Perkins&Will

Living With Wildfire

Exploring A Resilient Future for Fire Prone Areas

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Living with Wildfire: Exploring A Resilient Future for Fire Prone Areas

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Abstract

The threat of wildfires in California has significantly altered quality of life in the region. Adaptation will require fundamental corrections in land stewardship, development patterns, and building practices. Design professionals must make sense of an overwhelming array of information. This report summarizes design relevant information including the role of wildfire in California's ecosystem and the variables that affect its behavior. By developing an understanding of the recommendations of experts, architects and designers can aid in delivering effective solutions that better serve to protect life, property, and the environment within fire prone areas.

Keywords: Architecture, California, climate change, defensible space, ecology, fire behavior, fire prone areas, fire suppression, fuels reduction, home hardening, land management, prescribed burns, resilient landscapes, risk assessment, wildfire, wildfire design, wildland urban interface

1.0 Introduction

In the early morning hours of October 9th, 2017, while the city of Santa Rosa slept, the Tubbs Fire arrived in Coffey Park, a pleasant suburban neighborhood on the northeast side of the city. Residents, awoken by evacuation alerts, had mere moments to gather a few things before fleeing their homes amidst the over 60 mile-per-hour winds leading the encroaching firestorm. The fire had started over 15 miles away, on Tubbs Lane in rural Calistoga. The fire jumped a six-lane freeway, to arrive in Coffey Park. Transformers exploded. A 100,000 square foot K-Mart burned to the ground. What had started as a wildland fire, became something entirely different as the fuel source shifted from trees and vegetation to buildings and artifacts of industrialization. The Tubbs fire became the most destructive wildfire in California history at the time, claiming 22 lives and 5,636 structures (CALFireMostDestructiveList). In the aftermath, residents who returned found their homes and belongings reduced to piles of rubble, cars melted, trash bins liquified, and their futures uncertain.

Figure 1: Ventura, CA. 6th, December 2017: Firefighters preventing a Santa Ana Winds-driven fire from jumping Hwy. 101. Photograph by Kara Capaldo

Figure 2: Pleasure, CA. 10th, November 2018: Vehicles melted on the side of the road during the Camp Fire. Photograph by Kara Capaldo.

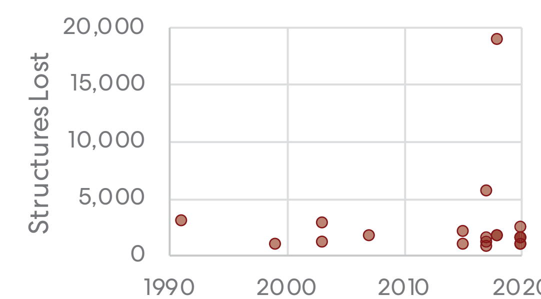


Figure 3: Top 20 Most Destructive Wildfires in California, by structures lost, according to CAL Fire.

1.1 The Risk: Catastrophic Wildfires

The devastation caused by the Tubbs Fire and the magnitude of the 2017 fire season was an astounding wake-up-call for California. The 2018 fire season proved to be even more devastating when the Camp Fire surpassed the Tubbs as the most destructive wildfire, causing 85 deaths, the loss of 18,804 structures, and the decimation of the entire town of Paradise.

In the last sixty years, the risk of extreme wildfire events has grown for communities in and adjacent to wildland vegetation (Keith T. Weber, 2018). Once considered an occasional disaster, extreme wildfire is now understood to be an established fixture in the Californian landscape. The increase in frequency and size of these fires has resulted in persistent fire seasons, burning for longer periods with no means of containment. In 2020, wildfires in California claimed the lives of 31 people, over 10,000 structures, and an estimated 4.2 Million acers of land (Insurance Information Institute, 2020). Five of the fires during 2020 ranked among the six largest in the state's recorded history.

The impact of wildfires extends beyond the flame front, as research also predicts increases in premature mortality due to chronic exposure to air pollution (B. Ford, 2018).

This trend of catastrophic wildfires is expected to continue because of climate change and other factors which we will discuss further. Figure 4, below, illustrates the role of extreme wildfires in a positive feedback cycle, in turn causing more smoke and ever higher temperatures (Newsom, Crowfood, Blumenfeld, & Porter, 2021).

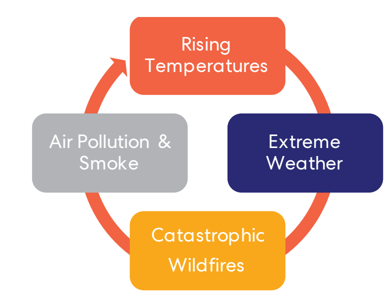


Figure 4: Wildfire Role in Positive Feedback Cycle

1.2 Road Map

In the coming sections, this document will look at how California arrived at this position and what designers, homeowners, and stewards can do about it. The source of this information is compiled from an extensive and wide-reaching review of scholarly journals, media, and state and national agency resources on the topic and related subjects.

2.0 How Did We Get Here?

2.1 Historic Fire Regimes

Wildfire is a natural phenomenon that has always been present in California's landscapes. Wildfires are the unplanned, uncontrolled burning of biomass. Unimpeded wildfires play an important role in shaping ecology and habitat: opening habitats to sun, encouraging reproduction of certain plant species, and controlling devastating pests. Periodic fires also serve to prevent the buildup of fuel which can lead to catastrophic fires (Pausas & Keeley, 2019).

California is home to several seasonal fire cycles. These cycles are called fire regimes, and they follow predictable patterns of intensity, frequency, size, and severity (Fryer & Luensmann, 2012). Historically lightning has been the source of non-human ignition, sparking dry vegetation during the hot summer and fall months.

A Berkeley study estimates that before humans, nearly 4.5 million acres of California wildlands burned annually (Stephens, Martin, & Clinton, 2007).

2.1.1 Indigenous Peoples' Use of Fire

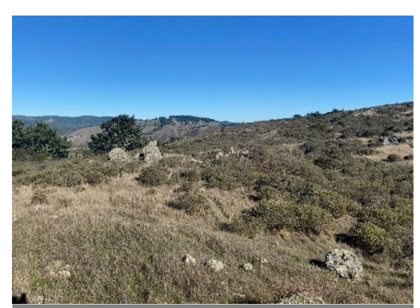
Archeologists believe that humans have used fire to impact the California landscape for nearly 11,000 years, since humans first occupied this region. Indigenous people in California understood the ecological impacts of fire. They used deliberate fire (cultural burning) to manage vegetation, wildlife, and food resources. Moreover, Indigenous people also set fires intentionally to burn excess vegetative fuel and prevent catastrophic wildfires (Anderson, 2018).

These cultures flourished through the supportive relationship of fire as a means of managing resources and landscapes. The Yoruk, Karuk, and Hoopa Tribes of Northern California used fire to encourage the growth of hazel into straight stems, which they used for weaving baskets. With fire, these Tribes promoted the production of foods, like acorns, huckleberries, and even salmon (Buono, 2020). Additionally, landscapes that were mechanically managed by cultural burning developed greater biodiversity than those reliant on natural ignition patterns (Anderson, 2018).

2.1.2 What Does the System Look Like in Equilibrium?

The health of an ecosystem requires biodiversity, redundancy, and sustained populations (Stand For Trees, 2021). Healthy ecosystems that exhibit these characteristics can continue to support habitats for a large range of organisms. California's Mediterranean climate features a wide mix of biomes including conifer forests, grasslands, oak woodlands, chaparral and shrublands (Newsom, Crowfood, Blumenfeld, & Porter, 2021). Each region experiences its own microclimate, biodiversity, and fire cycle.





Grasslands & Woodlands	Forest	Chaparral
○ 14m Acres – 18% of state's total land area ○ Vulnerable to expanded human development, agriculture, and invasive ecosystem conversion. ○ Fires pass quickly in this landscape burning understory and leaving legacy overstory. ○ Legacy habitats include oak trees, adapted to seasonal fire.	○ 33m Acres – 33% of state's total land area ○ 60% is publicly owned. ○ Of private forested land, 1/3 is held by timber companies, the rest by private households and Indigenous Tribes. ○ Legacy habitats include Redwoods, and Douglas fir adapted to fire.	○ 8.5m Acres – 9% of state's total land area, primarily in Southern California, and Coastal Ranges ○ Vulnerable to invasive ecosystem conversion. ○ Pre-settlement, fire may have occurred a few times a century. ○ Legacy habitats include the Manzanita adapted to fire.

Table 1: Characteristics of California's Principal Biomes, Assembled from California Chaparral Institute and others.

Figure 5: Second Year Growth after Medium-Intensity Fire in a Redwood and Doug Fir Forest. Photograph by Helen Schneider

Figure 6: Soberanes Fire, 2016: Forested Landscape after a Stand Replacing Mega-Fire caused by an illegal campfire. Photograph by Kara Capaldo

2.2 Centuries of Suppression

With the arrival of Spanish settlers in California, a practice of fire suppression supplanted Indigenous land management practices. The use of fire by Indigenous peoples threatened European settlers' ambitions of logging, agriculture, and mining. In 1793 Spanish Governor José Joaquín de Arrillaga issued a proclamation prohibiting cultural burning by Indigenous peoples.

Periods of rapid western immigration increased development and pushed settlers further into fire prone woodlands and shrublands. Early Western conservationists, interested in protecting timber and water resources, created California's first national forest reservation in 1892 (Strong, 1967). Then in 1910, wildfires burned 3 million acres in Montana, Idaho, and Washington. "The Big Blow-Up", as it was coined, led to a national policy of fire prevention and suppression (U.S. Forest Service Fire Suppression, n.d.).

Policies of suppression continued for another century, offsetting decades of fire and resulting in several societal impacts. The seasonal suppression of fire contributed to a widespread impression of fire as foe. It also created a false sense of security for urban communities residing in fire prone regions without incident.

A UC Berkeley study estimated that between 1950 and 1999, the total amount of land burned in California was only about 5% of what would have burned during a 50-year period in prehistoric times (Stephens, Martin, & Clinton, 2007).

2.2.1 The Growing Scale of Wildfires

The frequency, season, scale, and intensity of a burn are crucial variables in how an ecosystem rebounds after a fire. The ecosystems of California have for centuries adapted to consistent wildfire patterns. In recent years there has been a trending rise in wildfire frequency. The severity of these wildfires has also increased causing disruptions in fire behavior and habitat stability (CAL FIRE Department of Forestry and Fire Protection , 2019).

Severe conflagrations can alter the chemical composition of soil, impact nearby water sources, and homogenize the eventual vegetation that returns after the fire subsides. These "stand replacing fires" are not a new phenomenon in fire prone areas. They mark the end of old or diseased forests and the start of a new cohort (Jerry F. Franklin, 2007). However, the locations and frequency of fires at this scale were historically limited to specific regions and rare (National Wildlife Coordinating Group, 2021).See Figure 5 & 6 Above.

2.3 Components of Fire

Fire is the product of a chemical reaction, combustion, that requires sustained fuel, oxygen, and heat. Figure 7, below, is referred to as The Fire Triangle, and it serves to illustrate the three ingredients of combustion. If unimpeded, the chemical reaction will continue until one of the three either naturally decays or is actively removed (Hartin, 2018). This principle is the foundation of fire suppression. All fire mitigation strategies are preemptive separation of at least one of these three elements from the chemical chain reaction.

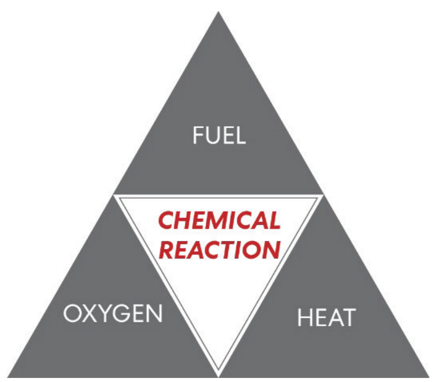


Figure 7: The Fire Triangle

2.4 Fire Behavior

Fire behavior is a result of site-specific conditions:

- Fuel: The greater the fuel load, the greater potential for conflagrations. Density, fuel height, and moisture content determine behavior of burn.
- Weather: Dry, hot summers mixed with strong winds can ignite and spread fire rapidly. The effects of periodic droughts dry out vegetation and create large expanses of kindling.
- Topography: Fire follows the path of easiest ignition. As fire transitions up slope, it propagates embers and preheats fuels in its path, allowing it to travel faster.

2.4.1 Fuel

Fuel, in the context of wildfire, should be understood as any combustible material. Vegetation and structures are both examples of fuel present in today's fire prone landscapes. Fuel loads are the approximate amount (often characterized by equivalent weight in wood) of fuel present in an area.

Fuel load is determined by the dead moisture content and density of fuels in an area. Dead fuel moisture content measures water content in vegetation (ranging up to 30% in fire season). Dry fuels with low moisture content increase the chances of combustibility. Fuels with high moisture levels (12 -30% depending on fuel type) result in moisture extinction, meaning that fire cannot spread (Mares, 2016). The higher the moisture content the more heat energy must be transferred for combustion to occur.

2.4.2 Weather

The moisture content of dead fuels fluctuates based on local weather conditions. The temperature and humidity change the gradient of moisture exchange between the air and fuel. Large fuels transfer moisture slower than small fuels resulting in delays of moisture equilibrium, see Table 1 below. (NOAA National Centers For Environmental Information, 2021). Prolonged periods of hot, dry, windy weather cause the lag times of different fuels to reach low moisture contents at the same time, making the area extremely susceptible to wildfire.

LAG TIME RATE	DIAMETER	PERIOD OF MEASURMENT
1 hour	Litter	Observed weather conditions
10 hour	.25" - 1"	Observed weather conditions
100 hour	1" – 3"	24 hour average weather conditions
1000 hour	3" – 8"	7 day average weather conditions

Table 2: Dead Fuel Moisture Time Lag, adapted from NOAA.

2.4.3 Topography

The aspect of a hill changes the solar exposure and moisture content of fuel. In the Northern Hemisphere, southwest aspects receive the greatest thermal energy and pose the most vulnerable conditions for wildfire. Narrow northern aspects offer greater self-shading, thereby increasing the retention of fuel moisture in understories. Living fuels are less responsive to swings in moisture content. When trees disappear from the landscape it serves to further imbalance the atmospheric equilibrium. (Schroeder M., 1970)

2.5 Humans and Wildfires

84% of wildfires today are caused by human activity. Aging infrastructure (typically overhead power lines), fireworks, sparks from equipment and railroads, debris burning, discarded cigarettes, and arson are all sources of human-caused wildfires.

Extremely hazardous air quality and smoke inhalation are a concern for the entire state of California, and its neighbors. Plastics, cleaners, leaded paints, fuels, and solvents are among the fuel in an urban wildfire. When burned, these toxic substances contribute to unprecedented hazardous air quality that has closed schools hundreds of miles away from the fire source (CANO, 2020). Doctors are already recommending that people with severe asthma or pulmonary diseases move elsewhere. We have yet to fully understand the impact that these incinerated toxins will have on biological systems. (Bierma, 'Waking Up to Wildfires', 2019)

Figure 8: Ignition of a Powerline: Downed power lines, accounted 1,500 wildfires in the past 6 years. Photograph by Kara Capaldo.

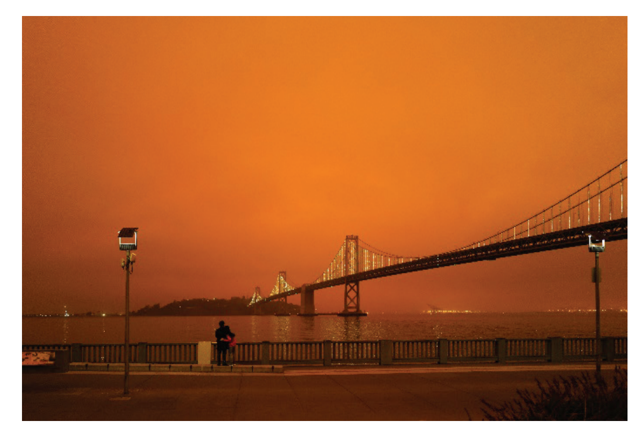


Figure 9: September 9, 2020, Smoke and Particulate Matter Occluded the Sun from SF to Yosemite

2.5.1 Emergency Responders

California depends on its emergency responders to protect its communities from wildfire. When responding to a wildfire, emergency personnel have three tiers of priorities:

1. Life
2. Property
3. Environment

Containment of a fire is not always an option, so decisions must be made that favor the safety of people and crew over buildings and land. There are increasing instances when the rate of advancement of a fire poses too great a risk for emergency personnel to respond. Often the defense of a structure is dependent on access, and safe extraction of crew. For this reason, access roads to remote properties with narrow or overgrown road edges are not viable to defend due to risk. (Miller, 1962)

Increasingly, the conditions that emergency personnel are called on to defend against have become more dangerous and overwhelming.

2.5.2 Intangible Costs

The physical and monetary effects of fire are often cited in a fire's aftermath, however there are intangible consequences to extreme cycles of wildfire.

The mental health of firefighters is impacted by relentless fire seasons (Rott, Febuary 26, 2021). Depression and post-traumatic stress disorder (PTSD), among firefighters is higher than in civilian populations (SAMHSA Substance Abuse and Mental Health Services Administration, May 2018). Fire service personnel report being severely underfunded and understaffed.

Wildfire survivors may also suffer devastating consequences for years to come. In addition to the trauma of losing a home, some may be forced to relocate, and many will experience PTSD, or other ongoing health consequences. It is estimated that 30-40% of people who are direct victims of a natural disaster will experience PTSD (Bierma, 'Waking Up to Wildfires', 2019). No assessment of development risk can be whole without consideration for the subsequent risk to first responders and residents.

2.6 Development Patterns

The Wildland-Urban Interface (WUI) is defined as a place where humans and human development occur among wildland vegetation, and quantitatively where there is at least one housing unit per 40 acres. Communities within one-half-mile of wildlands are included among the WUI (CPAW, 2012).

There are two main categories within the WUI where most wildfire structure loss occurs: The Intermix WUI and the Interface WUI.

- **Intermix WUI** describes areas where houses and wildland vegetation are interspersed, where vegetation occupies more than 50% of land area.
- **Interface WUI** describes settled communities that abut wildland, where vegetation occupies less than 50% of land area. Suburban developments adjacent to wildland typically fall within this category.

While Intermix WUI has more fire spread by acreage, Interface WUI experiences more structure damage. Over a thirty-year period from 1985-2013, 50% of structures destroyed by wildfire in California were in the Interface WUI, whereas 32% of structures were in the Intermix WUI. (Kramer, Mockrin, Alexandre, & Radeloff, 2019)

Increased development in the Wildland Urban Interface and adjacent areas has dramatically increased the fuel loads of already dense, dry conifer forests and overgrown chaparral foothills (Valachovic, 2018). Man-made structures prove extremely flammable and structure to structure ignition can be of greater risk than adjacent trees. This was the case with Coffey Park in 2017, and the Town of Paradise, which was leveled by the Camp Fire in 2018.

2.6.1 Who Lives in the WUI?

Among US states, California has the largest number of people living in the Wildland Urban Interface—11.2 million, or roughly 30% of state residents, as of the 2010 census (Alvarez, n.d.). This number is expected to grow significantly. In a "Business As Usual" growth scenario, 12.9 million acres of sparsely populated and agricultural lands will be added to existing WUI over the next 30 years (Mann, et al., 2014). The current WUI territory is 6.6 million acres of California's total 104.7 million acres (USDA, 2018). This is significant, because despite only occupying 6% of California by size, 82% of buildings destroyed by wildfires are in WUI zones. (Kramer, Mockrin, Alexandre, & Radeloff, 2019).

In California, the major populated urban areas are directly adjacent to wildland areas—urban densities separated by mere miles of WUI interface residential development. With catastrophic wildfires appearing to be the new normal in a changing climate, millions of urban residents, even those residing outside the WUI, could also be at risk.

Figure 2, below, illustrates the development density continuum from wildland to urban areas. In more densely populated areas, embers from a nearby wildland fire may travel over a mile and spark an urban wildfire.

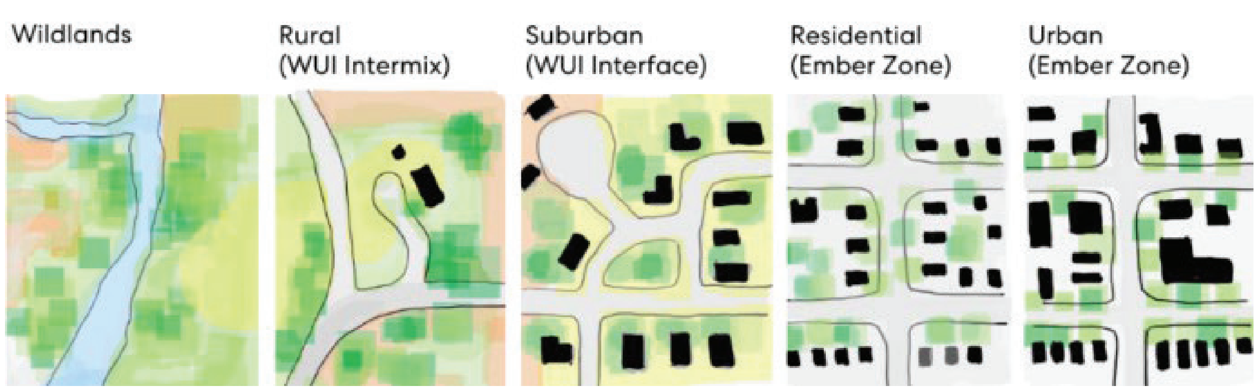


Figure 10: Wildland to Urban Development Continuum Adapted from Community Planning Assistance for Wildfire.

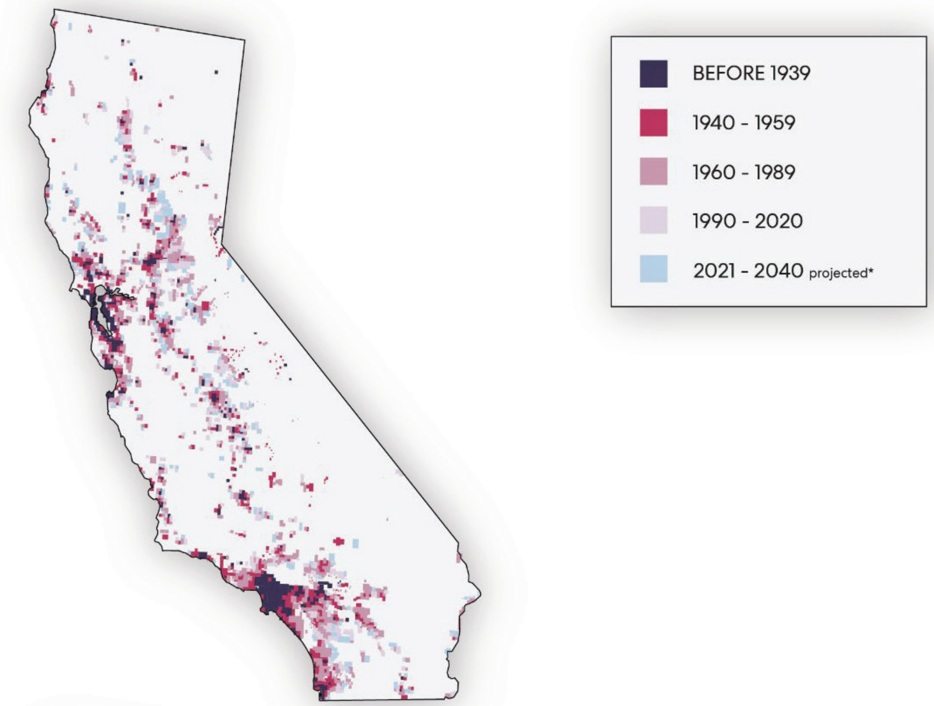


Figure 11: Developed Land in California and Projected Future Development, Adapted from Fire and Resource Assessment Program FRAP Data.

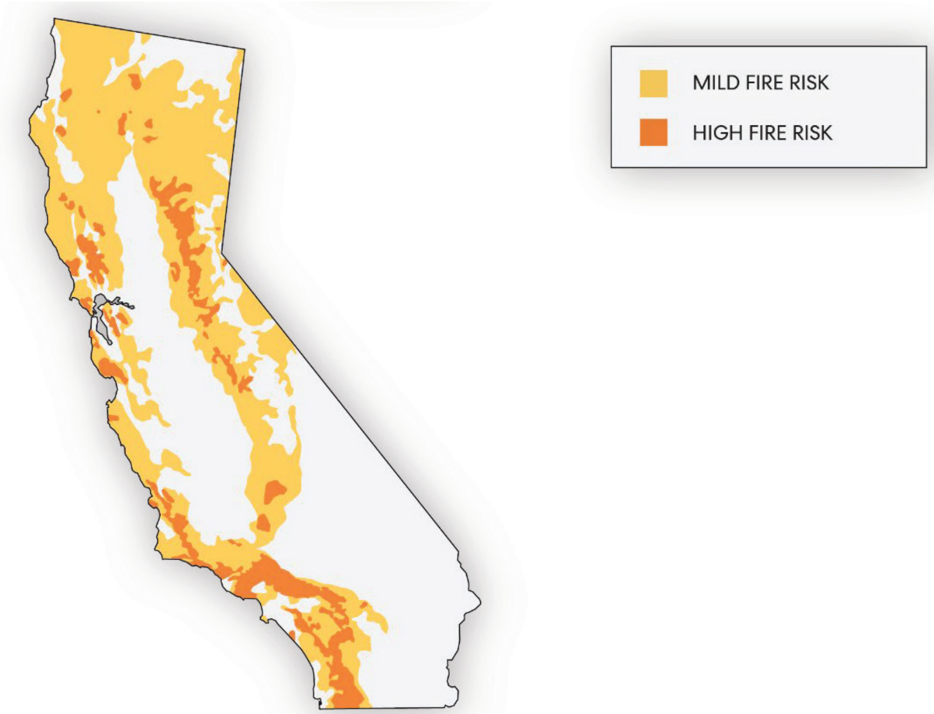


Figure 12: Wildfire Risk in California, Adapted from California Utilities Commission Data.

Figure 13: Scortched Redwood Tree with New Growth. Photography by Helen Schneider.

3.0 What Needs to Change?

To stem the frequency and magnitude of catastrophic wildfires in California, change needs to happen at all scales—from the vast amount of California's wildland vegetation to that of communities, and down to the details of a home. We fundamentally need to change the following three things:

1. Land Management Practices
2. Land Development Practices
3. Building Practices

3.1 A New Approach to Land Management

3.1.1 Learn from Indigenous Communities

Controlled, low-intensity fire is one of the best means to curb catastrophic wildfires. Recent Indigenous/Western partnerships offer glimmers of hope that California may begin to make amends for decades of suppression. Since 2013, the Yurok Tribe has been actively working to re-introduce cultural burning to their people and to their ancestral lands. To meet stringent legal requirements for prescribed burning (such as having Western equipment on hand), the Yurok Tribe started a knowledge share in 2014 – bringing together firefighters from across the country for a training exchange with Indigenous practitioners of prescribed burning. These now biannual exchanges led to national knowledge shares with the nation-wide Indigenous People's Burning Network. These partnerships are crucial and may scale to treat the vast expanses of land that desperately need fire for regeneration, and stem future catastrophic wildfires. (Buono, 2020)

3.1.2 California Resilience Plan

In January of 2021, the State of California released California's Wildfire and Forest Resilience Action Plan. This multiagency report acknowledges the impacts of human activity in to wildland areas.

The plan seeks to:

- Increase Wildland Health and Resilience
- Fortify Community Protection
- Coordinate Ecological and Economic Forest Management Goals

To meet these goals, the state committed to treating 500,000 acres of land with fire resilient management by 2025. They plan to achieve this with a combination of sustainable timber harvest and prescribed fire. The plan supports Indigenous/Western partnerships like those with the Yurok. (Newsom, Crowfood, Blumenfeld, & Porter, 2021).

This plan represents a significant step forward and appears to mark a new chapter in the state's response to wildfire; however, the amount land that will likely fall victim to catastrophic wildfire by 2025 is much greater than the area California has committed to treat.

The growth of the timber industry continues to loom large in setting land management goals. While the state acknowledges the importance of prescribed burns as a land management tool critical for ecosystem preservation, prescribed burns account for only 1/5 treated land. Accelerating training and permitting for the use of controlled fire is one of the most potentially impactful actions to prevent catastrophic wildfires and restore ecosystems in jeopardy.

Figure 14: Factors that Influence Fire Resilience

The factors that influence wildfire resilience are complex and include many variables. While climate change is largely responsible, there are several factors that are within human influence: Land Management, Land Development, and Building Practices. The scale of these measures includes the coordination of multiple state and local agencies, Indigenous Tribal communities, and private landowners and homeowners.

Figure 15: Firefighter ignites path of fire for the Bonnie Doon 2020 Prescribed Fire

Figure 16 (right): Firefighters observe managed burn of Bonnie Doon Spring 2020 Prescribed Fire. Photographs by Kara Capaldo

3.2 Fuels Reduction

Forest Management is the practice of human intervention to reduce fuel load in a wildland area. There are several different methods used by land stewards:

- Prescribed Burning
- Grazing
- Wood Chipping
- Tree Removal (Logging)
- Fuel Breaks

Fuel reduction practices essentially replicate a version of what a normal wildfire cycle would produce, aiding in the return of an ecosystem to its natural state. National, state and local agencies may choose to treat their land with some combination of the fuel reduction strategies listed above.

3.2.1 Balancing Fuels Reduction and Habitat

In a prescribed burn, fire occurs low across the understory, burning debris and smaller vegetation without entering the canopy of the tree. The height of vegetation affects flame heights. When an understory becomes overgrown, the flames can ladder up to the canopy above destroying legacy habitats. This type of vegetation is called "ladder fuels." It is important to remove lower limbs on legacy trees and cut back shrubs to avoid the fire from leaving the ground.

Fuel reduction projects end up with piles, and often they are intended to be removed or chipped. However, these piles can provide significant habitats. Land stewards may remove a habitat pile, away from nearby trees to prevent it from becoming a hotspot. Locating dead wood piles in a gap of vegetation, may allow it to serve significant habitat benefits. Dead wood features also contribute to the overall health of the forest returning nutrients and protection for a bevy of species.

3.3 A New Approach to Development

To mitigate against catastrophic loss of human life and property, California must adapt development practices that consider wildfire risk and collective dependency.

3.3.1 Guidelines for Development

Suburban and residential communities that reside adjacent to wildlands should be separated by 300-foot-wide defensive belts to help buffer structures from potential wildfires. The 300-foot belt may be a highway, or other zone kept clear of combustible material. This belt serves to protect against the flame front; however, with embers known to spark fire after floating airborne for over a mile, ember ignition is still a risk.

SPUR, in collaboration with California YIMBY and Greenbelt Alliance, recently set forth a set of development guidelines for wildfire resilience. Our team supports this initiative, and we have outlined these principles below:

SPUR's Principles

Managing Wildfire Risk and New Development

1. *Increase density in urban and in-fill locations that have less risk for wildfire.*
2. *Distinguish between levels of wildfire risk to inform regional planning and growth plans.*
3. *Stop growth of housing and town centers in zones with the highest risk of wildfire.*
4. *Create guidelines for existing communities in high fire risk areas to address growth and mitigate fire risk.*
5. *Protect existing structures with home hardening measures and defensible space.*
6. *Align incentives of insurance and utility planning to support safe infrastructure and reflect inherent risk of living in fire prone areas.*

Figure 17: Summary of SPUR Principles for Managing Wildfire Risk and New Development (Brown-Stevens, Hanlon, & Karlinsky, 2021)

3.4 A New Approach to Building

As architects designing buildings in the WUI and other fire prone areas, we have a significant influence and responsibility in creating sustainable, fire-resistant communities.

Given the global rising temperatures, increased droughts, and historic fire suppression, residents, and landowners within the WUI and adjacent fire prone areas will continue to be at risk from wildfire transmission.

Private property owners have a vital responsibility to maintain the land they settle, not only n service of the natural habitat, but also protect their own safety and economic investments.

While a wildfire cannot always be prevented, there are many measures that individual property owners can take to reduce the likelihood of ecosystem and structure loss in the event of a fire. These fall into three primary categories:

1. On-site Land Management, as addressed in the previous section.
2. Defensible Space
3. Home hardening

Figure 18: Road acting as a fuel breaks during prescribed burn, Bonnie Doon Spring 2020, Photograph by Kara Capaldo.

3.4.1 Defensible Space

Defensible space is a means of fuel reduction that seeks to reduce and spread-out fuel sources around the structure. There are three conceptual zones of increasing distance drawn around the perimeter of the structure. See Table 3, below. Each zone is intended to cut off the easy transmission of dense contiguous fuels to the next. During a fire, spacing may not only limit structure ignition from nearby vegetation but also the chances of structure-to-structure ignition. For this reason, it is important to coordinate defensible space with neighboring structures within the areas defined.

1. Ignition Zone
2. Intermediate Zone
3. Reduced Fuel Zone

Creating defensible space is not a onetime investment but a continued strategy of managing land around structures. Much like the upkeep of a building, the site also requires periodic servicing to keep it healthy and functioning. Overlooking this upkeep can greatly increase the risk of fire. Special vigilance should be taken during fire seasons.

Many communities recognize the shared benefits of establishing fire protection measures across large areas of land. It is important to check for local community guidelines or action plans as a starting point for creating a defensible space plan.

Table 3, below, outlines the guidelines for how to mitigate fire risk in each of the three zones.

Zone 1: **Ignition Zone** 5-Foot Radius around Structures	**Zone 2:** **Intermediate Zone** *Lean & Clean Zone* 30-Foot Radius	**Zone 3:** **Reduced Fuel Zone** 100-Foot Radius & Access Roads
Reduce chances that windblown embers will ignite the structure and cause damage. • **Ground Cover:** Avoid all combustible ground coverings including wood mulch and wood decks. "Fire-resistant" materials can still combust. Materials like gravel, stone, concrete, and metal decks are *suitable alternatives to planted building perimeters.* • **Vegetation:** *Avoid planting in this zone. Even the use of "fire-resistant" vegetation will not protect the home from ignition.* • **Maintenance:** Remove plant debris from roof and rain gutters. Remove branches overhanging roofs. • **Decks:** The underside of decks should be clear of debris and, if possible, enclosed by noncombustible materials.	*Maintain a landscape that will stop a spreading fire from continuing to the structure.* • **Remove all dead vegetation.** • **Maintain groundcover** to a max height of 6 inches. • **Remove large shrubs that can act as ladder fuels.** • **Maintain Trees:** o Keep branches a minimum of 10 feet from other trees. o Remove tree limbs 10-15 feet from the ground. o Remove tree limbs from young trees (less than 15-feet tall) so that 1/3 its height. o See Figure 18 • **Remove or prune flammable plants and shrubs.**	*Decrease energy and intensity of fire by eliminating continuous vegetation horizontally and vertically.* • **Buildings on moderate to steep slopes (8%-up) should increase Zone 3 to 200-Foot Radius.** • **Isolated wood piles can be relegated within this zone.** • **Maintain horizontal space between shrubs and trees.** • **Maintain vertical space between grass, shrubs, and trees.** • **Remove tree debris and plant litter that is greater than a depth of 3 inches.** • **Fuel tanks can be located within this zone.** Position perpendicular to structures, protect with non-combustible wall. If space is available, locate 200' from structures.

Table 3: Defensible Space Checklist (CAL FIRE, 2021) Note: some jurisdictions may have additional requirements.

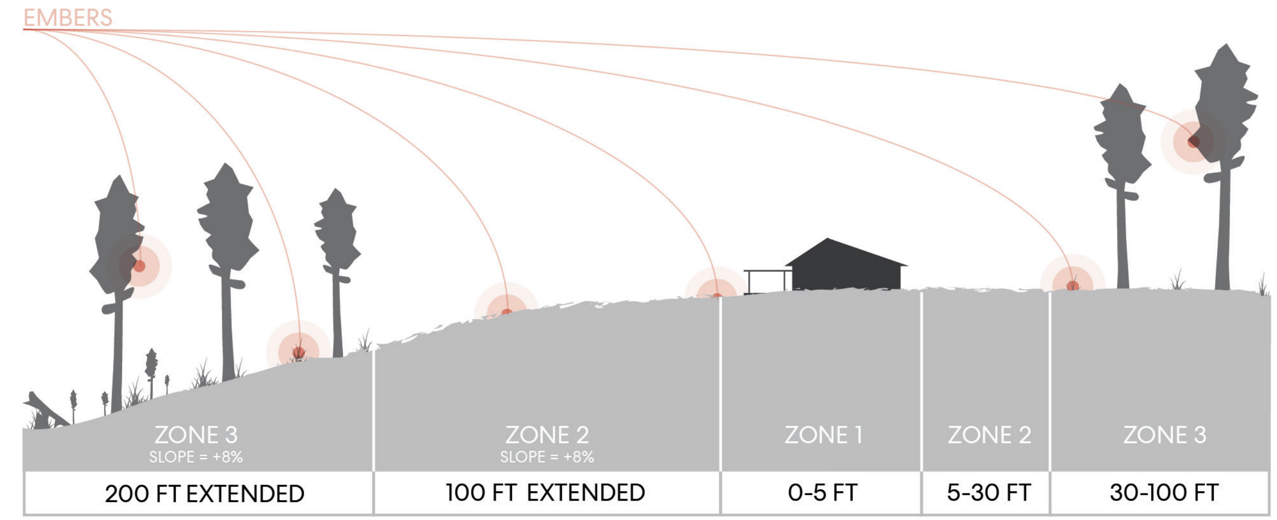


Figure 19: Defensible Space, Zones of protection extend at slopes to respond to fire behavior. Adapted from Fire Safe Council and others.

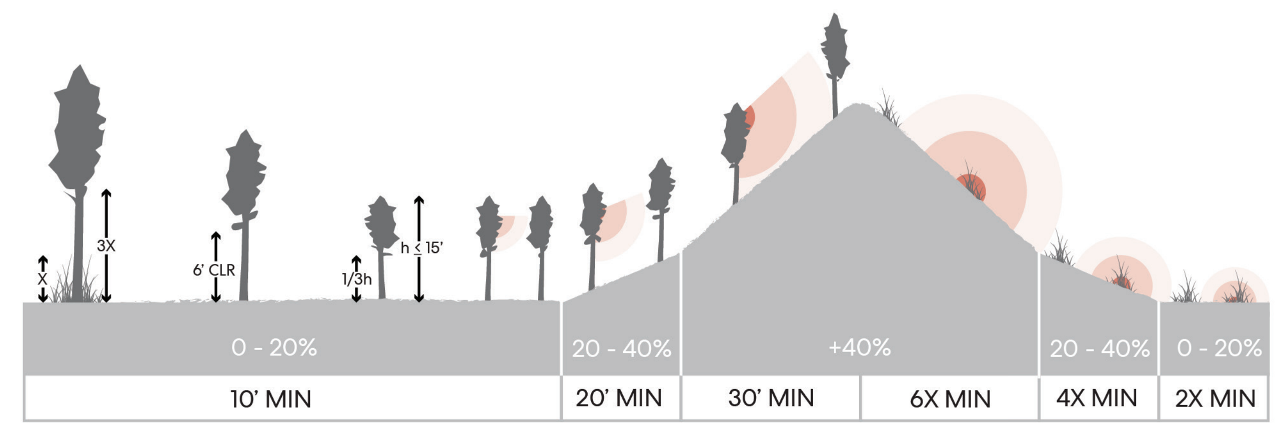


Figure 20: Tree & Shrub Clearances, grade and vegetation heights determine clear spacing recommended to avoid ladder fuels. Designers should seek consultant input on site specific conditions. Adapted from CAL FIRE.

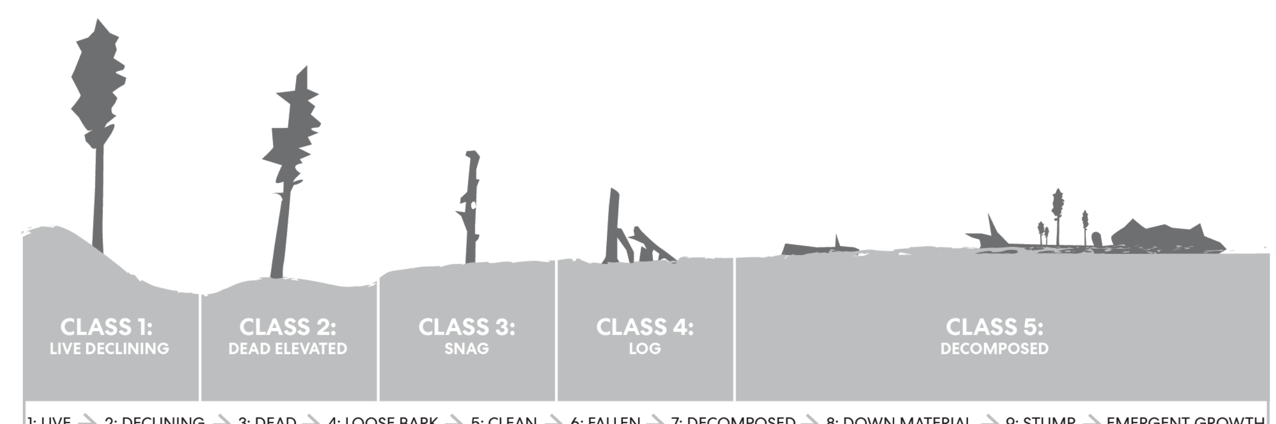


Figure 21: Tree Decay Classes and Life Cycle, Dead or dying trees can be sources of fuel within defensible zones. They are also vital habitat resources. All defensible space plans must balance the benefits and risks of removing or preserving dead wood form site. Adapted from The Columbus Dispatch and Maser.

3.4.2 Home Hardening

It is recommended that homeowners prioritize the home and its immediate area and work outward from the center, moving on to the zones of Defensible Space, discussed previously. This approach prioritizes the most vulnerable and impactful areas first and can be developed in stages.

The Home Hardening Table, below, outlines the steps one can take to improve the chances that a home or structure will resist ignition in the event of a wildfire.

Exterior Coverings

The primary cause of structure loss in a wildfire is from wind-blown embers landing on combustible material.

- **Exterior Coverings:**
  - Best practice is to use noncombustible material.

    Metal siding, stone, concrete, cement fiberboard, stucco are all suitable alternatives to wood siding.
  - Alt: heavy timber, SFM-approved assembly, Type X behind cladding
  - Use noncombustible materials for cladding from the ground to 12 to 18" above grade.
  - Consider eliminating plastics and toxic building materials from building construction.
  - Consider intumescent treatments for added protection.
- **Decking:**
  - The structure of decks should be constructed of non-combustible materials.
  - Keep the deck clear of debris.
  - If possible, enclose the underside of decks in non-combustible materials.
- **Roofing:**
  - Provide Class A, non-combustible roof.
  - Enclose open eaves and soffits with type X or equivalent.
- **Gutters**
  - Install non-combustible metal gutters, avoid plastic.
  - Install screens on gutters to prevent build-up of tree debris.
  - Maintain roof and gutters to ensure they are free of debris and vegetation.

Openings & Transitions

If openings fail in a fire, embers can enter the building and ignite the numerous combustible interior finishes and fittings.

- **Windows & Skylights**
  - Use double-paned glazing with one tempered pane.
  - Install 1/16" opening metal mesh screens.
  - Close windows when wildfire is nearby.
  - Consider deployable non-combustible shutters at windows.
- **Vents**
  - Protect all vent openings with ember protection approved by the SFM.
  - For retrofits, place metal coverings over vents in advance of oncoming wildfire.
- **Chimneys**
  - Cover outlet with screen to prevent ember intrusion.
  - Close flue during fire season.
- **Other Openings:**
  - Use doors that are noncombustible, solid core wood, or minimum 20-minute rated.
- **Flashing**
  - Install corrosion-resistant metal flashing at roof edge, peaks, and valleys.
- **Ground to Building Transition**
  - Use non-combustible material, like concrete stem wall from the ground to 12-18" above the ground.
- **Fence**
  - Separate fence from structure or ensure the 5' of fencing that abuts the structure is made of a noncombustible material.

Miscellaneous

Items below outline additional measures, active systems to aid in fire suppression, and Site Emergency Preparedness.

- **Separation**
  - Where possible, maintain minimum of 10' building separation. 30' is preferred.
- **Water**
  - **Interior Sprinklers**
  - Required in CA for many buildings in the WUI.
  - **Hydrants**
  - Provide hydrants with hook-ups and pressurization compliant with local fire departments.
  - **Storage/Supply**
  - Provide adequate water supply or storage to meet the demands of on-site sprinklers, and hydrants.
- **Warning System**
  - Audible fire alarm that can be heard site wide.
- **Garages**
  - Install weather stripping around door to prevent ember intrusion.
  - Store flammable liquids away from sources of ignition.
  - Ensure garage door can be operated if power is out.
- **Spark-Arrestors**
  - Install on sources of combustion.
- **Emergency Preparedness**
  - Develop an emergency plan for your household.
  - Keep tools such as a hose, rake, shovel, bucket, and fire extinguisher handy for emergencies.
  - Consider building ignition-proof shelter for occupants to shelter-in-place.

Table 4: Home Hardening Checklist, compiled from Wildfire Home Retrofit Guide, 2020; NFPA How to Prepare Your Home for Wildfires; and the 2019 California Building Code

3.4.3 Emerging Technologies

There are several emerging technologies that designers and homeowners may consider when developing a home hardening strategy. Often these systems are omitted in early design phases due to cost or maintenance concerns. However, as the requirements for building in fire prone areas increases the prevalence of such systems may become more common.

Depending on their positioning, exterior sprinklers may help to suppress ignition on and around a structure. Any active system that is reliant on electricity for pumping may face issues during a fire event if electricity is lost. Available water is also an important consideration.

Fire retardant membranes are a developing industry. These come in a variety of systems and may help resist surface ignition. Due to the wide range of products on the market it is difficult to ascribe effectiveness.

Fire retardant gels can be sprayed on in advance of an oncoming fire. These have a short window of effectiveness after application and are thereby not practical for most situations. Some gels may damage paint finishes. It is also prudent to verify the ecological impacts of any chemical introduced to the site. Manufacturers may use phrases like “environmentally friendly”, or “green” to intimate that their product is safe for the environment, but they are not an indication of specific qualifications.

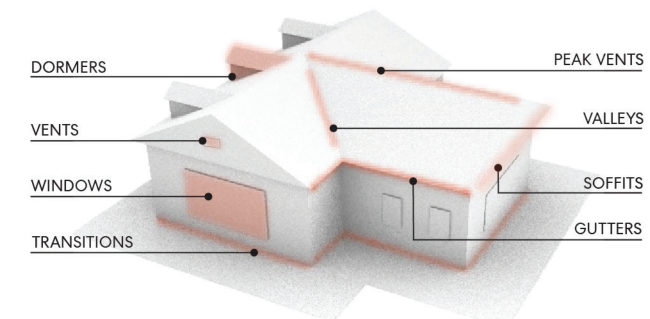


Figure 22: Points of Common Ignition

Figure 23: Richburg, S.C. - This ember storm simulation by the IIBH Research Center highlights common pathways of ignition. Photograph by The Insurance Institute for Business & Home Safety.

Access

Designing for Fire Department access and providing information about a property will increase the likelihood that fire personnel can protect a property.

- **Road Design**
  - Consistent with local Fire Department Requirements.
- **Redundant Access**
  - Multiple routes to access property.
- **Vegetation Maintenance**
  - Maintain roads so that vegetation is not overhanging and continuous across a roadway.
- **Provide Knox Box at locked gates.**
- **Signage:**
  - Maintain high-contrast and visible markings denoting property address.
  - Provide site map for Fire Department at property entrance.

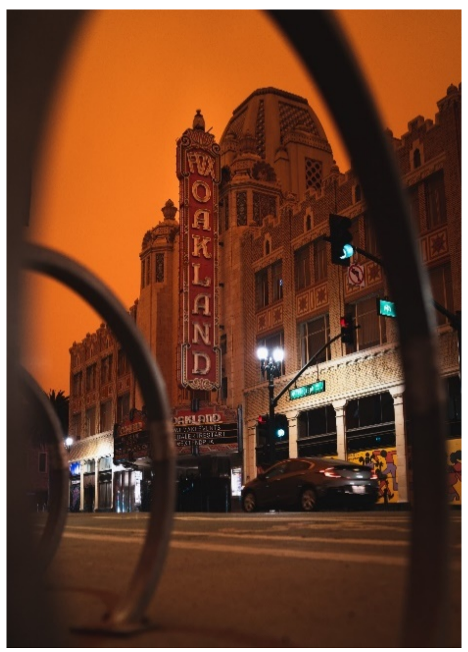


Figure 25, top: Camp Fire 2018, flames moving up hill. Photograph by Kara Capaldo

Figure 24, bottom: Fox Theater in Oakland, CA. Midday on September 9, 2020, the particulate matter from wildfire smoke obscured the sun and turned skies red across the state. Photo by DeVaun Salters @dmsalters58

4.0 Conclusion

There is no one-size-fits-all solution to establishing fire resilient environments. The exact strategies put in place must respond to a project's site-specific conditions. There is also no one party who is an expert in all aspects of wildfire response. Proper wildfire design is collaborative and multidisciplinary.

As designers committed to sustainable and regenerative design, we need to be attuned to the complex systems and landscapes in which our projects reside. While we have outlined steps to decrease wildfire risk to humans, no combination of these methods outlined will ensure complete protection. It would be misguided if one were to use the measures of fire defense without acknowledging the inherent risk of building in these areas. Continuing to develop in wildland areas renews our societal commitment to the dichotomous preservation of human settlements in landscapes that are defined by, and rely on, wildfires for their existence.

4.1 Further Study

We see this work as the beginning of an ongoing conversation about creating fire resilient landscapes and communities. Over the course of our research, our team identified a few areas where further study may be beneficial to our studio and our profession:

1. Expert Symposium: a series of interdisciplinary open-form discussions with experts on topics of wildfire resilience.
2. A New Vernacular: A multidisciplinary design exercise to develop a new fire-resilient typology for regenerative Californian construction.
3. Fire Insurance: exploring the influence of fire insurance on development and the building industry.
4. Silviculture: exploring the synergy between fuel reduction efforts and sustainable mass timber industries.
5. Design for Hazardous Air Quality: Investigating building and retrofit solutions for healthy indoor air.

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