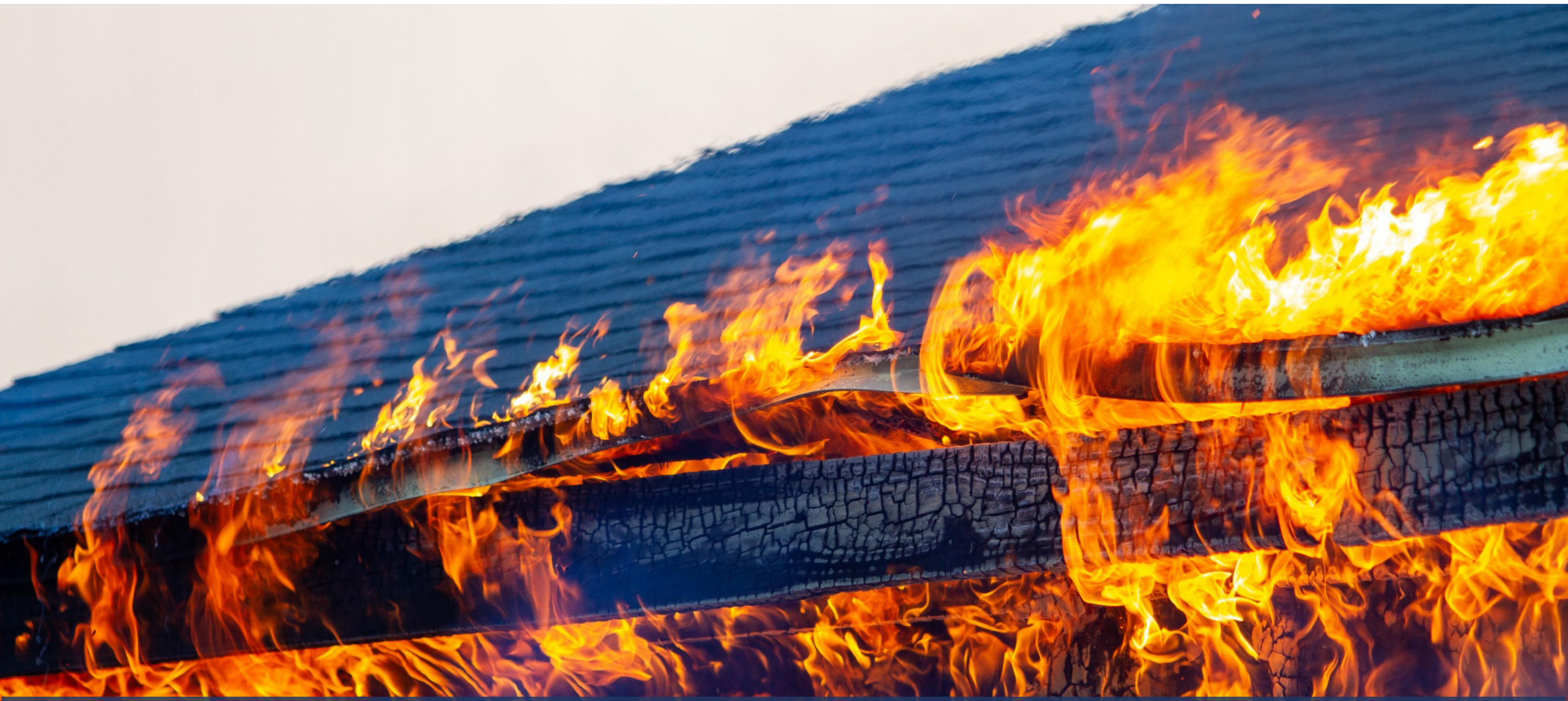
IBHS RESEARCH



IBHS Early Insights

Lahaina Fire—2023

Insurance Institute for Business & Home Safety (IBHS)

August 2023

Why It Matters: The August 9th Lahaina Fire on the island of Maui is the most recent example of a wildfire that transitioned to a nearby community with catastrophic and deadly results.

Dig Deeper: Like the 2021 Marshall Fire, high winds drove the fire, which entered the community of Lahaina though adjoining grasslands. It spread quickly once the built environment was ignited, and the resulting conflagration overwhelmed first response resources. Limited evacuation routes contributed to more than 100 known fatalities, making this fire more deadly than the 2018 Camp Fire, and potentially the largest loss of life from a wildfire in over 100 years.

It's Not Just One Thing: A notable exception to the widespread destruction is the survival of a development built in 2019–2020 with a mix of single family homes and a cluster of multifamily units in its interior. Within this development, no single-family structures were lost. Although several multifamily structures in the interior ignited (probably from embers), there was no structure-to-structure conflagration in this area. Despite close spacing, this area was spared in part because of:

- Class A roof covers, specifically asphalt shingles and metal.
- Non-combustible exterior wall materials.
- High-wind rated off-ridge attic vents, which have been shown by IBHS to also be effective at reducing ember entry.
- Due to the newness of the developed area, landscape vegetation did not cover as much area, providing less connective fuel between structures.

Real-World Impact: Modern building codes and community plans that consider wildfire along with programs like IBHS's Wildfire Prepared Home™ designation can reduce the losses and displacement caused by conflagration-level events such as the Lahaina Fire. Hawaii's modern building code has high-wind requirements that introduced elements that helped newer construction resist wildfire conditions.

OVERVIEW

The August 9, 2023, Lahaina Fire on the island of Maui, is the most recent example of a catastrophic wildland-urban interface (WUI) fire that transitions to a built environment conflagration. Fire entered the community though grasslands and spread quickly once the built environment conflagration took shape, overwhelming response resources. The rapid spread through both grasslands and the built environment coupled with limited evacuation routes contributed to over 100 fatalities so far, making this fire more deadly than the 2018 Camp Fire.

With over 2,200 structures destroyed, the Lahaina Fire is the seventh most damaging fire in the United States, based on structures destroyed, since 1990. The number of destroyed structures represents nearly three-quarters of all buildings in the community. Figure 1 provides a post-fire satellite view along with the estimated fire boundary and areas within Lahaina that survived.

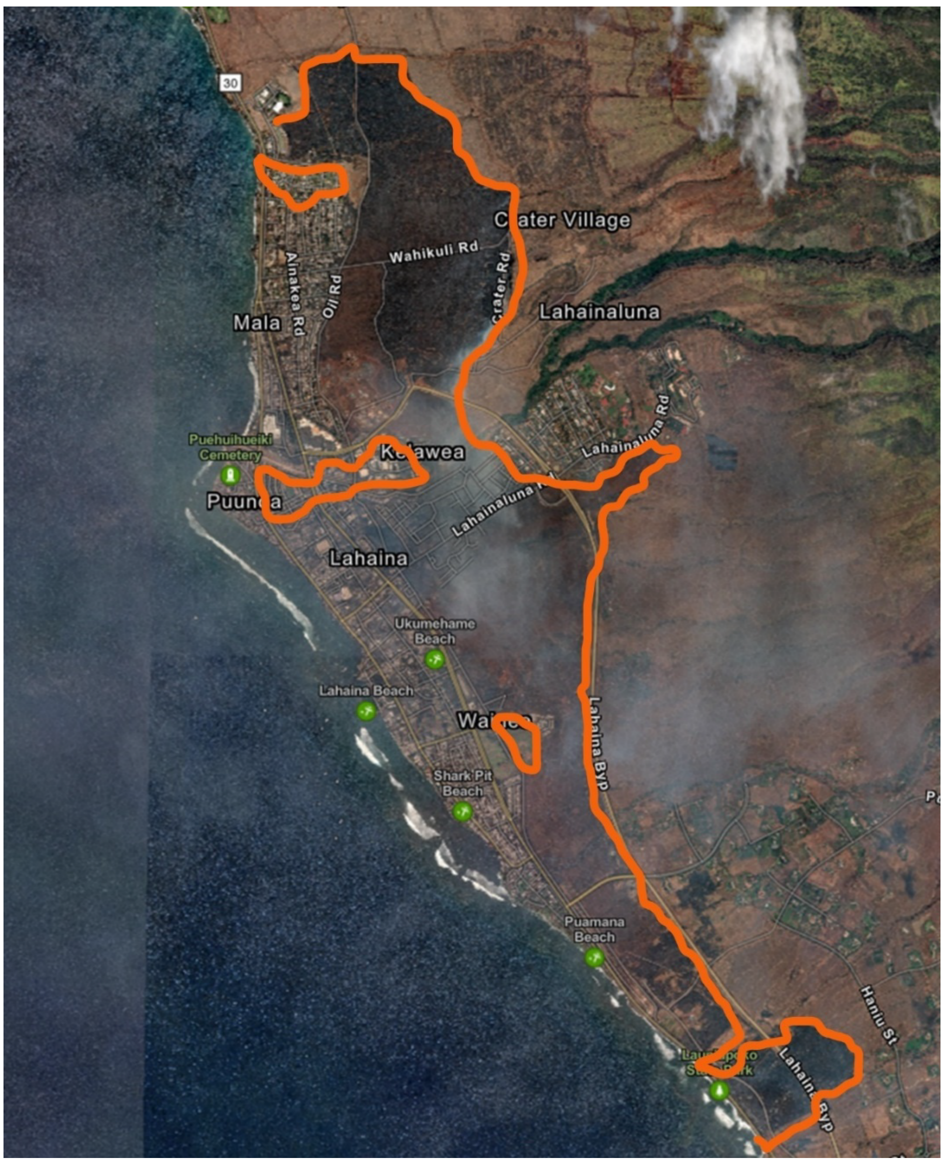


Figure 1: Post-fire satellite image showing the boundary of the Lahaina Fire and larger areas within the community that survived (orange lines). Imagery courtesy of Maxar.

WEATHER CONDITIONS

- Parts of the island of Maui were under moderate drought conditions.
- Strong easterly trade winds were intensified by a strong ridge of high pressure to the north of the Hawaiian Islands and Hurricane Dora (low pressure center) passing approximately 700 miles south of the Hawaiian Islands.
- Easterly trade winds flowed down the sloping terrain toward Lahaina, helping to dry the airmass further. Relative humidities were between 20 and 30 percent.

  Although not as extreme as those observed during the 2017–2018 western US wildfires, the humidity levels were low enough to reduce the moisture content of fuels, such as grasses, to single-digit percentages[1], contributing to rapid fire spread.

- Typical wind gusts during the event were likely between 50 and 60 mph, with peak gusts near 70 mph. This estimate is supported by available video during the fire and the limited surface weather observations available.

  The closest observing station to Lahaina was a RAWS automated observing station at Kealia Pond National Wildlife Refuge, approximately 15 miles southeast of Lahaina. It measured a peak gust of 53 mph. Winds in Lahaina were likely stronger given the mean north-east wind direction, as this station was not affected as much by the downsloping terrain as in Lahaina. The peak wind gust measured on Maui during the event was 67 mph near Kula.

- Wind flow conditions were likely ideal for tilting and stretching the large flames. Given the elevated wind speeds, the chance of long-range spotting embers from grass and shrubs was minimal. These embers would likely burn out completely during their airborne journey. However, in the case of embers originating from structures, these wind speeds could facilitate ember transport over longer distances.

BUILDING CODE ENVIRONMENT

- Hawaii has currently adopted the 2018 International Residential Code and the 2018 International Building Code; however, the state has several amendments to the model code, and enforcement is at the county level.
- Hawaii has adopted NFPA 1 as the statewide fire code. Within the state fire code, WUI provisions are provided (Chapter 17). The WUI provisions are based on the NFPA 1144 standard and are contingent on WUI areas being defined. However, it is unclear where or when these are required for new construction and what areas of the state are defined WUI areas. Life safety elements related to ingress/egress requirements, interior fire spread, and interior sprinkler systems (commercial only), are required in all instances.
- Maui County has a County Wildfire Preparedness Plan, originally developed in 2014. The county also has a Hazard Mitigation Plan, most recently published in 2018.

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[1] Overholt, K. & Cabrera, Jan-Michael & Kurzawski, A. & Koopersmith, M. & Ezekoye, Ofodike. (2014). Characterization of Fuel Properties and Fire Spread Rates for Little Bluestem Grass. Fire Technology. 50. 10.1007/s10694-012-0266-9.

BUILDING STOCK

As in all wildland-urban interface built-environment conflagrations, to slow or stop fire progression structures must function as fuel breaks rather than fuel sources. Many homes in Lahaina had some individual components of wildfire-resistant construction (for example, Class A roof covers or noncombustible wall material) but when all three ignition mechanisms (ember attack, direct flame contact, and radiant heat) are acting simultaneously in a built-environment conflagration, any major weak point in the system of protection is often exploited. Older construction, built prior to the common use of central air conditioning systems, is designed for cooling and ventilation by natural means which makes it more susceptible to ember entry. It does not appear likely that any structures were built with wildfire as a primary risk. Newer construction had the high-wind protection elements required by Hawaii's building codes.

- The building stock in Lahaina was approximately 80% single-family residential construction. The dominant era of construction was the 1960s to the 1980s. However, there are newer homes built under modern building codes.
- Commercial buildings ranged from historic structures along Front Street to typical light commercial seen in most communities. Multi-family construction was a mix of duplex, low-rise condominiums, and multi-structure apartment complexes.
- Roof cover was dominated by asphalt shingle roofs, with a small number of tile, metal, and wood shake roofs.
- Open eave roof construction is common, given the need for ventilation in a consistently warm climate.
- Wall cover materials are highly variable ranging from concrete masonry unit (CMU) block walls, wood panel siding (dominant on homes built in the 1960s and 1970s), concrete fiber board, stucco, and a small number with vinyl or aluminum siding.
- Structure separation distances are varied but on average were between 15 and 25 feet apart in most residential areas.

FIRE EVOLUTION

The evolution of the Lahaina Fire followed a classic wildland-urban interface progression, as outlined by Cohen (2008)[2], and quickly became a built-environment conflagration. In general, the sequence of events was like those observed during the 2021 Marshall Fire.

- Fire spread quickly through dry grasslands, down the gently sloping terrain toward Lahaina following the general mean wind direction. In this event, complex terrain was not present. The terrain is a nearly constant downward slope from approximately 160 ft of elevation east of Lahaina to the ocean. At this time, the exact cause of the fire is unknown. However, analysis of the fire boundary, distribution of destroyed structures and wind flow characteristics supports the potential for multiple points of ignition within or near the grasslands.
- Like the Marshall Fire, this fire likely entered the built environment through a combination of direct flame and radiant heat ignitions on the initial structures, likely in multiple locations. Once the initial structure ignitions occurred, all three ignition mechanisms took hold in these

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[2] Cohen, J., (2008). The wildland urban interface fire problem: A consequence of the fire exclusion paradigm. *Forest Hist. Today*, 20–26.

areas. Structure separation distances of less than 20 feet were present and the area contained sufficient fuels connecting homes, both vegetative, and other elements such as vehicles and sheds.

- As with most WUI fires, a major weak link was the presence of tall dense vegetation and other connective fuels near homes, specifically in the 0 to 5-foot home ignition zone (also referred to as Zone 0). With combustible materials inside the home ignition zone, the open eave roof configuration was likely easily exploited by flames and radiant heat build-up. Also, general architectural design for cooling and ventilation may have contributed to a greater ember entry threat.

Post-fire satellite imagery courtesy of Maxar and Umbra Space synthetic aperture radar data does suggest varying degrees of fire exposure and severity within the community. An example of this is shown in the northern residential areas of Lahaina, north of Malanai Street (Figure 2 - left).

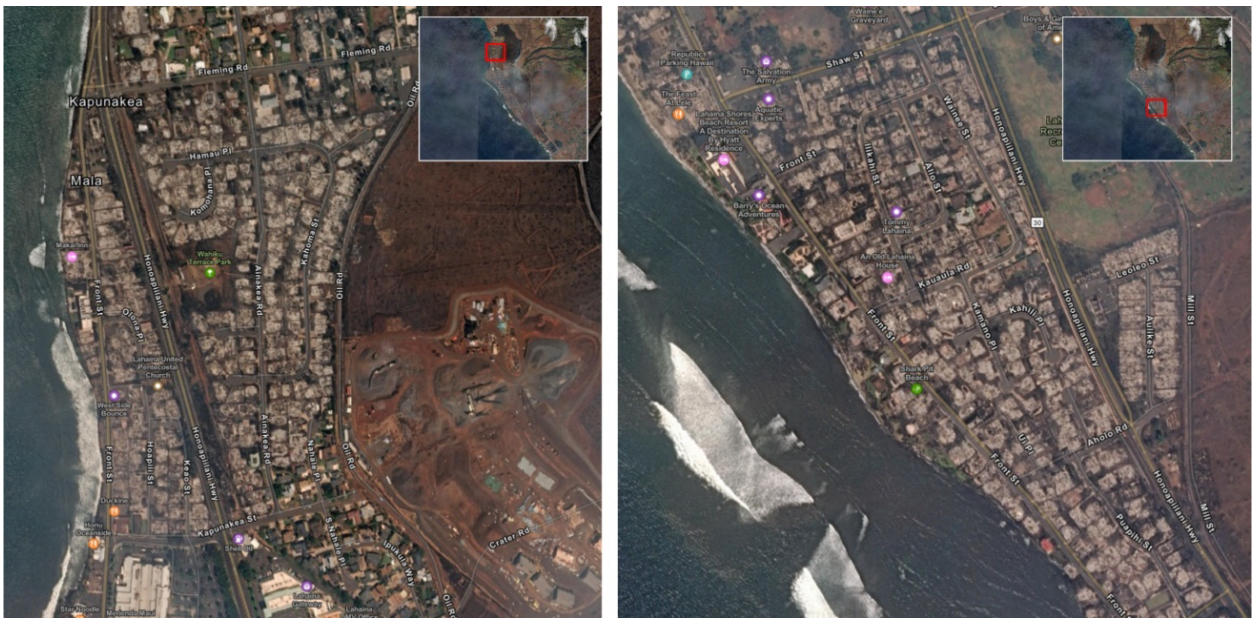

Figure 2: Satellite imagery of two areas where some of the most intense fire exposure possibly occurred, (left) south of Fleming Rd. to Kapunakea St. and (right) the area south of Shaw Street and bounded on the east side by the Honoapiilani Highway, including along Front Street. Satellite imagery courtesy of Maxar.

In this area of mostly single-family homes, the fire intensity was not enough to consume all vegetation and the presence of some sporadic homes that survived suggests that ember-driven ignitions (from both vegetative and structural fuels) may have been the dominant spread mechanism. This area also had structure spacing ranging from approximately 11 ft to greater than 25 ft for a few parcels.

South of Fleming Road, in a slightly denser area of older single-family homes, imagery indicates a more intense fire, with little materials remaining. In this area, all three ignition mechanisms (ember attack from structural fuels, direct flame contact, and radiant heat) were likely present and each were substantial contributors to the intense fire. It is likely fire spread from this area into the historic structures along Front Street. Pier and beam construction was common in this section of Lahaina. Wood lattice often surrounded the elevated structures along with a larger number of elevated decks. Vegetation coverage was near or greater than 50% on many parcels.

The area of mixed commercial construction between Kapunakea Street and the Kahoma stream channel survived and appeared to function as a partial fuel and ember break between this area and a new residential development immediately downwind to the south-southwest. However, fire spreading through the grassland east of Lahaina appeared to enter the community through residential areas on the eastern side and either continued or started a new chain of structure-to-structure spread.

Fire ultimately spread through nearly the entire community, with another area of intense fire noted in the residential areas at the southern extent of Lahaina (Figure 2-right). The area south of Shaw Street and bounded on the east side by the Honoapiilani Highway, including along Front Street, appeared to also experience some of the most extreme fire conditions.

Efforts to decrease the fire's intensity in proximity to buildings, whether through the establishment of fuel breaks or protecting structures, did not yield the desired results. Several factors, including power outages, the failure of operational hydrants, and a scarcity of fire engines on the island, compounded these difficulties.

SUCCESSES

The most notable success story was a new development, built in 2019-2020. This neighborhood had single-family home construction with multi-family units in its interior. The development is located immediately south of the Kahoma stream channel and bordered by Front Street on the west, the Honoapiilani Highway to the east, and Kenui Street on the south side (see Figure 3). Within this development, no single-family structures were lost, but four multi-family structures in its interior ignited (initially likely from embers), but a structure-to-structure conflagration was avoided in this area.

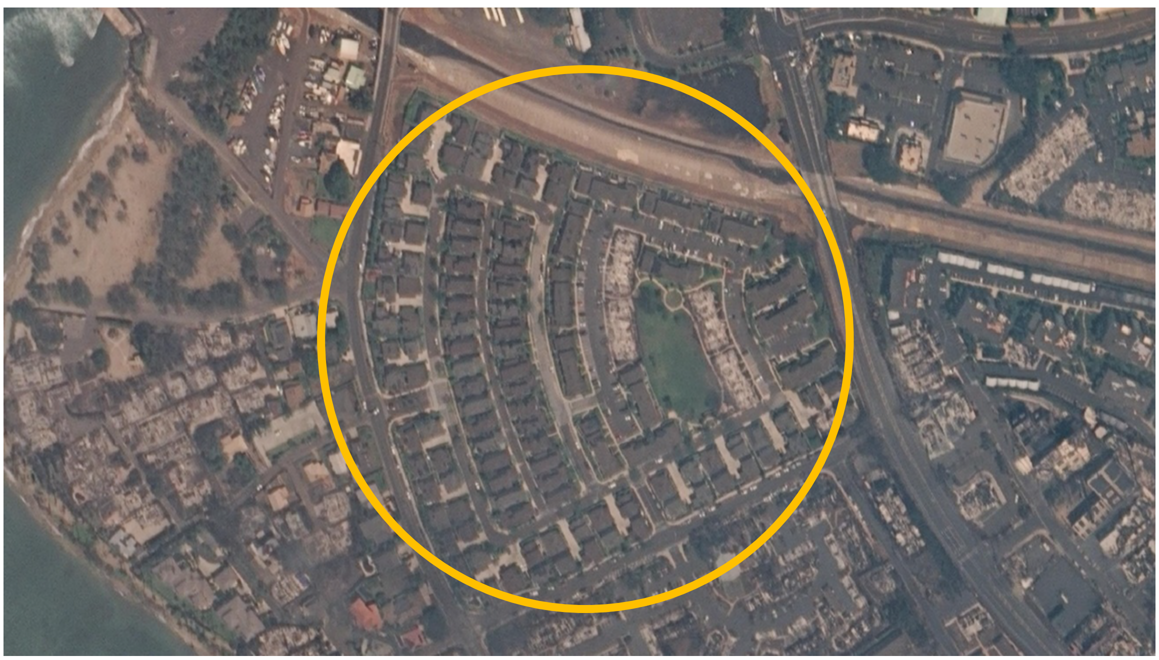

Figure 3: Post-fire satellite image of a new development, built in 2019-2020, that survived the Lahaina Fire. Note the four multifamily structures within the development that were destroyed. The initial ignition here was likely ember-driven, but a structure-to-structure conflagration scenario did not unfold here. Imagery courtesy of Maxar.

Favorable elements may have included:

- Upwind fire and ember break from commercial construction and the Kahoma Stream channel.
- Class A roof covers, specifically asphalt shingles and metal.
- Non-combustible wall cover materials

- High wind-rated off-ridge attic vents (for wind and wind-driven rain mitigation). IBHS tests have shown that these vents are effective at reducing ember entry[3].
- Less dense connective fuels between structures, including vegetation.
- Vegetation, due to the new construction, was less mature, with lower areal coverage compared to other residential areas in the community.

Elsewhere, in the areas where fire exposure was not extreme, some individual structures survived amidst those that were destroyed, indicative of the sometimes-random nature of ember attack as a dominant ignition mechanism. In these cases, fuel density in the 0 to 5-foot zone was often less than neighboring structures, the presence of non-combustible wall materials, or structure separation distances greater than 40 feet. An example of a home that survived within an area of intense fire is shown in Figure 4.

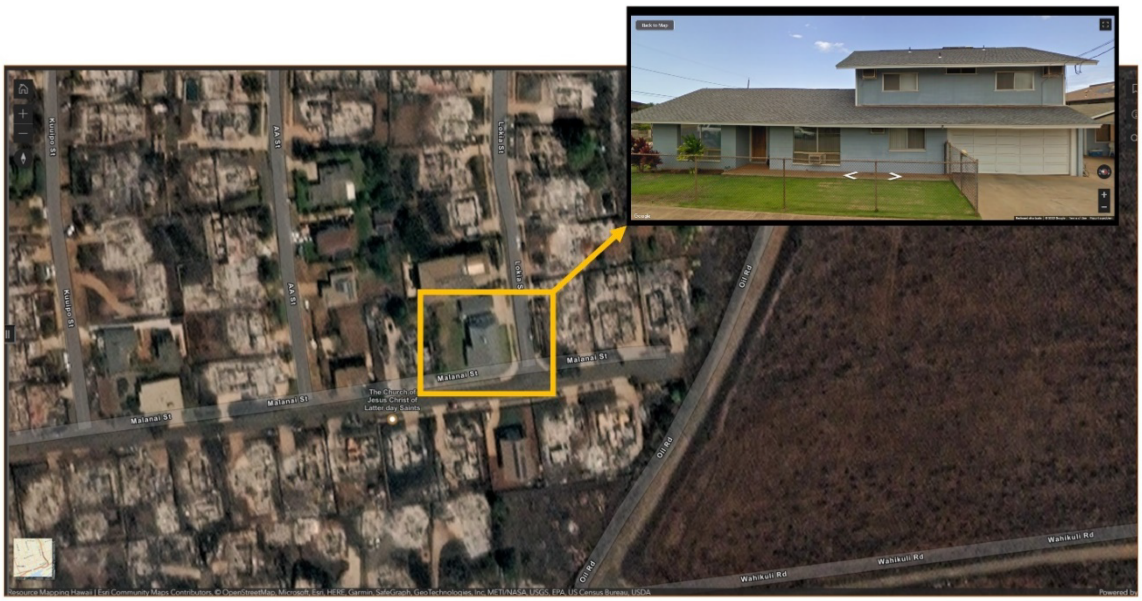

Figure 4: An example of a home that survive, with low density fuel coverage, especially in the 0–5-foot home ignition zone, an asphalt shingle roof, and non- combustible concrete masonry unit wall material. Post-fire imagery courtesy of Maxar and pre-fire condition image courtesy of Google-Street View.

Homes that were built under modern codes have wind mitigation elements along with other requirements that can foster construction styles and materials that provide some level of mitigation against fire. An example is the potential use of ridge and/or off-ridge attic vents that have both high wind and wind-driven rain protection. These vents have also been found to reduce ember entry[3]. Also, the use of concrete foundations extending above 6-inches on-grade for termite protection is also an element that would meet the IBHS Wildfire Prepared Home™—Base level of protection.

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[3] Quarles, S. 2017: Vulnerability of vents to wind-blown embers. *Insurance Institute for Business & Home Safety*. Technical Report. 24 pp. https://ibhs.org/wildfire/ember-entry-vents/

WILDFIRE PREPARED HOME™

Wildfire Prepared Home™ is a program that defines specific actions homeowners in a WUI area can take to reduce the possibility that their home is ignited by wildfire.

Wildfire Prepared Home – Base

The Wildfire Prepared Home™—Base level focuses on ember defense. It is not clear if this system would have been sufficient to stop the initial structure ignitions, which likely occurred due to direct flame and/or radiant heat from the grassland fire.

In areas with less extreme fire conditions and structure separation distances greater than 20 feet, and especially those greater than 30 feet, the Wildfire Prepared Home—Base level could have been effective in slowing or even potentially preventing structural ignitions.

If the mitigations are applied comprehensively in residential areas, at a minimum they would have been effective at reducing fire spread rates with some potential to stop the rapid chain of building-to-building fire spread.

Wildfire Prepared Home Plus

The Wildfire Prepared Home™ Plus system would have likely been effective at stopping the initial structure ignitions.

In areas of intense fire in neighborhoods with typical spacing distances of 10 to 30 feet, all three ignition mechanisms were probably acting simultaneously. In this situation, a full system of protection against all three types of ignition, such as the Wildfire Prepared Home Plus standard, is necessary for any success in slowing or stopping fire spread in the absence of large-scale fire service intervention.

In a dense community (less than 10 feet between structures) it is likely that the system of protection offered by Wildfire Prepared Home Plus would have needed to be coupled with other required defensible space measures outside the home ignition zone, effectively reducing the areal coverage of connective fuels, including vegetation. Ongoing research by IBHS and our academic partners suggests this may be as low as 20 to 30 percent areal coverage of any combustible fuel on the parcel.

SUMMARY

The Lahaina Fire is the most recent example of a wildfire acting as a catalyst for a built-environment conflagration. The pre-fire weather conditions readily supported the potential for a conflagration and the common vulnerabilities of the built environment, such as dense construction with little fire resistance, were present. The chain of events conceptually followed Cohen's (2008)[2] original wildland-urban interface fire concept and were very similar to that of the Marshall Fire.

The rapid fire spread into the built environment overwhelmed limited suppression resources and the limited number of evacuation routes unfortunately led to significant casualties. The Lahaina Fire is now the deadliest United States wildfire in 100 years. With over 2,200 structures destroyed, the Lahaina Fire is the seventh most damaging wildfire in the United States since 1990, based on structures destroyed.

With the absence of effective suppression efforts and the relatively homogenous, downsloping coastal topography, this fire presents an intriguing opportunity to examine how different buildings materials and designs responded to varying heat intensities depending on their surroundings. IBHS is currently considering deploying a ground team to conduct assessments of building performance in support of ongoing research objectives and the Wildfire Prepared Community initiative.

ACKNOWLEDGEMENTS

IBHS would like to acknowledge Maxar Technologies for their rapid and public dissemination of post-fire satellite imagery.

Special thanks to Umbra Space for providing access to post-fire synthetic aperture radar data.

Data from the Microsoft building footprint database was used to develop the initial insights presented here.