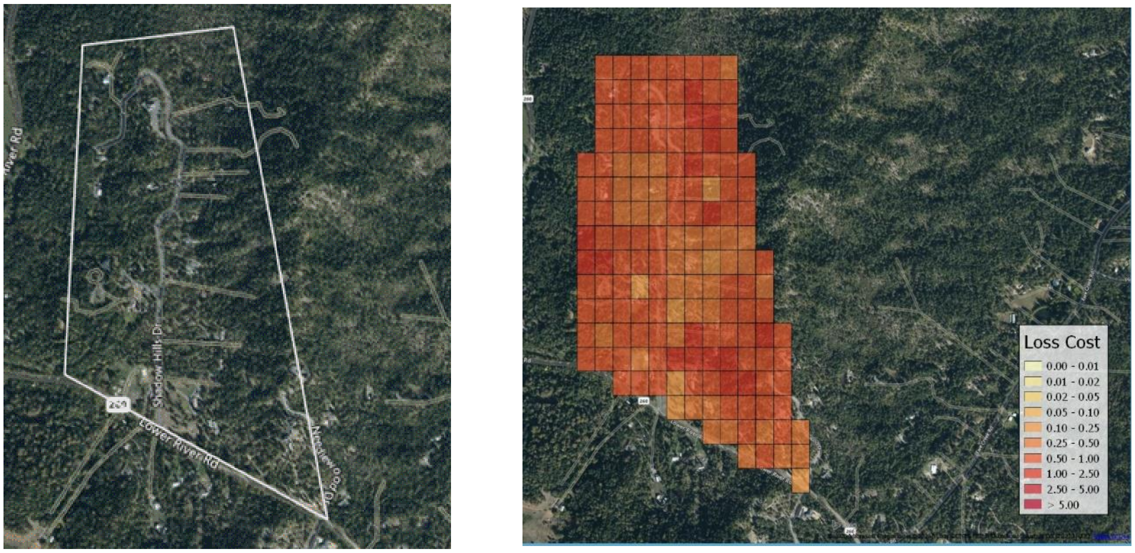



**Figure 30: Brookings sub-division community; Aerial view (left) and Loss Cost Map (Right)**


**Figure 31: Sweet Home sub-division; Aerial view (left) and Loss Cost Map (Right)**

In the below table we present the various OEP return period (100, 250, 500, 1000, and 10,000 year) mean losses and losses per $1000 of coverage for each of the three Oregon communities. We can see that the mean 1000 year return period loss in Brookings is approximately 61 percent loss from the $510,661 TIV. The mean 1000 year return period loss is not as relatively high in Shadow Hills, but significant nonetheless at $103,091. A 1000 year return period event in Sweet Home registers a loss of $208. Importantly, these tail return period losses highlight the potential significant impact of just one event occurring in a community, an aspect that is not as readily apparent from the AAL view of loss.

**Table 16: Study Community Average Return Period (RP) Loss per structure and normalized Return Period Loss per $1000 coverage**

| Community / Return Period | Average RP Loss per Structure | Normalized RP Loss per $1000 Coverage |
|---|---|---|
| **Shadow Hills (FireWise)** | | |
| 10,000 yr. | $173,414 of $450,000 | 385.30 |
| 1000 yr. | $103,091 | 229.05 |
| 500 yr. | $68,152 | 151.42 |
| 250 yr. | $10,248 | 22.77 |
| 100 yr. | $684 | 1.52 |
| **Brookings** | | |
| 10,000 yr. | $390,584 of $511,000 | 763.78 |
| 1000 yr. | $312,522 | 611.13 |
| 500 yr. | $269,296 | 526.60 |
| 250 yr. | $193,551 | 378.48 |
| 100 yr. | $15,945 | 31.18 |
| **Sweet Home** | | |
| 10,000 yr. | $797 of $378,000 | 2.11 |
| 1,000 yr. | $208 | 0.55 |
| 500 yr. | $102 | 0.27 |
| 250 yr. | $34 | 0.09 |
| 100 yr. | $0 | 0.00 |

## Structural Mitigation Benefits - Oregon

Given our neutral setting AAL results, we determine the structural maximum credit and the structural maximum penalty as differences from these values by adjusting the ten secondary modifiers (roof system covering, roof shape, roof age, roof vents, ember accumulators, suppression, wall cladding, patio deck, opening heat resistance, and accessibility) simultaneously for each structure in each community. The table below, Table 17, presents both the mean AAL percent difference and the mean AAL dollar value difference from the neutral setting results for all fuel types in each community as well as for the overall community.

Looking across all three communities we see that on average structural credits as a percentage difference from the neutral value AALs are fairly significant in two of the of three communities ranging anywhere from 19 to 36 percent reductions in expected losses depending upon the fuel type. These percent differences are highest in Shadow Hills (33% less on average), but certain fuel types in Brookings are comparable such as shrubs-brush fuel types (32% less on average).

Conversely, poorly built wildfire resistant structures suffer even more significant structural penalties as a percentage difference from the neutral value AALs. For example, Shadow Hills penalties across all structure are 104 percent higher on average, whereas Brookings are 80 percent higher on average.

There is not one fuel type in these two communities that does not incur at least a 58 percent penalty from the neutral value AALs when moving to a poorly built wildfire resistant structure.

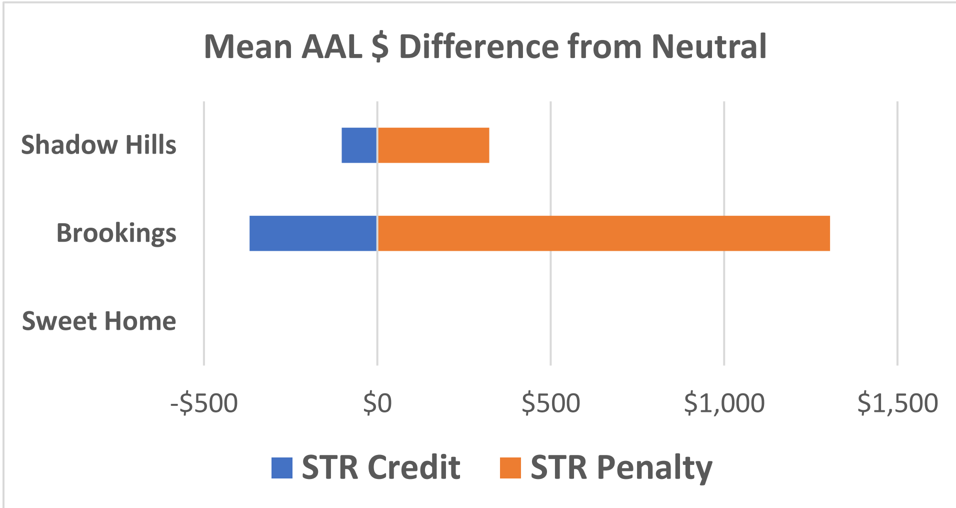
Additionally, another way of thinking about these percentage difference results is not just moving from an assumed CAT modeling neutral setting, but rather from a poorly built wildfire resistant structure to a well-built one. From this perspective, mean community AAL percent differences are 137 percent in Shadow Hills and 102 percent in Brookings. Clearly, from an expected loss percentage reduction perspective substantial differences are achieved from this view for these two communities.

However, while percent differences are a useful measuring stick, the actual dollar value differences these percent differences represent are even more critical for implementing wildfire mitigation measures given the implementation costs. In Figure 32 we present the mean AAL dollar value differences for all three communities from the neutral value setting AAL results (mean AAL dollar value differences by fuel type are also presented in the Table 17).

**Table 17: Credits and Penalties of the Structural Mitigation relative to Neutral Scenario for locations in various fuel classes**

| Community / Fuel Type | STR Credit (%) | STR Penalty (%) | STR Credit ($) | STR Penalty ($) |
|---|---|---|---|---|
| **Shadow Hills** | | | | |
| Urban (non-burnable) | -33% | 64% | -$33 | $66 |
| Grass – Short | -32% | 93% | -$69 | $197 |
| Grass – Timber understory | -32% | 97% | -$92 | $278 |
| Shrubs – Brush | -34% | 104% | -$105 | $326 |
| Timber – Needle and leaf litter only | -36% | 103% | -$103 | $294 |
| Timber – Hardwood litter and occasional dead-down material | -33% | 104% | -$106 | $338 |
| Timber / Slash | -33% | 108% | -$112 | $369 |
| **Community Average** | **-33%** | **104%** | **-$102** | **$322** |
| **Brookings** | | | | |
| Urban (non-burnable) | -21% | 83% | -$331 | $1,281 |
| Shrubs – Brush | -32% | 84% | -$565 | $1,483 |
| Timber – Needle and leaf litter only | -24% | 79% | -$399 | $1,335 |
| Timber – Hardwood litter and occasional dead-down material | -19% | 58% | -$410 | $1,267 |
| **Community Average** | -22% | 80% | -$368 | $1,306 |
| **Sweet Home** | | | | |
| Urban (non-burnable) | -8% | 0% | $0 | $0 |
| Grass – Short | -5% | 1% | $0 | $0 |
| Grass – Timber understory | -6% | 0% | $0 | $0 |
| **Community Average** | -7% | 0% | $0 | $0 |

**Figure 32: Mean Average Annual Loss Difference from Neutral ($) by Community, Oregon**




Not surprisingly, we see that the largest AAL dollar value differences incurred from well-built wildfire resistant structures happen where the wildfire risk is greatest in Brookings. Here, expected losses are on average $368 less from the neutral setting for well-built wildfire resistant structures. Conversely, poorly built wildfire structures in Brookings have mean AAL increases that are on average $1,306 higher than the neutral setting. In total, moving from a poorly built wildfire resistant structure to a well-built one in Brookings saves on average $1,674 annually in wildfire expected losses.

While AAL percent differences in Shadow Hills were the largest for all three Oregon communities, expected losses are on average $102 less from the neutral setting and AAL increases $322 more on average as compared to a neutral setting. Overall then, moving from a poorly built wildfire resistant structure to a well-built one in Shadow Hills saves on average $425 annually in wildfire expected losses.

## Structural Plus Vegetation Mitigation Benfits - Oregon

In addition to the structural credits and penalties only, we also apply two distance to vegetation mitigation cases where we apply both distance to vegetation maximum credits (160 feet of defensible space) and distance to vegetation maximum penalties (less than 5 feet of defensible space). As described earlier, the vegetation credit is only applied in addition to the structural credit, and the vegetation penalty is only applied in addition to the structural penalty. The table below, Table 18, presents both the mean AAL percent difference and the mean AAL dollar value difference from the neutral setting results for all fuel types in each community as well as for the overall community. Note that in the table, “Veg Credit” values are the combined mitigation loss reductions of a well-built wildfire resistant structure with the additional distance to vegetation mitigation. And similarly, the “Veg Penalty” values are the combined mitigation penalties of a poorly built wildfire resistant structure with the additional distance to vegetation penalty applied. “STR Credits” and “STR Penalty” values are as they were in Table 17 above.

**Table 18: Credits and Penalties of the Structural and Vegetation Mitigation relative to Neutral Scenario for locations in various fuel classes**

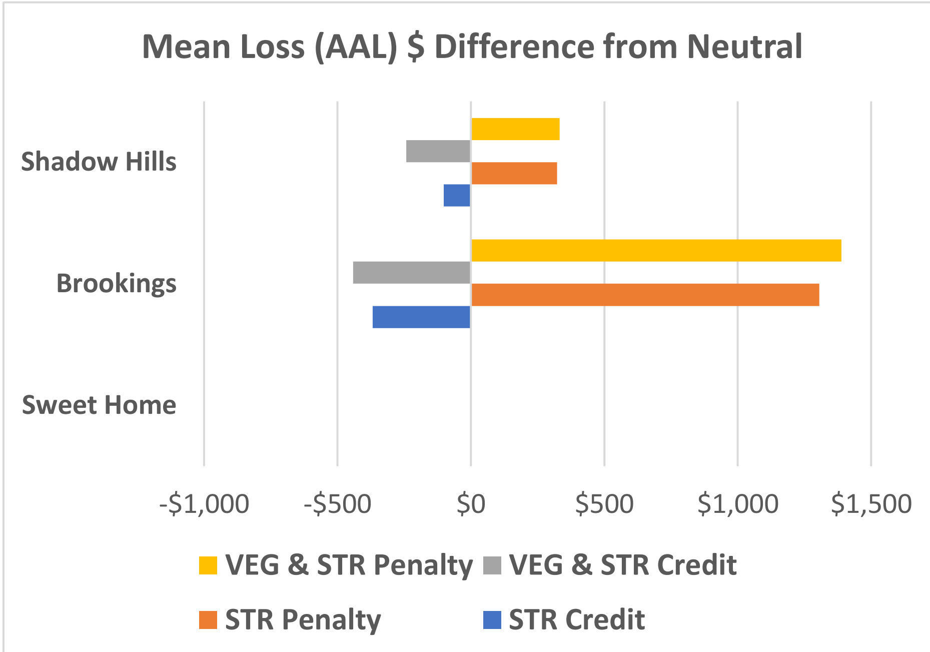
| Fuel Type | VEG Credit | STR Credit | STR Penalty | VEG Penalty | VEG Credit | STR Credit | STR Penalty | VEG Penalty |
|---|---|---|---|---|---|---|---|---|
| Urban (non-burnable) | -35% | -33% | 64% | 247% | -$36 | -$33 | $66 | $251 |
| Grass – Short | -70% | -32% | 93% | 93% | -$149 | -$69 | $197 | $197 |
| Grass – Timber understory | -78% | -32% | 97% | 97% | -$221 | -$92 | $278 | $278 |
| Shrubs – Brush | -79% | -34% | 104% | 104% | -$246 | -$105 | $326 | $326 |
| Timber – Needle and leaf litter only | -75% | -36% | 103% | 103% | -$214 | -$103 | $294 | $294 |
| Timber – Hardwood litter and occasional dead-d | -79% | -33% | 104% | 104% | -$259 | -$106 | $338 | $338 |
| Timber / Slash | -79% | -33% | 108% | 108% | -$272 | -$112 | $369 | $369 |
| **Shadow Hills** | **-78%** | **-33%** | **104%** | **108%** | **-$242** | **-$102** | **$322** | **$333** |
| | | | | | | | | |
| Urban (non-burnable) | -21% | -21% | 83% | 89% | -$332 | -$331 | $1,281 | $1,387 |
| Shrubs – Brush | -47% | -32% | 84% | 84% | -$830 | -$565 | $1,483 | $1,483 |
| Timber – Needle and leaf litter only | -31% | -24% | 79% | 79% | -$521 | -$399 | $1,335 | $1,335 |
| Timber – Hardwood litter and occasional dead-d | -37% | -19% | 58% | 64% | -$802 | -$410 | $1,267 | $1,395 |
| **Brookings** | **-27%** | **-22%** | **80%** | **85%** | **-$441** | **-$368** | **$1,306** | **$1,388** |
| | | | | | | | | |
| Urban (non-burnable) | -8% | -8% | 0% | 0% | $0 | $0 | $0 | $0 |
| Grass – Short | -5% | -5% | 1% | 1% | $0 | $0 | $0 | $0 |
| Grass – Timber understory | -6% | -6% | 0% | 0% | $0 | $0 | $0 | $0 |
| **Sweet Home** | **-7%** | **-7%** | **0%** | **0%** | **$0** | **$0** | **$0** | **$0** |

From these results we can ascertain the marginal value provided by the vegetation-based mitigation (i.e., building a defensible space around one's home) in addition to the structural mitigation efforts that have already been afforded to the structure. In Shadow Hills, the overall combined vegetation and structural percentage AAL reduction is 78 percent, with vegetation mitigation providing an additional 45 percent in mitigation benefits on average at the margin. In Brookings, the overall combined vegetation and structural percentage AAL reduction is 27 percent, with vegetation mitigation providing an additional 5 percent in mitigation benefits on average at the margin. However, in Sweet Home we determine no additional benefit on average in this community since the baseline distance to nearest vegetation is already at 160 feet or more for most homes given that 96 percent of the structures in our analysis are of an urban fuel type.

We can also examine the marginal impact of a vegetation penalty in addition to the structural penalties already in place. In this scenario, our AAL results show that an additional vegetation penalty makes relatively minimal difference to expected losses. In Shadow Hills penalties go from 104 percent penalty on average for the poorly built wildfire resistant structure to 108 percent with the additional poorly maintained distance to vegetation. In Brookings penalties go from 80 percent penalty on average for the poorly built wildfire resistant structure to 85 percent with the additional poorly maintained distance to vegetation.

Again, while percent differences are a useful measuring stick, the actual dollar value differences these percent differences represent are even more critical for implementing wildfire mitigation measures given the implementation costs. In the below figure, Figure 33, we present the structural and vegetation mitigation mean AAL dollar value differences for all three communities from the neutral value setting AAL results (mean AAL dollar value differences by fuel type are also presented in Table 18 above).

**Figure 33: Mean Average Annual Loss Difference from Neutral ($) by Community, Oregon**




Not surprisingly again, we see that the largest AAL dollar value differences incurred from well-built wildfire resistant structures with defensible space happen where the wildfire risk is greatest in Brookings. Here expected losses are on average $441 less from the neutral setting with the additional vegetation mitigation representing $73 of this amount. Conversely, poorly built wildfire structures combined with poorly maintained defensible space in Brookings have mean AAL increases that are on average $1,388 higher than the neutral setting with the vegetation penalty representing only $82 of this amount. In total then moving from a poorly built wildfire resistant structure with poorly maintained defensible space to a well-built one with well-maintained defensible space in Brookings saves on average $1,829 annually in wildfire expected losses.

In Shadow Hills expected losses are on average $242 less from the neutral setting with the additional vegetation mitigation representing $139 of this amount. Conversely, poorly built wildfire structures combined with poorly maintained defensible space in Shadow Hills have mean AAL increases that are on average $333 higher than the neutral setting with the vegetation penalty only increasing this total amount by $11. In total then moving from a poorly built wildfire resistant structure with poorly maintained defensible space to a well-built one with well-maintained defensible space in Shadow Hills saves on average $575 annually in wildfire expected losses. In Sweet Home, there is no meaningful difference in the vegetation mitigation results as compared to the structural only results.

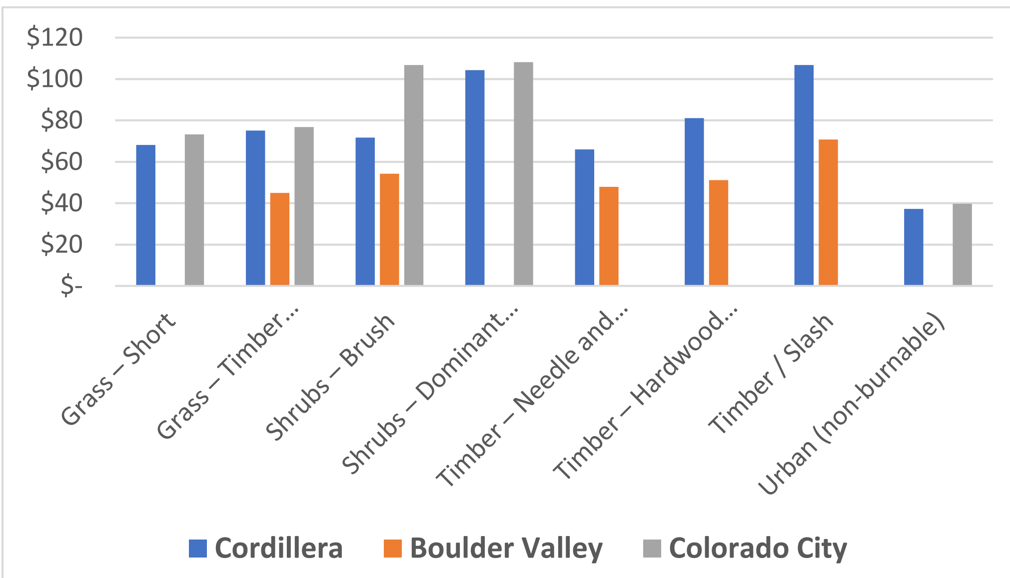
# Colorado Community Mitigation Benefits

## Comparison to Prevailing Insurance Rates - Colorado

For our 3 Colorado communities of Cordillera (341 structures), Boulder Valley (85 structures), and Colorado City (142 structures), mean AAL across all structures in each community is $71, $54, and $75 respectively when all secondary modifiers have been set to the neutral setting. Therefore, on average the wildfire risk in Cordillera is 1.3 times greater than the wildfire risk in Boulder Valley, and approximately equal to the wildfire risk in Colorado City.

As noted earlier, local conditions in the immediate vicinity of a structure including the fuel type are critical for estimating the likelihood of ignition during a wildfire. In Figure 34 we present the mean AAL by fuel type per community. In Cordillera, AAL ranges from $37 for urban fuel type (5% of total structures) to $107 for timber/slash fuel type (4% of total structures). In Boulder Valley, AAL ranges from $45 for grass-timber understory fuel type (1% of total structures) to $71 for timber/slash fuel type (20% of total structures). And in Colorado City AAL ranges from $40 for urban fuel type (34% of total structures) to $108 for shrubs-dominant brush, hardwood slash fuel type (9% of total structures)

**Figure 34: Mean Average Annual Loss by Community, Colorado**




These determined AALs represent an unloaded premium for wildfire risk only. For relative comparison purposes, we pulled the Colorado 2017 NAIC state-wide premium data in Table 19. In 2017, Colorado HO-3 average premium values were $2,466 and Colorado HO-5 average premium values were $2,921, both for exposure values $500,000 and over. These are the nearest NAIC premium values matching to our Colorado communities modeled structure total insured value that ranges from $325,414 to $1,489,947.

**Table 19: Colorado Average Premium and Loss Costs for expposure values $500,000 or more (NAIC 2017)**

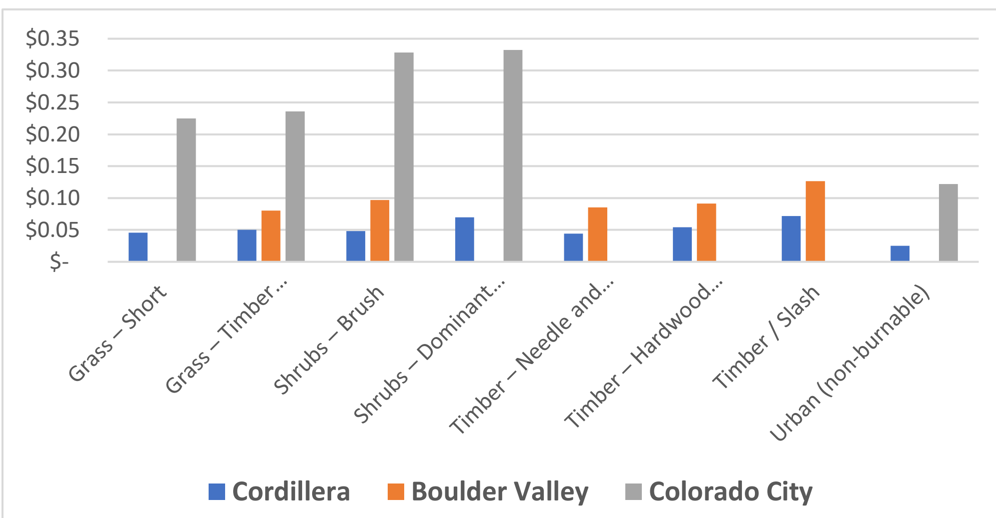
| Policy Type | Average Premium | Loss Cost ($ / $1000) |
|---|---|---|
| HO-3 | $2,466 | $4.93 |
| HO-5 | $2,921 | $5.84 |

Source (NAIC Premiums); Loss Cost = Premium / $500,000 * $1000

Thus, our determined wildfire AAL value per fuel type as a percentage of the Colorado NAIC H0-3 state-wide average premium are: 1.5% to 4.3% in Cordillera; 1.8% to 2.9% in Boulder Valley; and 1.6% to 4.4% in Colorado City. Of course, these NAIC premium values do account for more than just wildfire risk. While it is unknown how much of the existing 2017 premium accounts for wildfire risk, our determined wildfire risk AAL represents a relatively small percentage of existing premiums in all three Colorado communities.

All else being equal, AAL will be higher the larger is the TIV. To account for the TIV impact on our determined AAL we calculate the loss costs per $1000 of insurance coverage which is equal to the (AAL/TIV) * 1000. In Figure 35 we present the mean loss cost per $1000 of coverage by fuel type per community. In Cordillera, loss costs per $1000 of coverage range from $0.03 for urban fuel type (5% of total structures) to $0.07 for timber/slash fuel type (4% of total structures). In Boulder Valley, loss costs per $1000 of coverage range from $0.08 for grass-timber understory fuel type (1% of total structures) to $0.13 for timber/slash fuel type (20% of total structures). And in Colorado City loss costs per $1000 of coverage range from $0.12 for urban fuel type (34% of total structures) to $0.33 for shrubs-dominant brush, hardwood slash fuel type (9% of total structures). For our three Colorado communities, given the differences in TIV representing loss costs per $1000 coverage we see now that the mean wildfire risk in Colorado City compared to Cordillera is 4.8 times higher, not relatively equal as was the case with the mean AAL values.

**Figure 35: Loss Cost per $1000 of Coverage by Fuel Type for Colorado communities**



Again, for relative comparison purposes, we determined a loss cost per $1000 of coverage from the Colorado 2017 NAIC state-wide premium data (Table 19) . In 2017, Colorado HO-3 loss costs per $1000 coverage were $4.93 and Colorado HO-5 loss costs per $1000 coverage were $5.84, both for exposure values $500,000 and over.

Thus, our determined wildfire loss costs per $1000 of coverage values per fuel type as a percentage of the Colorado NAIC H0-3 state-wide loss costs per $1000 of coverage are: 0.5% to 1.5% in Cordillera; 1.6% to 2.6% in Boulder Valley; and 2.5% to 6.7% in Colorado City. Wildfire loss cost per $1000 coverage are still relatively insignificant in all three Colorado communities.

Normalizing associated with Loss Cost means that we can compare risks within and between the communities. In Figure 36 to Figure 38, the variation of the loss costs for each notional location are plotted with the same color ramp in the legend. These plots show that there are variations within the communities that are related to the nearby fuels, local topography, and distance to dense vegetation. As with the similar figures in California and Oregon presented earlier, the variations in loss cost within these communities highlight the need to use location specific data for pricing development.

## Potential for Extreme Wildfire Losses - Colorado

The EP curve also provides the probability of surpassing any loss level, expressing this probability in the form of a return period. Return periods are calculated by sorting the occurrence and yearly losses to create occurrence (OEP) and aggregate (AEP) curves, respectively. These curves are often used to look up key return period losses, such as 1 in 100 or 1 in 250, to help with solvency, rating agency evaluation, and reinsurance purchasing decisions. They can also be used to understand the tail risks of the loss distribution.

**Figure 36: Cordillera sub-division community; Aerial view (left) and Loss Cost Map (Right)**

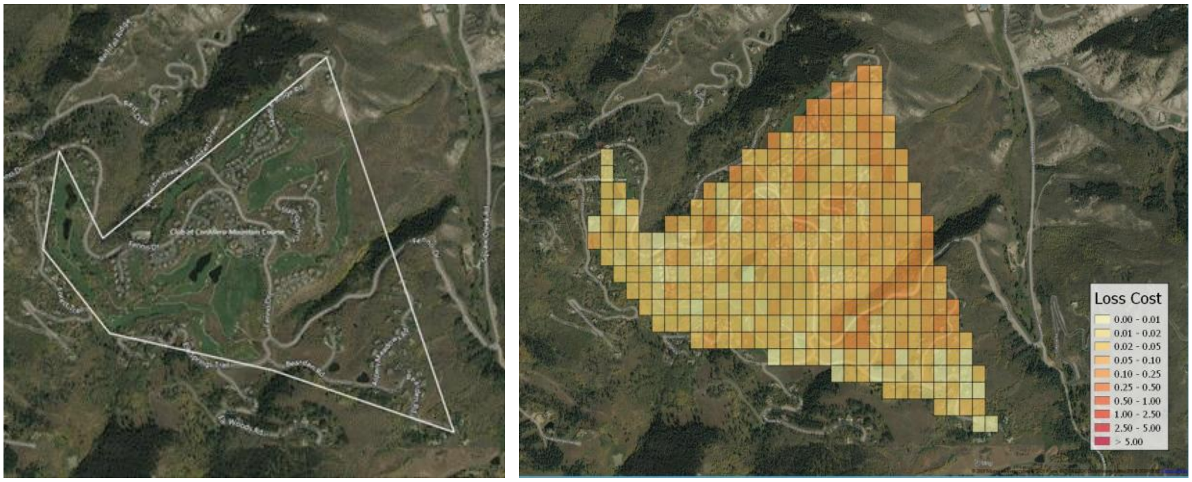



**Figure 37: Boulder Valley sub-division community; Aerial view (left) and Loss Cost Map (Right)**

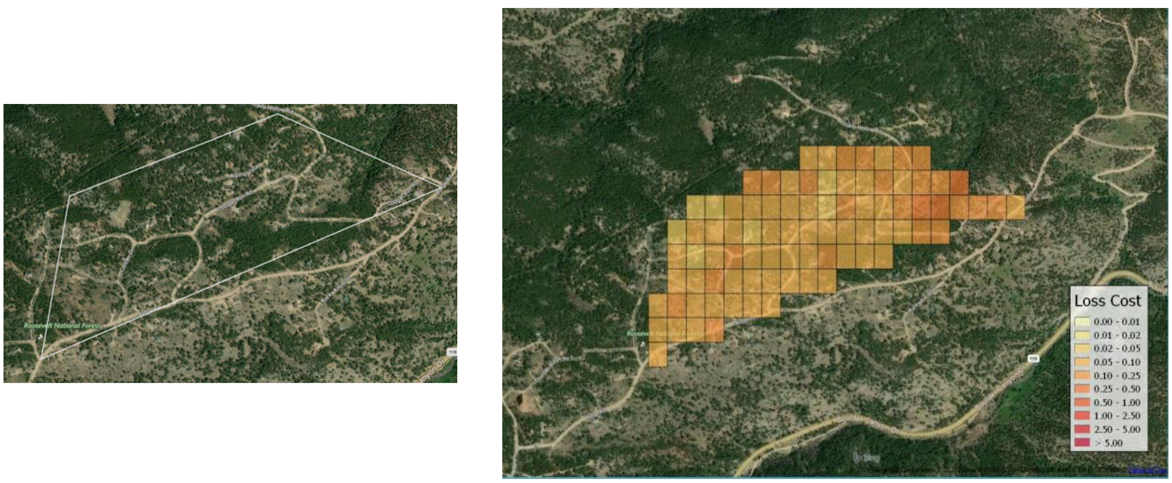
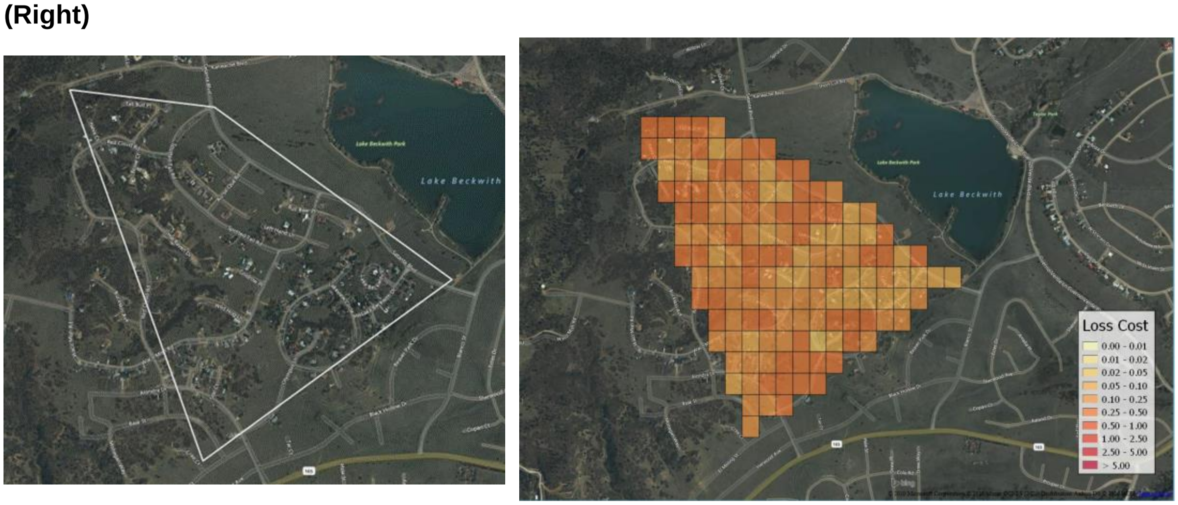



**Figure 38: Colorado City sub-division community; Aerial view (left) and Loss Cost Map (Right)**



In Table 20, we present the various OEP return period (100, 250, 500, 1000 and 10,000 year) mean losses and losses per $1000 of coverage for each of the three Colorado communities. We can see that the mean 1000 year return period loss in Colorado City is the most significant 1000 year return period loss at $30,708 which given TIV of $325,414 is a $94.37 loss per $1000 coverage. Boulder Valley mean 1000 year return period loss is $19,700 which given TIV of $559K is $35.21 loss per $1000 coverage. Importantly, these tail return period losses highlight the potential significant impact of just one event occurring in a community, an aspect that is not as readily apparent from the AAL view of loss. For example, the 10,000 year loss event in Cordillera has a normalized RP loss of $108 per thousand, whereas the loss cost (average annual loss / TIV) for Cordillera is a tiny amount of about $0.05 reflecting the possible but extremely rare likelihood of a very severe event.

**Table 20: Typical Return Period Losses for community reported as loss per notional structure, and normalized loss.**

| Community / Return Period | Average RP Loss per Structure | Normalized RP Loss per $1000 Coverage |
|---|---|---|
| **Cordillera (FireWise)** | | |
| 10,000 yr. | $161,813 of 1,489,000 | 108.60 |
| 1,000 yr. | $919 | 0.62 |
| 500 yr. | $101 | 0.07 |
| 250 yr. | $0 | 0.00 |
| 100 yr. | $0 | 0.00 |
| **Boulder Valley** | | |
| 10,000 yr. | $72,425 of $559,000 | 129.46 |
| 1,000 yr. | $19,700 | 35.21 |
| 500 yr. | $4,022 | 7.19 |
| 250 yr. | $322 | 0.57 |
| 100 yr. | $0 | 0.00 |
| **Colorado City** | | |
| 10,000 yr. | $57,895 of $325,000 | 177.91 |
| 1,000 yr. | $30,708 | 94.37 |
| 500 yr. | $16,990 | 52.21 |
| 250 yr. | $278 | 0.85 |
| 100 yr. | $10 | 0.03 |

## Structural Mitigation Benefits -Colorado

Given our neutral setting AAL results, we determine the structural maximum credit and the structural maximum penalty as differences from these values by adjusting the ten secondary modifiers (roof system covering, roof shape, roof age, roof vents, ember accumulators, suppression, wall cladding, patio deck, opening heat resistance, and accessibility) simultaneously for each structure in each community. The table below, Table 21, presents both the mean AAL percent difference and the mean AAL dollar value difference from the neutral setting results for all fuel types in each community as well as for the overall community.

**Table 21: Credits and Penalties of the Structural Mitigation relative to Neutral Scenario for locations in various fuel classes**

| Fuel Type | STR Credit | STR Penalty | STR Credit | STR Penalty |
|---|---|---|---|---|
| **Cordillera** | | | | |
| Urban (non-burnable) | -23% | 33% | -$9 | $12 |
| Grass – Short | -34% | 76% | -$23 | $52 |
| Grass – Timber understory | -36% | 78% | -$27 | $58 |
| Shrubs – Brush | -36% | 94% | -$26 | $68 |
| Shrubs – Dominant brush, hardwood slash | -37% | 105% | -$38 | $110 |
| Timber – Needle and leaf litter only | -36% | 93% | -$24 | $62 |
| Timber – Hardwood litter and occasional dead-down material | -37% | 91% | -$30 | $74 |
| Timber / Slash | -36% | 107% | -$39 | $114 |
| **Community Average** | **-35%** | **84%** | **-$25** | **$60** |
| **Boulder Valley** | | | | |
| Grass – Timber understory | -40% | 93% | -$18 | $42 |
| Shrubs – Brush | -41% | 97% | -$22 | $53 |
| Timber – Needle and leaf litter only | -41% | 92% | -$20 | $44 |
| Timber – Hardwood litter and occasional dead-down material | -41% | 92% | -$21 | $47 |
| Timber / Slash | -41% | 104% | -$29 | $73 |
| **Community Average** | **-41%** | **96%** | **-$22** | **$52** |
| **Colorado City** | | | | |
| Urban (non-burnable) | -30% | 58% | -$12 | $23 |

| Fuel Type | STR Credit | STR Penalty | STR Credit | STR Penalty |
|---|---|---|---|---|
| Grass – Short | -39% | 91% | -$29 | $67 |
| Grass – Timber understory | -39% | 91% | -$30 | $70 |
| Shrubs – Brush | -42% | 103% | -$44 | $110 |
| Shrubs – Dominant brush, hardwood slash | -41% | 106% | -$45 | $114 |
| **Community Average** | **-39%** | **92%** | **-$29** | **$68** |

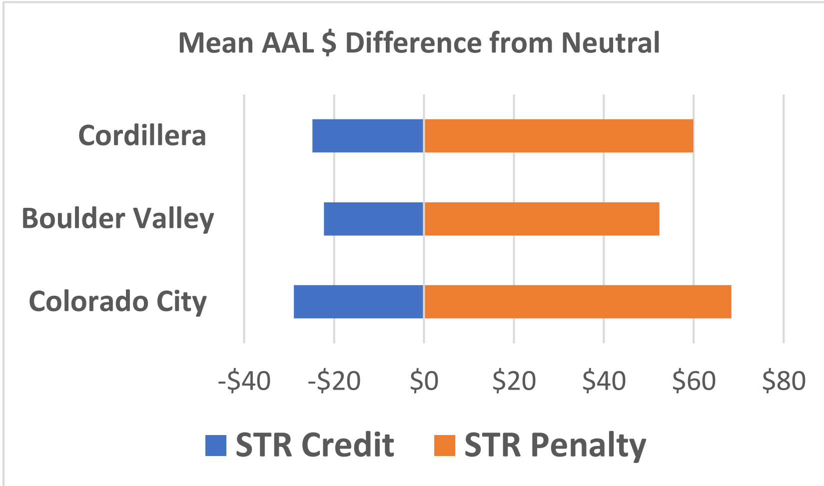
Looking across all three communities we see that on average structural credits as a percentage difference from the neutral value AALs are significant ranging anywhere from 23 to 42 percent reductions in expected losses depending upon the fuel type. These percent differences are highest in Boulder Valley (41% less on average), but certain fuel types in the other communities are comparable such as timber-hardwood litter fuel types in Cordillera (37% less on average) and shrubs-brush fuel types in Colorado City (42% less on average).

Conversely, poorly built wildfire resistant structures suffer even more significant structural penalties as a percentage difference from the neutral value AALs. For example, Boulder Valley penalties across all structure are 96 percent higher on average, whereas Cordillera and Colorado City are 84 percent and 92 percent higher on average, respectively. Outside of the two urban fuel type penalties in Cordillera and Colorado City (33 and 58 percent penalties), there is not one fuel type in any of our communities that does not incur at least a 76 percent penalty from the neutral value AALs when moving to a poorly built wildfire resistant structure.

Additionally, another way of thinking about these results is not just moving from an assumed CAT modeling neutral setting, but rather from a poorly built wildfire resistant structure to a well-built one. From this perspective, mean community AAL percent differences are 119 percent in Cordillera, 137 percent in Boulder Valley, and 130 percent in Colorado City. Clearly, from an expected loss percentage reduction perspective substantial differences are achieved from this view for all three communities.

However, while percent differences are a useful measuring stick, the actual dollar value differences these percent differences represent are even more critical for implementing wildfire mitigation measures given the implementation costs. In the below figure, Figure 39, we present the mean AAL dollar value differences for all three communities from the neutral value setting AAL results (mean AAL dollar value differences by fuel type are also presented in the Table 21).

**Figure 39: Mean AAL Difference from Neutral ($)**




Not surprisingly, we see that the largest AAL dollar value differences incurred from well-built wildfire resistant structures happen where the wildfire risk is greatest in Colorado City. Here, expected losses are on average $29 less from the neutral setting for well-built wildfire resistant structures. Conversely, poorly built wildfire structures in Colorado City have mean AAL increases that are on average $68 higher than the neutral setting. In total, moving from a poorly built wildfire resistant structure to a well-built one in Colorado City saves on average $97 annually in wildfire expected losses.

While AAL percent differences in Boulder Valley were the largest for all three Colorado communities, expected losses are on average $22 less from the neutral setting and AAL increases $52 more on average as compared to a neutral setting. Overall, moving from a poorly built wildfire resistant structure to a well-built one in Boulder Valley saves on average $75 annually in wildfire expected losses. In Cordillera, moving from a poorly built wildfire resistant structure to a well-built one saves on average $85 annually in wildfire expected losses.

## Structural Plus Vegetation Mitigation Benefits - Colorado

In addition to the structural credits and penalties only, we also apply two distance to vegetation mitigation cases where we apply both distance to vegetation maximum credits (160 feet of defensible space) and distance to vegetation maximum penalties (less than 5 feet of defensible space). As described earlier, the vegetation credit is only applied in addition to the structural credit, and the vegetation penalty is only applied in addition to the structural penalty. Table 22 presents both the mean AAL percent difference and the mean AAL dollar value difference from the neutral setting results for all fuel types in each community as well as for the overall community. Note that in the table "Veg Credit" values are the combined mitigation loss reductions of a well-built wildfire resistant structure with the additional distance to vegetation mitigation. And similarly, the "Veg Penalty" values are the combined mitigation penalties of a poorly built wildfire resistant structure with the additional distance to vegetation penalty applied. "STR Credits" and "STR Penalty" values are as they were in Table 21.

From these results we can ascertain the marginal value provided by the vegetation-based mitigation (i.e., building a defensible space around one's home) in addition to the structural mitigation efforts that have already been afforded to the structure. In Cordillera, the overall combined vegetation and structural percentage AAL reduction is 66 percent, with vegetation mitigation providing an additional 32 percent in mitigation benefits on average at the margin. In Boulder Valley, the overall combined vegetation and structural percentage AAL reduction is 61 percent, with vegetation mitigation providing an additional 20 percent in mitigation benefits on average at the margin. In Colorado City, the overall combined vegetation and structural percentage AAL reduction is 70 percent, with vegetation mitigation providing an additional 31 percent in mitigation benefits on average at the margin.

We can also examine the marginal impact of a vegetation penalty in addition to the structural penalties already in place. In Cordillera penalties go from 84 percent penalty on average for the poorly built wildfire resistant structure to 89 percent with the additional poorly maintained distance to vegetation. In Brookings penalties are 96 percent on average for the poorly built wildfire resistant structure and remain at 96 percent with the additional poorly maintained distance to vegetation. However, in Colorado City penalties go from 92 percent penalty on average for the poorly built wildfire resistant structure to 125 percent on average with the additional poorly maintained distance to vegetation. We see the largest increase here with the urban fuel types moving from 58 percent to 228 percent penalties.

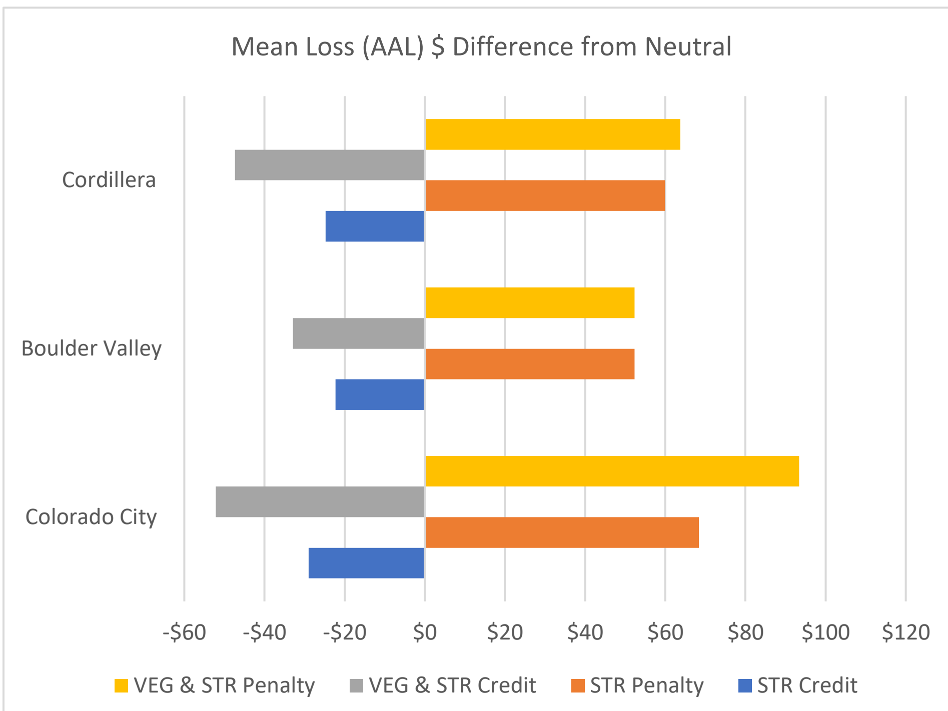
**Table 22: Credits and Penalties of the Structural and Vegetation Mitigation relative to Neutral Scenario for locations in various fuel classes**

| Fuel Type | VEG Credit | STR Credit | STR Penalty | VEG Penalty | VEG Credit | STR Credit | STR Penalty | VEG Penalty |
|---|---|---|---|---|---|---|---|---|
| Urban (non-burnable) | -33% | -23.3% | 33% | 187% | -$12 | -$9 | $12 | $70 |
| Grass – Short | -62% | -33.7% | 76% | 79% | -$42 | -$23 | $52 | $54 |
| Grass – Timber understory | -62% | -35.5% | 78% | 78% | -$47 | -$27 | $58 | $58 |
| Shrubs – Brush | -72% | -36.5% | 94% | 94% | -$52 | -$26 | $68 | $68 |
| Shrubs – Dominant brush, hardwood slash | -78% | -36.6% | 105% | 105% | -$82 | -$38 | $110 | $110 |
| Timber – Needle and leaf litter only | -72% | -35.9% | 93% | 93% | -$48 | -$24 | $62 | $62 |
| Timber – Hardwood litter and occasional dead-d | -71% | -37.2% | 91% | 93% | -$58 | -$30 | $74 | $75 |
| Timber / Slash | -81% | -36.4% | 107% | 107% | -$87 | -$39 | $114 | $114 |
| **Cordillera** | **-66%** | **-35%** | **84%** | **89%** | **-$47** | **-$25** | **$60** | **$64** |
| | | | | | | | | |
| Grass – Timber understory | -53% | -40% | 93% | 93% | -$24 | -$18 | $42 | $42 |
| Shrubs – Brush | -62% | -41% | 97% | 97% | -$34 | -$22 | $53 | $53 |
| Timber – Needle and leaf litter only | -57% | -41% | 92% | 92% | -$27 | -$20 | $44 | $44 |
| Timber – Hardwood litter and occasional dead-d | -55% | -41% | 92% | 92% | -$28 | -$21 | $47 | $47 |
| Timber / Slash | -66% | -41% | 104% | 104% | -$47 | -$29 | $73 | $73 |
| **Boulder Valley** | **-61%** | **-41%** | **96%** | **96%** | **-$33** | **-$22** | **$52** | **$52** |
| | | | | | | | | |
| Urban (non-burnable) | -44% | -30.1% | 58% | 228% | -$18 | -$12 | $23 | $91 |
| Grass – Short | -69% | -39.2% | 91% | 91% | -$51 | -$29 | $67 | $67 |
| Grass – Timber understory | -70% | -39.4% | 91% | 108% | -$54 | -$30 | $70 | $83 |
| Shrubs – Brush | -79% | -41.6% | 103% | 104% | -$84 | -$44 | $110 | $111 |
| Shrubs – Dominant brush, hardwood slash | -79% | -41.2% | 106% | 112% | -$86 | -$45 | $114 | $121 |
| **Colorado City** | **-70%** | **-39%** | **92%** | **125%** | **-$52** | **-$29** | **$68** | **$93** |

Again, while percent differences are a useful measuring stick, the actual dollar value differences these percent differences represent are even more critical for implementing wildfire mitigation measures given the implementation costs. In the below figure (Figure 40) we present the structural and vegetation mitigation mean AAL dollar value differences for all three communities from the neutral value setting AAL results (mean AAL dollar value differences by fuel type are also presented above in Table 22).

Not surprisingly again, we see that the largest AAL dollar value differences incurred from well-built wildfire resistant structures with defensible space happen where the wildfire risk is greatest in Colorado City. Here expected losses are on average $52 less from the neutral setting with the additional vegetation mitigation representing $23 of this amount. Conversely, poorly built wildfire structures combined with poorly maintained defensible space in Colorado City have mean AAL increases that are on average $93 higher than the neutral setting with the vegetation penalty representing only $25 of this amount. In total then moving from a poorly built wildfire resistant structure with poorly maintained defensible space to a well-built one with well-maintained defensible space in Colorado City saves on average $145 annually in wildfire expected losses.

**Figure 40: Mean Loss (AAL) Difference from Neutral ($) – All Mitigation Cases**




In Boulder Valley expected losses are on average $33 less from the neutral setting with the additional vegetation mitigation representing $11 of this amount. Conversely, poorly built wildfire structures combined with poorly maintained defensible space in Boulder Valley have mean AAL increases that are on average $52 higher than the neutral setting with the vegetation penalty not increasing this total amount. In total then moving from a poorly built wildfire resistant structure with poorly maintained defensible space to a well-built one with well-maintained defensible space in Boulder Valley saves on average $85 annually in wildfire expected losses. In Cordillera, expected losses are on average $47 less from the neutral setting with the additional vegetation mitigation representing $23 of this amount. Conversely, poorly built wildfire structures combined with poorly maintained defensible space in Cordillera have mean AAL increases that are on average $64 higher than the neutral setting with the vegetation penalty increasing this total amount by $4. In total then moving from a poorly built wildfire resistant structure with poorly maintained defensible space to a well-built one with well-maintained defensible space in Cordillera saves on average $111 annually in wildfire expected losses.

# Benefit-Cost Analysis of Wildfire Mitigation

From an economic perspective, undertaking an action such as wildfire mitigation is considered worthwhile when the benefits are greater than the costs. Further, these benefits and costs can be accrued over different future time periods, where benefits and costs occurring in future periods need to be discounted to compute the present value. In a benefit-cost analysis (BCA), all costs and benefits accruing over time are monetized and aggregated so that they can be compared using the common economic efficiency criterion.

In general, if the stream of discounted benefits exceeds the stream of discounted costs (i.e., positive net present value economic benefits) a proposal is considered 'economically-efficient'. During the BCA, the total discounted benefits are divided by the total discounted costs. By definition, a benefit-cost ratio of 1 means that the expected discounted benefit of implementing the mitigation equals its cost. Any measure where a benefit-cost ratio is greater (less) than 1 is considered to be economically-efficient (not economically-efficient) and should (should not) be implemented as the benefits exceed (do not exceed) costs and a project thus adds (does not add) value to society.

To undertake a BCA of wildfire mitigation across different time horizons and discount rates as we do below, we first need to consider the costs of wildfire mitigation

## Wildfire Mitigation Costs

Undertaking wildfire mitigation measures incurs an upfront cost. For existing residences, Headwaters Economics (Headwaters, 2018) estimated the costs of retrofitting the roof and exterior walls from a "typical" property to a wildfire resistant one. Costs were estimated for a 2,500-square-foot, single-story, single-family home representative of wildland-urban interface building styles in southwest Montana. The typical home was assumed to have an asphalt shingle roof, wood siding, dual-pane windows, and a wood deck. Wildfire-resistant materials were selected for similar aesthetics but also comply with wildfire-resistant building codes. Their estimated costs are presented in Table 23 which shows roof retrofit costs including roofing, vents, soffits, and gutters totalling $22,010. Retrofitting exterior walls including doors and windows is an additional $40,750 in costs. These retrofit costs would be best associated with the benefits of moving from a poorly built wildfire resistant structure to a well-built one from our catastrophe modeling results.

**Table 23: Cost of Retrofitting Roof and Exterior Wall from Typical to Wildfire-resistant.**

| | |
|---|---|
| **Roof** | |
| Roofing | 13,180 |
| Vents | 370 |
| Soffit & Fascia | 5,600 |
| Gutters | 2,860 |
| **Subtotal** | **$22,010** |
| | |
| **Exterior Walls** | |
| Sheathing and Siding | 20,580 |
| Doors | 8,120 |
| Windows | 12,050 |
| **Subtotal** | **$40,750** |

(Source: https://headwaterseconomics.org/wp-content/uploads/building-costs-codes-report.pdf)

IBHS also recently released retrofit cost estimates related to its recommended mitigation actions (IBHS, 2020). A cost range for each mitigation action is provided below. Costs of roofing, vents, and soffits comparable to the Headwaters study data would range from $12,200 to $30,200. Costs for replacing siding to stucco would be $20,000 to $30,000 as compared to the sheathing and siding costs of $20,580 from the Headwaters study. IBHS also included a cost for creating a defensible space around one's home ranging from $3000-$15,000. No primary characteristics were identified for these costs estimates.

**Table 24: Costs of Wildfire Mitigation options from IBHS**

| | | |
|---|---|---|
| Make sure your roof is fire-rated | Replacement cost of wood shake to asphalt comp class A roof: | $10,000–$25,000 |
| Create a buffer around your home (0-5 foot home ignition zone) | Landscape cost using a contractor (labor included): | $3,000–$15,000 |
| Add or upgrade your vent screens | Screen addition or replacement cost: (DIY) | $200 |
| Replace combustible fencing or gates attached to the home | | $500–$1,500 |
| Replace your siding | Cost for replacing just the lowest one foot of siding: | $2,000–$5,000 |
| | Cost for concrete-fiber board: | $8,000–$15,000 |
| | Cost for stucco: | $20,000–$30,000 |
| | Cost for brick or stone veneer: | >$40,000 (retrofit) |
| Enclose eaves | Boxed-in Eaves cost: | $500–$1,500 |
| | Soffit cost: | $2,000–$5,000 |
| Build a fire-resistant deck | Cost: For 500 sq ft deck, depending on complexity and footings | $9,000–$15,000 |
| Upgrade windows | Cost: per window (including labor) | $500–$1,000 |

(Source: modified from https://disastersafety.org/wildfire/wildfire-ready/)

Lastly, the natural hazard mitigation saves 2019 report (MMC, 2019) provides the estimated costs to retrofit a building to comply with the International wildland-urban interface code's chapter 5 requirements of classes 1, 2, and 3 ignition resistant construction. These costs were split out for building and vegetation related mitigation. The geometric mean for class 1 or 2 ignition resistant construction is $72,000.

**Table 25: Estimated Cost to Retrofit an Existing Home to Comply with the 2018 International Wildland-Urban Interface Code.**

| Mitigation | Class 1 | | Class 2 | | Class 3 | |
|---|---|---|---|---|---|---|
| | Suburban | Rural | Suburban | Rural | Suburban | Rural |
| Building | $ 72,200 | $80, 900 | $64,200 | $65,400 | $3000 | $3000 |
| Vegetation | $5000 | 0 | $2500 | 0 | $1250 | $1250 |
| Total | $77,200 | $,80,900 | $66,700 | $65,400 | $4250 | $4250 |
| Average | $79,050 | | $66,050 | | $4250 | |

(Source: MMC, 2019 - Natural Hazard Mitigation Saves - https://cdn.ymaws.com/www.nibs.org/resource/resmgr/reports/mitigation_saves_2019/mitigationsaves2019report.pdf)

These three wildfire risk reduction cost studies show that the costs for retrofitting the structural and vegetative aspects from a "typical" property to a wildfire resistant one can range fairly significantly depending upon the risk reduction activity being undertaken and the assumptions of the property. Overall, the data provides costs on the low end of the spectrum from about $25,000 in total depending upon the activities (e.g., estimated derived by simply taking the low end of the range for all activities from IBHS) to the high-end totalling around $75,000.

## Benefit-Cost Analysis Results

For our BCA, we utilize the determined average annual wildfire avoided losses moving from a poorly built wildfire resistant structure to a well-built wildfire resistant structure that we detailed earlier. These average annual avoided losses are for the structural only mitigation case as well as the structural and vegetation combined mitigation case (Table 26). We present the mean values by community in each state (note for Oregon, we do not present the Sweet Home community given the minimal values there that were <$1.00).

Given that these avoided losses are annual, we take them over time and discount them back to present value terms to compare to the upfront wildfire mitigation costs. We analyse results for 10, 25, and 50 year time horizons and with 1 and 3 percent assumed discount rates.[5] From the wildfire mitigation cost ranges discussed above, we run three costs scenarios: 1) low ($20,000 structural; $25,000 structural and vegetation); 2) medium ($40,000 structural; $50,000 structural and vegetation); and 3) high ($60,000 structural; $75,000 structural and vegetation).

**Table 26: Mean Average Annual Loss Difference for Mitigation Cases by Community**

| Community | Structural Mitigation Loss Difference | Structural & Vegetation Mitigation Loss Difference |
|---|---|---|
| **California** | | |
| Upper Deerwood | $ 3,307 | $ 4,529 |
| Berry Creek | $ 856 | $ 1,092 |
| Oroville | $ 26 | $ 27 |
| **Colorado** | | |
| Cordillera | $ 85 | $ 111 |
| Boulder Valley | $ 75 | $ 85 |
| Colorado City | $ 97 | $ 145 |
| **Oregon** | | |
| Shadow Hills | $ 425 | $ 575 |
| Brookings | $ 1,674 | $ 1,829 |

[5] These values are in-line with the assumptions utilized in the Natural Hazard Mitigation Saves report that utilized up to 75 year time horizons as well 2.2, 3, and 7 percent discount rates.

Mean Benefit-cost ratios by cost scenario and community assuming the 1 percent discount case are presented for the structural mitigation cases only in Table 27 and the structural plus vegetation mitigation cases in Table 28. Cases that are considered economically-efficient for the community, on average, are highlighted with green shading.

**Table 27: Mean Benefit Cost Ratios by Analysis Time (10,25,50 years) for Structural Mitigation Cases– 1% Discount**

| Community | Low Cost Scenario ($20,000 Structural) | | | Medium Cost Scenario ($40,000 Structural) | | | High Cost Scenario ($60,000 Structural) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 25 Year | 50 Year | 10 year | 25 Year | 50 Year | 10 year | 25 Year | 50 Year |
| **California** | | | | | | | | | |
| Upper Deerwood | 1.6 | 3.6 | 6.5 | 0.8 | 1.8 | 3.2 | 0.5 | 1.2 | 2.2 |
| Berry Creek | 0.4 | 0.9 | 1.7 | 0.2 | 0.5 | 0.8 | 0.1 | 0.3 | 0.6 |
| Oroville | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Colorado** | | | | | | | | | |
| Cordillera | 0.0 | 0.1 | 0.2 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 |
| Boulder Valley | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| Colorado City | 0.0 | 0.1 | 0.2 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 |
| **Oregon** | | | | | | | | | |
| Shadow Hills | 0.2 | 0.5 | 0.8 | 0.1 | 0.2 | 0.4 | 0.1 | 0.2 | 0.3 |
| Brookings | 0.8 | 1.8 | 3.3 | 0.4 | 0.9 | 1.6 | 0.3 | 0.6 | 1.1 |

**Table 28: Mean Benefit Cost Ratios by Analysis Time (10,25,50 years) for Structural+Vegetation Mitigation Cases– 1% Discount**

| Community | Low Cost Scenario ($20,000 Structural + $5000 Vegetation) | | | Medium Cost Scenario ($40,000 Structural +$10,000 Vegetation) | | | High Cost Scenario ($60,000 Structural+ $15,000 Vegetation) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 25 Year | 50 Year | 10 year | 25 Year | 50 Year | 10 year | 25 Year | 50 Year |
| **California** | | | | | | | | | |
| Upper Deerwood | 1.7 | 4.0 | 7.1 | 0.9 | 2.0 | 3.6 | 0.6 | 1.3 | 2.4 |
| Berry Creek | 0.4 | 1.0 | 1.7 | 0.2 | 0.5 | 0.9 | 0.1 | 0.3 | 0.6 |
| Oroville | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Colorado** | | | | | | | | | |
| Cordillera | 0.0 | 0.1 | 0.2 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 |
| Boulder Valley | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| Colorado City | 0.1 | 0.1 | 0.2 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 |
| **Oregon** | | | | | | | | | |
| Shadow Hills | 0.2 | 0.5 | 0.9 | 0.1 | 0.3 | 0.5 | 0.1 | 0.2 | 0.3 |
| Brookings | 0.7 | 1.6 | 2.9 | 0.3 | 0.8 | 1.4 | 0.2 | 0.5 | 1.0 |

**Table 29: Benefit Cost Ratios for Medium Cost Scenario ($40,000 Structural; $10,000 Vegetation) – 3 % Discount Case**

| Community | Structural Mitigation BC Ratios | | | Structural & Vegetation Mitigation BC Ratios | | |
|---|---|---|---|---|---|---|
| | 10 year | 25 Year | 50 Year | 10 year | 25 Year | 50 Year |
| **California** | | | | | | |
| Upper Deerwood | 0.7 | 1.4 | 2.1 | 0.8 | 1.6 | 2.3 |
| Berry Creek | 0.2 | 0.4 | 0.6 | 0.2 | 0.4 | 0.6 |
| Oroville | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Colorado** | | | | | | |
| Cordillera | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 |
| Boulder Valley | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Colorado City | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 |
| **Oregon** | | | | | | |
| Shadow Hills | 0.1 | 0.2 | 0.3 | 0.1 | 0.2 | 0.3 |
| Brookings | 0.4 | 0.7 | 1.1 | 0.3 | 0.6 | 0.9 |

Mean Benefit Cost ratios for the medium cost scenario and community assuming the 3% discount case are presented in Table 29.

While results are dependent upon the specific time horizon and discount rate levels, in all presented cost scenarios we find at least two communities where wildfire mitigation is deemed to be economically efficient on average across the community (indicated by green shading with mean BC ratios > = 1.0). In our low-cost scenario (and 1% discount rate), for 10, 25, and 50 year time horizons both structural only as well as structural and vegetation wildfire mitigation are economically efficient on average in the Upper Deerwood California community. For Berry Creek California, economic efficiency for structural mitigation is achieved on average in the 50 year time horizon and also in the 25 and 50 time horizons for structural and vegetation mitigation. Lastly, in Brookings, Oregon economic efficiency is achieved on average for structural mitigation in the 25 and 50 year time horizon, and also in the 25 and 50 time horizons for structural and vegetation mitigation.

As mitigation costs increase we see from our medium and high costs scenario results that only Upper Deerwood California and Brookings Oregon achieve any economic efficient wildfire mitigation results on average in any of the 9 communities. And in the high cost scenario for Brookings Oregon this is only for the 50 year time horizon.

However, this does not mean that individual structures in these higher cost scenarios do not achieve economically efficient mitigation results. For example, in Berry Creek in the medium cost scenario (1% discount rate) and for a 25 year time horizon, 6 of the 98 structure in the community have a BC ratio > 1. Further, 29 of the 98 structures in the Berry Creek community have a BC ratio of 0.8 or greater in this scenario. Indicating that if actions could be taken to reduce the direct costs of mitigation to the property owner, even more properties would find wildfire mitigation to be economically worthwhile.

# Policy Discussion

## Policy Implications of Results in Context of 2020 Wildfires

For homeowners in wildfire prone areas of the United States, as the underlying wildfire risk continues to increase there are exacerbating pressures on the affordability and availability of homeowner's insurance. Unfortunately, the 2020 wildfire season shows no indication that this insurance affordability and availability issue will abate anytime soon. For example, 5 of the 6 largest wildfires in California history have occurred in the 2020 season. Similarly, in Colorado where three of the four largest wildfires in state history have ignited just since July[6], and in Oregon where the 2020 wildfires in the state are some of the most destructive on record.

Furthermore, many of the 2020 fires in California are burning in areas that have been impacted by wildfires in the past five years (Figure 41). With already 4 million acres burned in 2020 alone in California – more than three times the annual average acreage burned in the 2010s – and climate research suggesting that the average area of California that burns may increase by more than 75%, clearly there is a need for improved wildfire risk reduction activities to play a more prominent role moving forward.

This reality of course has not gone unnoticed by policymakers in our study locations. For example, in 2019 the Governor's Council on Wildfire Response was created in Oregon. As part of their 2019 issued recommendations report (Oregon 2019), one of the recommendations ranked very high is focused on risk mitigation incentives as it relates to property insurance. Specifically, the recommendation calls for – "Support and encourage insurance industry implementation of innovative policy changes and underwriting standards. These updates would motivate policy holders to make changes aligned with Oregon Cohesive Wildfire Strategies; to harden structures, provide for and maintain defensible space, create access for fire vehicles and evacuation routes."

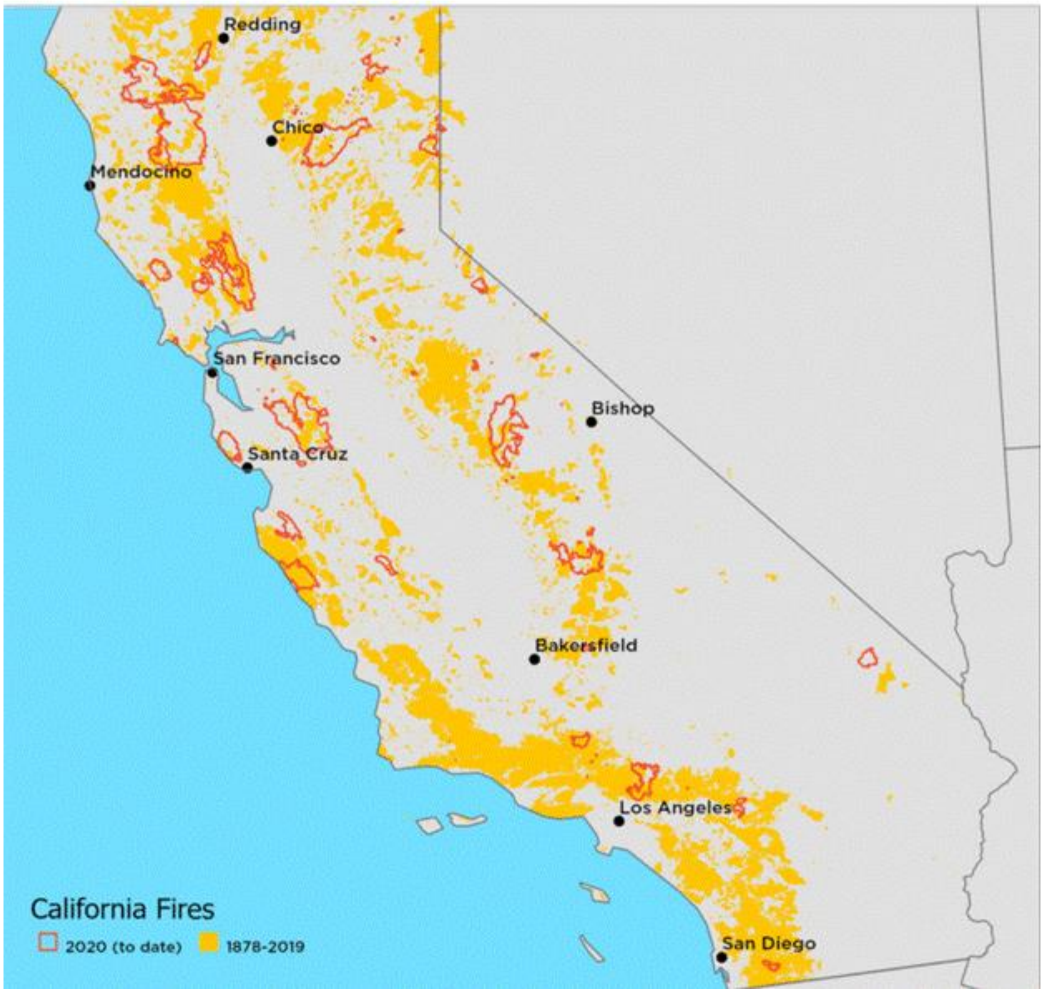
In California, the department of insurance has taken several actions since 2015 aimed at enhancing wildfire risk including developing incentives for homeowners to meet defensible space guidelines, alignment of a rating structure with IBHS risk-mitigation standards, and implementing community wide abatement programs (CDI, 2018). And as of the time of the writing of this report, California, Insurance Commissioner Ricardo Lara recently convened an investigatory hearing on Monday, October 19, 2020 to initiate a series of regulatory actions to include the following (CDI, 2020):

- Developing home-hardening standards that are consistent, based in fire science, and apply to all insurance companies.

[6] https://www.vox.com/2020/10/19/21522994/cameron-peak-calwood-colorado-wildfire-fire-record-east-troublesome-lefthand-canyon

- Giving transparency to consumers about their wildfire risk score and what they can do to reduce it. Insurance companies use wildfire risk scores to determine which homes they will write and the premium they charge.
- Creating insurance incentives recognizing home hardening, mitigation of properties, and community mitigation actions; and,
- Requiring that insurance companies seek adequate and justifiable rates to protect the solvency of the market

**Figure 41: Map of 2020 Wildfires relative to historical footprints 1878-2019)**




(Source: https://blog.ucsusa.org/kristy-dahl/5-of-californias-6-largest-fires-on-record-are-burning-now-the-astonishing-2020-wildfire-season-in-context)

Insurers have started to respond to the need for more homeowner risk reduction activities to take place as well. For example, again at the time of the writing of this report, on October 13, 2020 Mercury Insurance announced a new program the company is launching to help Californians better protect their homes and families if they live in areas prone to wildfires. Homeowners who take one or more steps to either harden their homes against wildfires or live in a community recognized by the

National Fire Protection Association® (NFPA) as a Firewise USA® site will be eligible to receive discounts of up to 18 percent. [7]

Clearly, there is a need for the type of analysis we have performed here to help to guide the implementation of such wildfire risk reduction actions as we have modeled and to inform the policy discussion for how to make this happen in an economically efficient manner.

And this need is immediate in communities we have selected for this analysis such as Berry Creek California where this risk is unfortunately something they have had to directly deal with in 2020. Berry Creek had the highest number of homes destroyed (1,147) and people killed (15) in the North Complex West Zone fire in September 2020[8] (Figure 42)

**Figure 42:Comparioson of Aerial views of Berry Creek after the North Complex Fire 2020.**


Source: https://www.mercurynews.com/2020/09/19/watch-officials-post-dramatic-drone-videos-before-and-after-photos-fire-devastation-near-berry-creek/

We do note that for our BCA analysis we have calculated only the direct economic benefits stemming from wildfire risk reduction and not considered other direct benefits (e.g., reduced fatalities and injuries), nor have we looked at the indirect economic benefits such as the savings in the costs of permanently relocating

7 (https://www.prnewswire.com/news-releases/mercury-insurance-launches-programs-to-help-california-homeowners-with-wildfire-risk-301149746.html#:~:text=FAIR%20Plan%20coverage.-,Mercury%20Insurance%20is%20one%20of%20the%20first%20companies%20to%20offer,portion%20of%20their%20insurance%20policy)

8 https://www.latimes.com/california/story/2020-09-22/the-people-in-this-california-town-have-much-to-begin-with-fire-took-it-away) and https://www.sacbee.com/news/california/fires/article245722090.html

residents, or related health impacts from wildfire exposure. Furthermore, wildfire risk reduction costs for new construction would be significantly lower than for existing construction, which could make mitigation of new homes much more appealing.

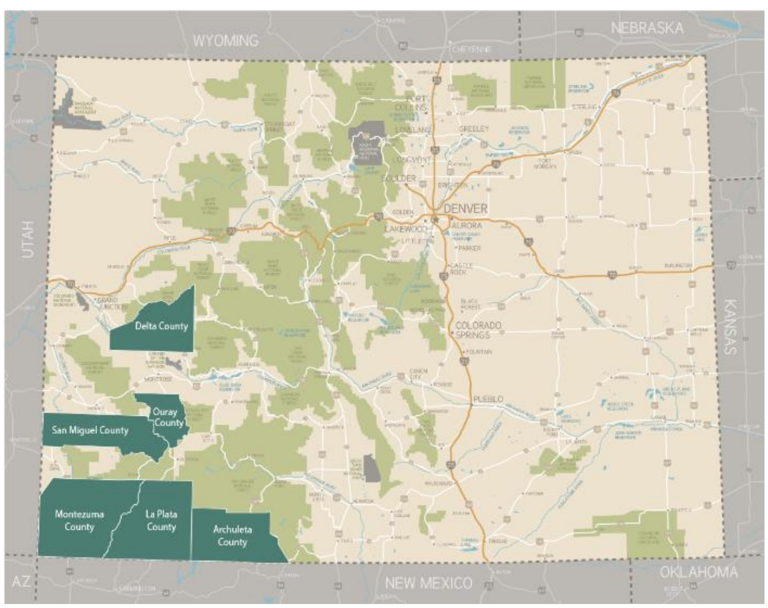
## Wildfire Risk Perception and Mitigation: Recent Research

While understanding the economic efficiency of wildfire risk reduction activity is critical for informing related policy making, homeowner behavior driven by perceptions of wilidfire risk can also be a key determinant of mitigation uptake. Here, we provide an overview of research reports by scientists affiliated with the Wildfire Research Team (WiRē), an interdisciplinary collaboration on community adaptedness to wildland fire based in Colorado. The WiRē consortium was formed to integrate local social science with wildfire education and mitigation. The group's research outputs combine two main forms of data collection:

- Rapid wildfire risk assessments, in which professionals rate the relative risk of a given property within its community based on factors including building materials, nearby vegetation, fire fuel, land topography, and fire department access.
- Social surveys of approximately 2,000 residents in the professionally-assessed communities to investigate their perceptions of wildfire risk, risk mitigation behaviors, and responses to incentives to mitigate risk.

An overview of key takeaways from these reports is described below in order to highlight central areas of discussion and lessons applicable for insurance regulators facing ongoing wildfire risk - particularly to consider the role of risk perception in wildfire risk reduction uptake.

**Figure 43: Wildfire risk assessment data came from interrelated studies conducted in 6 counties in western Colorado: Archuleta, Delta, La Plata, Montezuma, Ouray, and San Miguel.**



**Homeowners' perception of risk is complicated and multidirectional.**

Risk perception is influenced by numerous factors, including first-hand experience of wildfire or evacuation. While perceiving that they face wildfire risk can motivate people to undertake mitigation activities, such as clearing brush, completing mitigation activities can also make people expect their risk will be somewhat alleviated. Research by Meldrum et al. (2019) "suggests that residents conduct mitigation in the expectation that doing so will lower the chance that a fire burns on their property and that doing so will also reduce their home's vulnerability if that occurs" (p.13).

The researchers also found that people living in areas exposed to wildfire hazards largely understand their risk and make decisions based not only on their complicated risk perceptions but also factors that stand in the way of taking action and beliefs about how effective such efforts will be. Barriers to action include a lack of options for brush removal, time to work on outdoor mitigation projects, and money to complete such projects.

*Relevance to insurance regulation:* Information alone is not enough to motivate people in high-risk areas to take mitigation action. Homeowners understand wildfire risk but face other constraints. Outreach efforts should focus not only on providing information but also helping residents overcome barriers to mitigation, for example by offering cost-sharing programs or aiding elderly residents unable to complete work on their own.

**Compared to professional evaluation, people generally underestimate their property's wildfire risk.**

In a study comparing professional and homeowner assessments, residents generally rated their property more favorably related to risk factors such as fire-safe building materials and ease of access to their property for first responders. Trained professionals generally rated nearby vegetation as more dense, dangerous topography closer to structures, and the overall slope of property steeper than respondents did.

*Relevance to insurance regulation*: Professional assessment should be paired with self-assessment to help residents objectively evaluate the wildfire dangers they face. Insurance companies should conduct regular on-site inspections and help residents understand their property's particular issues, outlining steps toward mitigation.

**Wildfire mitigation must be a community effort.**

A majority of residents had spoken with their neighbors about wildfire. Those who had were more likely to maintain defensible space around their home and have a more fire-proof structure. In contrast, people who said their neighbors had dense vegetation around their homes had little defensible space on their own property. The upshot? Neighborhood relationships may contribute to increased community-wide wildfire mitigation efforts.

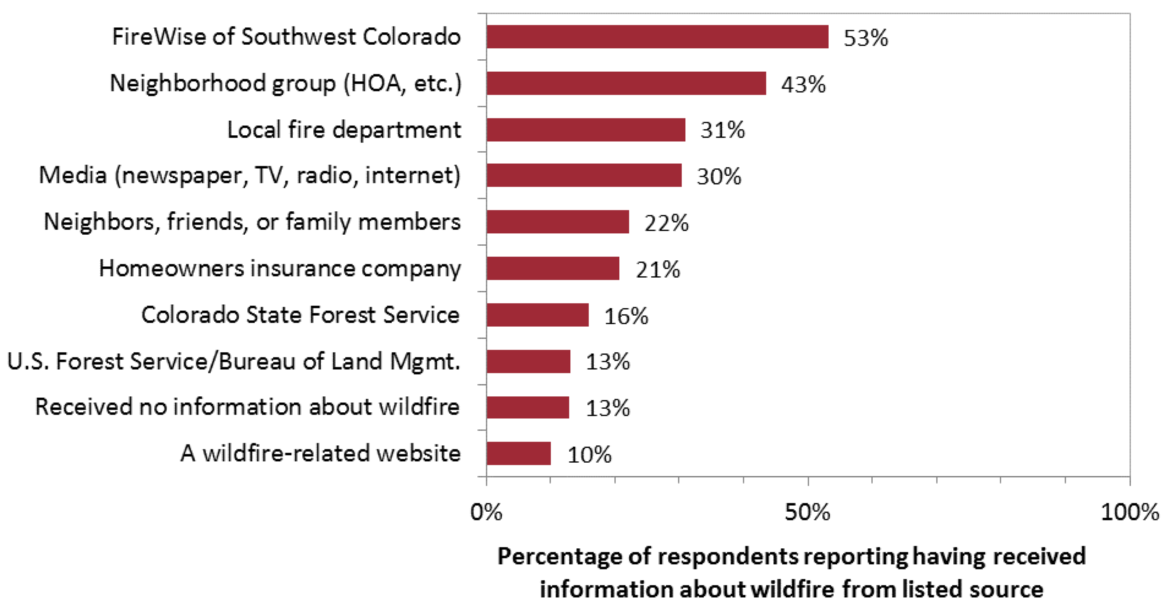
*Relevance to insurance regulation:* Organizations seeking to influence wildfire mitigation should focus on community-wide efforts to achieve wider results and help build relationships with positive spill over effects. Initiatives such as community chipper days could bring neighbors together to promote mitigation while helping them overcome stated barriers such as a lack of options for yard waste removal.

**Information gap:**

Compared with other sources of information, consumers reported receiving a relatively small amount of wildfire risk information from their homeowners insurance company. Meldrum et al. (2018) found that only a fifth of respondents reported getting information from their insurance company, whereas more than half had received information from FireWise of Southwest Colorado. Other key information sources were neighborhood groups such as HOAs, the local fire department, and local media.

*Relevance to insurance regulation:* An opportunity exists for homeowners insurance companies to expand or initiate wildfire education. Companies could model efforts on initiatives such as State Farm's support of NFPA's Wildfire Community Preparedness Day campaign, which provides community-based education on topics such as how to reduce combustible material around vulnerable homes and offers residents the chance to talk to local firefighters about community preparedness.

**Figure 44:Comparison of effectivness of information channels in communicating wildfire risk.**




Source: Meldrum, J. R., Brenkert-Smith, H., Wilson, P., Champ, P. A., Barth, C. M., & Boag, A. (2018). Living with wildfire in Archuleta County, Colorado: 2015 data report.

## Challenges to creating Insurance discounts

Insurance products can be used to provide clear signals to policy holders about effective ways to reduce risk, and they have been applied in various ways in other catastrophe perils like hurricane risk with some success (RMS, 2010). For wildfire, one of the objectives of this report is to provide indicative proof points that the risk curve for this peril can be modified enough to suggest that primary insurance companies could design products to highlight these risk reduction signals. And while we have illustrated this, there are significant limitations to underscore when reviewing the relativities provided in this report that include the following:

- Location / Communities selected in this report are not selected to be representative of an average case, nor even upper/lower range of possible mitigation relativities possible. These are indicative, hypothetical examples only. Possible ranges of mitigation relativity may be smaller, or larger, than reported in this report for each state.
- The notional structure represented in the 'neutral' cases is a hypothetical mix of attributes across the region and may not even exist within the studied communities. The 'neutral' cases here are not indicative of any base rate case for a given insurance company in the state.
- No site-specific information was collected for these communities so even making conclusions that the risk is a given community is adequate to cover the wildfire risk quantified by the model cannot be made from this study.
- The model results in this study represent 'technical premium' - no consideration variable or fixed loss costs have been made in these simple assessments.

What makes wildfire different from other natural catastrophe perils is the hyper-local nature of the hazard gradient. Results and mitigation relativities will vary widely within distances as short as a few hundred meters.

As insurance regulators consider how to let mitigation signals be incorporated into insurance rates if at all, we encourage insurance regulators to consider the learnings highlighted from prior mitigation credit approaches used for other perils.

Because of the hyper-local nature of the peril and the complex interaction between site-level mitigation and community-level mitigation, insurance companies are going to need site-specific attribute information to provide realistic Wildfire mitigation credits. Collection of detailed information from professionals trained to assess fire risk are critical to an effective mitigation program. And relativities cannot be developed from historical loss data. Too many conditions are changing invalidating experience rating as an effective tool in rate making.

Be careful not to have factors that a homeowner cannot really control be part of the mitigation credit scheme. For example, in the state of Florida in the recommended windstorm mitigation credit program (RMS 2010), roof shape was an attribute included in the credit scheme. While an important factor in overall wind risk determination, it provided an artificial 'credit' that basically de-emphasized other factors that were under the control of a homeowner, essentially discouraging those homes to undertake any further risk reduction. Instead factors that cannot be easily controlled should be part of the base rating approach rather than part of possible mitigation credit schemes.

Do not assume every building in the state is a ‘worst-case’ scenario. Note that 30-60% of structures even in the 2020 events survive the fire. There are already structures that are (or at least partially) wildfire resistant. The goal is to identify the key factors, based on building science, that increase the survivability and incentive investment in those factors.

While not fully described in this report, the catastrophe models for wildfire risk are as robust as those currently used in the market for hurricane and earthquake risk. The building science community has been studying wildfire risk for several decades, and the hazard assessment techniques in models like the RMS Wildfire model are an effective tool to overcome the limitations inherent in historical loss data. Insurance companies need the flexibility to create new insurance rating scheme that will provide the right incentives quantify and reduce the risk.

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