IBHS POST-EVENT INVESTIGATION:

CALIFORNIA WILDFIRES OF 2017 AND 2018

July 2020

SUMMARY

The Camp Fire of November 2018 was the most deadly and costly wildfire in the recorded history of California wildfires. Extremes of weather, fuel, and complex topography came together to create a worst-case scenario. Following the fire, scientists from the Insurance Institute for Business & Home Safety (IBHS) and several IBHS member companies conducted a post-event investigation to examine the factors that contributed to this destructive fire.

The following summarizes the results of the investigation:

- The city of Paradise was aware of the threat from wildfires. The community has experienced approaching fires several times before and had planned accordingly. During the Camp Fire, the combination of extreme fire weather conditions and topography contributed to the rapid fire spread that quickly overwhelmed the town.
- Defensible space was found to be an important characteristic of homes that survived. However, well-maintained defensible space did not guarantee survivability. Rapid fire spread through favorable topography overwhelmed even well-maintained defensible space. Therefore, the level of risk reduction defensible space provides in this type of event is still undetermined.
- Firefighter intervention was critical in preventing the loss of some structures in Paradise. The intervention likely occurred at, or shortly after, the time of ignition and before the structure became fully involved. The concept of roving structure protection is not likely in all scenarios, and in several instances (such as burning material in gutters, wooden fences, etc.) the need for intervention could have been avoided through proper mitigation.
- Fire spread occurred quickly near ground level. Short-distance, ground-level ember transport due to high winds contributed to the rapid ground-level fire spread and embers from burning structures were easily transported by the high winds to adjacent structures. Although individual trees were burned, the fire did not spread through the tree canopy.
- In several neighborhoods, evidence of structure-to-structure fire spread was observed due to closely spaced homes. The structure-to-structure spread is similar to rapid fire spread through continuous vegetative fuels.
- Building damage levels after the Camp Fire were almost always either undamaged or destroyed. This is consistent with previous significant wildfire events.

Given the either/or outcomes often seen with structures after a fire, there is a greater need to explore what combinations of factors (building components, terrain, defensible space, etc.) matter most in survivability, both in the wildland urban interface and in suburban environments where we have seen wildfires produce rapid structure-to-structure fire spread.

INTRODUCTION

With the top five costliest wildfires occurring in 2017 and 2018, insured losses were significant, totaling $15 billion and $18 billion, respectively.[1] This is a substantial increase from previous years. In 2017, just two fire sieges (multiple, simultaneous, long-burning wildfires that covered large areas) accounted for more than $11.7 billion of the total losses:[2]

- October Northern California fires: $10 billion
- December Southern California fires: $1.7 billion

Three wildfires accounted for more than $12 billion of the total losses[3] in 2018:

- Camp Fire: $8.4 billion
- Woolsey Fire: $2.9 billion
- Carr Fire: $892 million

Over the past decade the total number of fires has decreased while the number of acres burned has remained effectively constant,[2] indicating more intense fires. The potential impact from wildfire is a combination of the hazard, occurrence, and severity, along with the threat to assets such as homes, businesses, and infrastructure. Weather-driven extreme fire behavior was a common factor in the destructive 2017 and 2018 California wildfires and was intensified by acute drought conditions.

Wildland fire suppression efforts are often successful in the initial attack phase. In the last decade, approximately 97 percent of fires were contained and the majority affected less than 0.25 acres[4] of land. The remaining 3–5 percent are fires that are typically driven by extreme weather conditions. These are large, fast-moving, and difficult-to-control wildfires that result in a large number of home and building ignitions. Because most of the civilian population has evacuated and the number of threatened buildings outnumbers the available resources, buildings that ignite are typically destroyed. Very few buildings suffer partial damage.[5]

ENVIRONMENTAL CONDITIONS

High temperature and drought conditions that began in 2017 continued into 2018. As of December 2017, the US Forest Service reported a record 129 million dead trees in California, primarily linked to drought and bark beetles.[6] The high number of dead trees during the intense drought period posed an increasing wildfire risk. On July 27, the National Interagency Fire Center (NIFC) set the National Preparedness at its highest level (Level 5) for only the fourth time in 10 years.[7] This level indicates that national resources are fully committed to wildland fires. During July and August, a series of large wildfires erupted across California; most occurred in the northern part of the state.

[1] Faust, E., Steuer, M., "New hazard and risk live for wildfires in California and worldwide", MunichRE
[2] NFPA Large-Loss Fires in the United States 2017
[3] NFPA Large-Loss Fires and Explosions in the United States During 2018
[4] Stephens, S.L., Ruth, L.W., "Federal Forest Fire Policy in the United States", Fire Management, 2005
[5] Syphard, A.D., Keeley, J.E., (2019) "Factors Associated with Structure Loss in the 2013-2018 California Wildfires", Fire
[6] "Record 129 Million Dead Trees in California". USDA Forest Service. December 12, 2017
[7] "NIFC moves up to Preparedness Level 5, nationally". Wildfire Today. July 27, 2018

CAMP FIRE

The Camp Fire started on Thursday, November 8, 2018 at 6:45 a.m. PT, approximately 8 miles northeast of Paradise, California. Sustained winds of 25–30 mph, with gusts of 40–50 mph, drove rapid fire spread (Figure 1). The National Weather Service had already issued a red flag warning and relative humidity across the area was generally below 20 percent. The fire advanced nearly 15 miles in the first 12 hours, burning over 55,000 acres.[8] Within the first 2 hours, the fire front traversed nearly 4 miles and first affected the small community of Concow (approximately 6 miles northeast of Paradise).

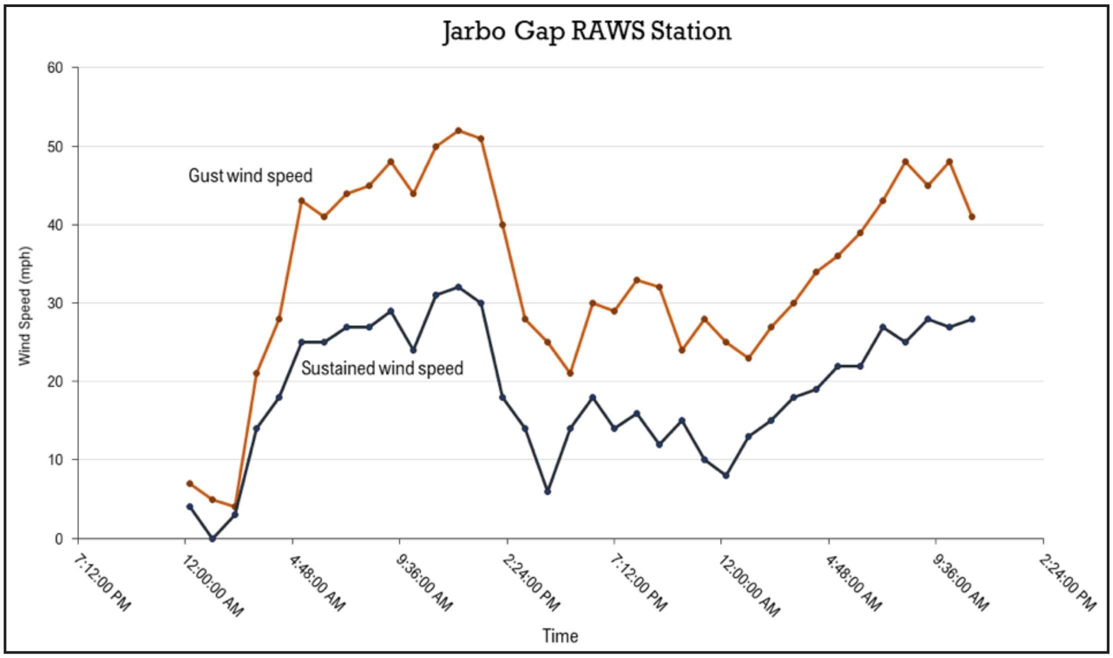

Figure 1. Hourly time history from Jarbo Gap Remote Automated Weather Station (RAWS) for wind gust (orange) and sustained wind speed (blue), 00 UTC 8 November through 12 UTC 9 November 2018.

At 7:54 a.m. PT, a mandatory evacuation order was issued for Paradise. Shortly thereafter, ember-driven fires began within the town limits. By 10:00 a.m., fire was observed throughout Paradise while evacuations were still ongoing. The fire burned through the town over the next 2–3 hours.

[8] CAL FIRE Green Sheet "Burn Injuries November 8, 2018 Camp Incident"

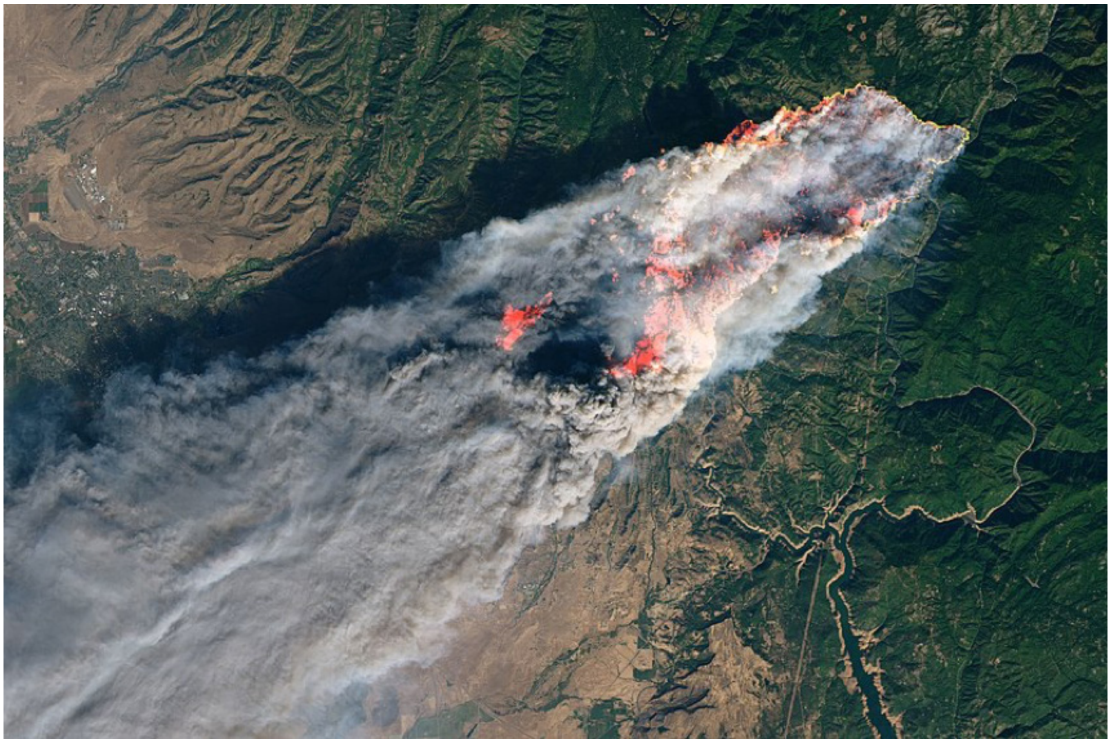

Figure 2. Landsat image of Camp Fire late-morning of November 8. The image is Infrared enhanced to show the location of active fires.

The Camp Fire became the most deadly and destructive wildfire in California's history. It ultimately burned 153,336 acres (nearly 240 sq mi), destroyed 18,804 structures, and led to 86 deaths. The fire was finally fully contained nearly a month after it began. The final perimeter of the Camp Fire and the density of structures destroyed is shown in Figure 3 (next page).

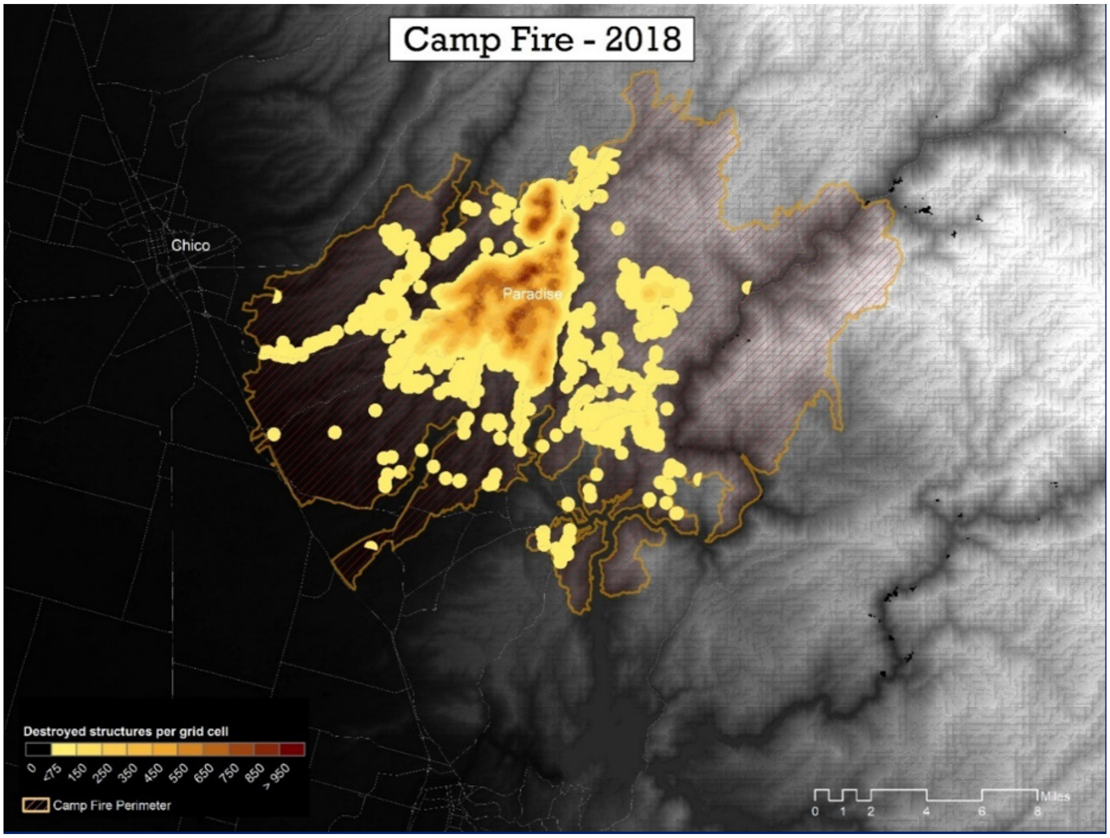

Figure 3. Shaded relief map showing the full perimeter of the Camp Fire (red-hatched) and a spatial analysis of the density of structures destroyed during the fire.

IBHS POST-EVENT SURVEY

After the fire passed, access to the town of Paradise was restricted by law enforcement, and limited to emergency responders and residents until December 16 (nearly six weeks after the fire). During this time, crews were busy clearing debris such as fallen trees and power lines from roadways, along with the initial stages of hazardous materials cleanup. When public access was allowed, IBHS and representatives from several member companies conducted a post-event survey within the towns of Paradise and Magalia.

Over the course of three days, the group conducted drive-by and site-specific investigations of the two communities. A general observation throughout the survey was that buildings were destroyed while vegetation remained (see Figure 4 on next page). The lack of a significant crowning fire suggests ember-driven ignitions of buildings with limited ground fuels, rather than the continuous burning of vegetative fuel throughout the the whole community.

Figure 4. Panorama taken at a manufactured-home community on the east side of Paradise. Note tops (crowns) of evergreen trees still have visible pine needles.

Observations in the field were consistent with those observed in laboratory testing for the performance of building materials, vulnerabilities in building design, and fuel management around structures. Building materials includes the components of a home or business such as the roof, vents, siding material, and attached structures such as decks. In 2008, California added specific requirements (generally known as Chapter 7A) to the state building code for materials and construction methods in areas where exterior components are exposed to wildfire. This makes the town of Paradise an excellent case study because it contained buildings constructed before and after implementation of Chapter 7A requirements.

An analysis of CAL FIRE post-event data published in The Sacramento Bee examined the effectiveness of California's Chapter 7A requirements on reducing damage and destruction of structures in Paradise. Their analysis found that newer single-family homes (built in 2008 or later) were much more likely to survive than homes built before the building code specifically addressed exterior wildfire exposure.

MITIGATION STRATEGIES AND TOPOGRAPHY

Mitigation strategies are effective up to a certain thermal exposure intensity, beyond which the effectiveness of wildfire-resistant building materials and design are limited. Exposure, in the form of embers, direct flame contact, or radiant heat, can be mitigated by fuel management around the building known as defensible space. Evaluators observed several properties and buildings with well-maintained defensible space that were undamaged. However, other destroyed homes also exhibited varying degrees of effective fuel management.

One of the unique observations during post-wildfire damage investigations is the effect that human intervention during the event can have on structure damage. For example, there were several homes with evidence of firefighter intervention, where burning fences had been knocked down or gutters containing burning debris had been pulled away from the roof. These seemingly small acts can have a tremendous effect on reducing the intensity of exposure to the home and result in an intact structure.

Topography is known to affect the spread of wildfires. Figure 5 depicts an oblique view of the east-facing slope of Paradise (Valley View Drive). As shown, all houses on top of the ridge are destroyed except one. When examining the pattern of charred vegetation, an unburned area between the two burned strips (highlighted in Figure 5) was found. The unburned area of terrain is located on a convex part of the escarpment. The two burned strips of vegetation have a concave shape. Fire spreads rapidly uphill. However, the local terrain shape of the small convex feature downhill from the home created a pathway for the flames and intense heat to flow around the home. This small convex terrain feature likely reduced the exposure intensity on this one home and, coupled with its well-maintained mitigation features, enabled it to survive, while the other structures, at the edge of this ridge, experienced high-intensity fire spreading uphill that could overwhelm any mitigation strategies.

Figure 5. Home on the western edge in the community of Paradise, built after 2008 and to the California Building Code Chapter 7A requirements. Photograph courtesy of Munich Re.

Examination of the home that was not destroyed (see Figure 6) showed that surface fuels around the home are limited, including underneath the deck and the 5-foot noncombustible zone around the building. (The homeowners stated that visible items were placed there after the fire.) The home was built after 2008 and conforms to the Chapter 7A requirements. In addition, the homeowners created a noncombustible zone around the building with rock gravel and vegetative fuel on the down-slope that is well managed. This reduced the potential direct flame contact underneath the deck. In this case, mitigation strategies were effective when low to medium thermal exposure conditions were encountered.

Figure 6. Combination of recommendations and less intense exposure. Well-maintained defensible space and noncombustible zone (rock mulch) around the building and underneath the deck.

EFFECTIVENESS OF FUEL MANAGEMENT

A central part of IBHS guidance to home and business owners is creating and maintaining defensible space around a structure. IBHS research has shown that a key attribute of defensible space is a 5-foot noncombustible zone around a structure.[9] While defensible space does not guarantee a structure's survival, it was found to be an effective mitigation strategy for numerous structures surveyed. Figure 7 shows the backyard of a surviving home. It was clear that fire burned up to the outside edge of their defensible space, 30 ft of well-maintained lawn.

Examining the property in more detail, the corner of the deck on this home is charred, almost certainly due to ember exposure (Figure 8). IBHS has previously observed that embers accumulate in the area between the deck boards and can cause ignition.[10] During the investigation it was also noted that the underdeck area was blocked with mesh screen. The screen would limit the entrance of wind-blown vegetative debris and embers that can accumulate underneath the deck and potentially expose the underside of the deck to flames. IBHS research has shown this type of exposure can often ignite the deck and create a significant risk to the structure.

Figure 7. Series of photographs of a home that survived the Camp Fire. The image on the left shows evidence of a nearby structure that was destroyed approximately 20 ft away. The images on the right show in general, well-maintained defensible space except for a tree and large bush near the home (bottom-right image).

Figure 8. Charred deck and mesh screen from the same home shown in Figure 7.

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[9] Faraz Hedayati, C.S., Daniel Gorham, Stephen L. Quarles, Near-Building Noncombustible Zone. IBHS Technical Reports, 2018.

[10] Stephen L. Quarles, C.S.-A., Ignition Potential of Decks Subjected to an Ember Exposure. IBHS Technical Reports, 2018.

Another example of the effectiveness of fuel management in reducing thermal exposure to a house is shown in Figure 9. The photos were taken on the west side of Paradise on Valley View Drive. Embers lofted from the wildland area (from the left in Figure 9-A), travelled uphill toward the community, and landed on different fuels. The entire area in Figure 9-A acted as the fuel bed for the flying embers. The charred area was more susceptible to the ember attack compared to green grass. However, the available fuels were low density surface fuel with relatively low heat release rate. This caused a reduced exposure to the building.

The photos on the right side of Figure 9 (B and C) depict the same part of the home from different angles. As shown, the immediate zone around the structure is charred from ember-driven ignitions. The ignition of surface fuel in that area exposed the siding on the building to direct flame contact and radiation. The damage was minor due to the relatively low heat release rate of surface fuels and noncombustible siding on the building. The other side of the building (a garage door, not shown) received a similar ember exposure, but due to a quality noncombustible zone, is intact.

Figure 9. Effectiveness of vegetative fuel management around the house up to property line.

INTERVENTION BY FIRST RESPONDERS

Thermal exposure on buildings during a wildfire depends on numerous parameters, which makes it difficult to describe quantitatively. Although applying recommended strategies might not be effective under severe exposure, it provides enough time for first responders to intervene. Several cases of the immediate implementation of IBHS-recommended strategies by first responders were observed during the post-event investigation.

Figure 10 shows a home in the Magnolia community north of Paradise where the gutter had been pulled from the house by first responders and was lying on the ground. Further inspection indicated that there had been burning debris in the gutter, likely ignited by an accumulation of embers, and minor burn damage was observed on the edge of the roof where the gutter had been attached. This has been seen in previous fires and is an intervention by firefighters where if they see flames in a gutter, they quickly pull it to the ground to prevent ignition of the building.[11]

Figure 10. Examples of vulnerability of gutter to ember exposure in the Magnolia community after the Camp Fire.

Gutters often accumulate combustible debris (for example, pine needles) if they are not properly maintained. IBHS has shown the tendency of accumulated debris in gutters to ignite due to wind-blown embers. As shown in Figure 11 (next page), the burning debris in the gutter creates a direct flame contact exposure to the edge of the roof and illustrates how non-metal gutters can detach, carrying fire to the base of the building.

[11] Maranghides A, McNamara D., Vihnanek R., Restaino J., Leland C., A Case Study of a Community Affected by the Waldo Canyon Fire – Event Timeline and Defensive Actions. NIST Technical Note 1910.

Figure 11. Gutters on fire and melting during an ember attack demonstration in the IBHS large test chamber.

Figure 12 (top) shows a scene observed at many homes where a wooden fence showing signs of burning was knocked down to the ground. Similar to the observed gutter fire intervention, this is likely the result of emergency responders doing emergency mitigation to prevent structure ignition. IBHS testing has repeatedly demonstrated that fences can provide a pathway for fire spread to the building (Figure 12 - bottom).

Figure 12. Top: Fence with evidence of burning that was knocked down. Bottom: a similar combustible wood fence during testing at the IBHS Research Center.

While it is not possible to know definitively, it is likely the two structures in Figure 10 and Figure 12 would have been destroyed without firefighter intervention. The scale of the Camp Fire and the limited first responder resources in the area would suggest that these houses survived somewhat by random chance. That is, first responders happened to be driving past at a time close to ignition and were able to take quick and decisive action. However, an important point in both cases is that the risk to the structure can be evaluated and could have been reduced. Had appropriate mitigation steps been taken, their survival would not have been dependent on a random encounter and intervention by first responders.

STRUCTURE SEPARATION

Similar to other fires in 2017 and 2018, several Paradise neighborhoods showed evidence of building-to-building fire spread. Building-to-building fire spread is a known challenge to resiliency for wildland-urban fires. To maximize use of available land, communities are often densely packed with minimal home separation. Examples include Coffey Park (Tubbs Fire, 2017) and manufactured-home communities in Paradise (Figure 13). In wildfire conditions with high winds, fire has the potential to rapidly spread from building to building and this phenomenon is similar to the way fire spreads through continuous vegetative fuels.

Figure 13. Manufactured-home community completely destroyed in Paradise, California. Separation distance between structures was approximately 10 ft.

Building-to-building spacing is a key factor in cascading damage from one burning building to another. This phenomenon needs significantly more attention because there is little research-based guidance available. In 2019, IBHS analyzed measurements taken by the UL Firefighter Safety Research Institute (FSRI) in Dayton, Ohio, during a series of experiments on full-sized homes, including free-burn tests. As a result, IBHS found that a spacing of less than 10 ft posed a significant risk of building-to-building ignition, while separation distances greater than 50 ft posed little risk. The wind speed at the time these experiments were performed was 2–5 mph, which is not representative of a wildfire situation. To provide meaningful and practical guidance on this issue, further research is needed to understand the degree of risk reduction for separation spacings of less than 50 ft.

KEY FINDINGS

- Evaluating wildfire risk should include use of improved fuel models and a better way to account for high-wind events, such as those that drove the Camp Fire. Because there was a history of fire around the city of Paradise, the community had taken the time to develop and practice an evacuation plan. Despite this, the fuel, weather, and ignition conditions on November 8, 2018 led to a disastrous fire.
- Defensible space was found to be an important mitigation tactic to protect against all three ignition exposures—embers, direct flame, and radiant heat. While most hardening strategies can protect against one or two of the ignition mechanisms, the ones that reduce the thermal exposure to the building are the most reliable. However, defensible space did not guarantee survival and quantifying the degree of associated risk reduction remains a challenge.
- Previous testing at the IBHS Research Center has accurately reproduced several of the ignition scenarios observed during the post-event investigation. The ability to control for specific variables in a research environment is vital to understanding what combination of mitigation actions are effective in reducing the vulnerability of homes and communities to wildfire.
- Firefighter intervention has been shown to be a key factor in preventing loss of houses. This intervention usually occurs at, or shortly after, the time of ignition and before the structure becomes fully involved. However, this type of roving structure protection is unlikely in all scenarios. In most instances, the need for this intervention could have been avoided through proper mitigation strategies.
- IBHS found that even when using machine learning techniques, the simple building attribute information offered little predictive value. IBHS built a classifying model using post-event data to determine how simple building attributes (such as vegetative clearance, roof and siding material, window type, and local topography) affected survivability and whether they could provide some predictive capability. The results showed that survivability is far more complex, with many different factors combining to determine whether or not a structure survived.

The wildfires of 2017 and 2018 were a chilling reminder of what can happen when all the necessary ingredients for significant wildfires come together at the wrong time and wrong place. The confluence of the built environment, weather conditions, and an ignition source was a disastrous combination that resulted in numerous record-breaking wildfires, including the most deadly and destructive fire in the state's history.

California experienced its worst wildfire season on record[12] in 2018, quickly breaking the record set the previous year with 24,226 structures damaged or destroyed. During 2018 CAL FIRE and other partner agencies responded to 7,639 wildfire incidents that burned over 1.9 million acres. These disastrous events illustrated the challenge of evaluating the risk state-wide and across other wildfire-prone regions of the country. Wildfire history and perimeters may be useful for landscape-scale assessment but lack relevant details for assessing risk to communities and individual buildings. Research is still fighting to catch up and understand what combinations of mitigation actions are the most important and under what set of conditions. Communities must continue to apply the best science-based guidance to combat this dangerous and growing hazard.

[12] https://www.fire.ca.gov/incidents/

IBHS POST-EVENT INVESTIGATION:

CALIFORNIA WILDFIRES OF 2017 AND 2018

IBHS RESEARCH