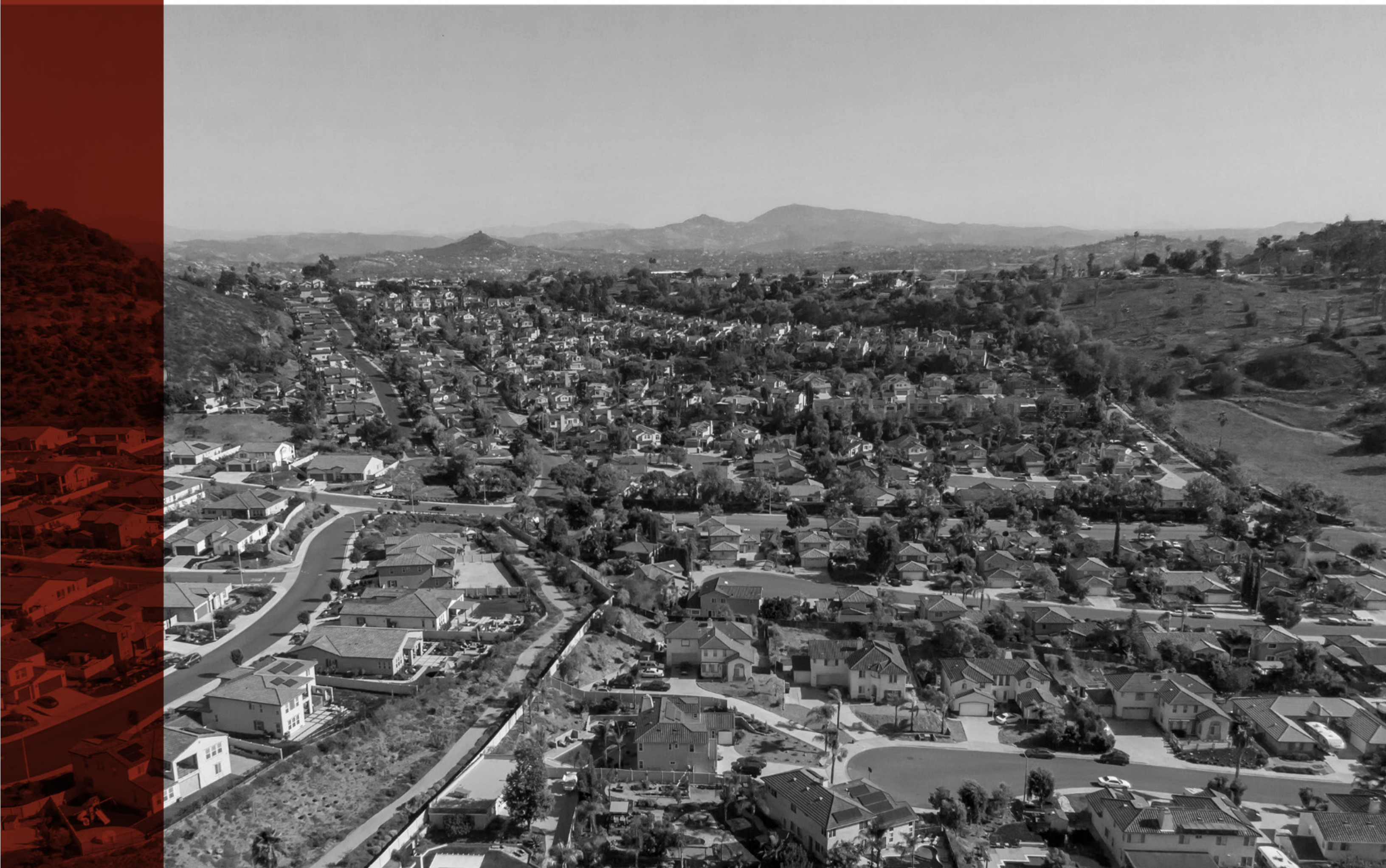
WILDFIRE PREPARED®
NEIGHBORHOOD

TECHNICAL STANDARD

VERSION 2025



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FOREWORD

Roy Wright, President & CEO of the Insurance Institute for Business & Home Safety

Mother Nature can intrude into communities bringing all manner of disasters, each with its own unique challenges.

Wildfires—unlike wind, flood, or hail—intensify when they encounter our built environment. While adding hurricane clips and straps to a home's structure can reduce its vulnerability to a high wind event, the construction quality of a home against wind has only small impacts on the next-door neighbor and does not affect the strength of the hurricane itself. However, the wildfire risk of adjacent homes not only correlates to its exposure but can also amplify the vulnerability. When one home ignites and then sets the next structure on fire, it triggers a cascade of destruction.

This significant wildfire risk did not develop overnight. We are addressing a multi-generational issue that has been evolving for over 75 years in neighborhoods adjacent to lands where fire has been part of their ecosystems for millennia.

Yet we are neither helpless nor hopeless in the face of wildfire's fierce effects.

Our understanding of wildfire science, especially its interaction with the built environment, is advancing rapidly. The equation requires adaptation at both the parcel and community scale. Effective strategies to reduce wildfire risk for individual properties are proving their value. Now, we are tackling the next piece of the wildfire risk puzzle: addressing the neighborhood risks that drive large-scale conflagrations.

Each neighborhood is unique, even those developed by volume builders. They have different surrounding fuels, layouts, and connective fuels. To address these realities, **we need a mitigation system that can adapt to these characteristics while providing protections to reduce the probability of a conflagration that leads down the path to catastrophe.**

We can envision a scenario where the neighborhood, with its passive defense features, acts as a fuelbreak rather than a fuel source.

***The Wildfire Prepared Neighborhood Standard* by *IBHS* moves toward a community-scale, performance-based design rather than prescriptive elements.**

Adapting to wildfire is not easy. **These requirements of the standard will be tough for new neighborhoods and require extraordinary efforts for existing neighborhoods. However, intentional choices, targeted redesigns, and communal commitments offer the clearest path to wildfire survivability and enduring home insurability.**

Join us in preparing your neighborhood for wildfire. Together, we can create survivable, more resilient communities.

PREFACE

Wildfires, more than any other weather-related peril, become intrinsically connected to the built environment upon encounter. The built environment can serve as a fuel source, influence fire behavior, and govern fire spread. The progression of fire through the built environment highlights how each *structure* and its probability of ignition are influenced by its surroundings. In *neighborhoods* within the *wildland-urban interface*, where buildings may be separated by only feet or tens of feet, the survivability of a *structure* is highly influenced by its *neighbors*.

To address this critical need, the Insurance Institute for Business & Home Safety (*IBHS*) developed the *IBHS Wildfire Prepared Neighborhood Standard*. This technical standard aims to meaningfully reduce the probability of a built-environment conflagration in the *neighborhoods* where it is applied.

The standard focuses on the following core principles:

- Reducing the probability of initial ignitions along the perimeter of the *neighborhood* from an approaching wildfire, where direct flame and radiant heat can first impinge on homes.
- Protect the *neighborhood* from embers.
- If ignitions occur, reduce the rate of fire spread.
- Enable the entire n*eighborhood* to act as a passive system to defend against wildfire in all directions and to not serve as a volatile fuel source.

In developing this technical standard, a performance-based design approach was utilized, recognizing that all *neighborhoods* are different. Factors such as surrounding fuels, layout, size, shape, and the arrangement of *structures* and spaces between them can influence fire spread and fire behavior. The *IBHS Wildfire Prepared Neighborhood Standard* integrates the current state of knowledge on how wildfire interacts with the built environment. It combines insights from post-event analyses, dynamical modeling, and experimental testing. The adaptive and objective process provided here determines the most beneficial mitigation strategies for each specific *neighborhood*, aligning with the core principles of the standard. The standard is also designed to incorporate new scientific knowledge and data sources while maintaining an objective approach and accounting quickly and efficiently for the uniqueness of each *neighborhood*.

This technical standard document is intended for use by builders, practitioners, code officials, engineers, developers, community planners, and fire officials for wildfire mitigation in both new developments and retrofits of existing *neighborhoods*. The standard consists of five main chapters covering applicability, definitions specific to this standard, a user guide, objective assessment processes, mitigation requirements, and associated references. Three appendices accompany the standard: *Appendix A* provides the data requirements and recommendations necessary to apply the standard. *Appendix B* focuses on scientific commentary on the methodology behind the standard and *Appendix C* is an additional practitioner guide including process diagrams for using the standard. Italicized words within the document indicate terms with standard-specific definitions, which are found in *Chapter 2*.

The *IBHS* Wildfire Prepared Neighborhood Technical Working Group is acknowledged for their contributions towards developing this standard:

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IBHS would also like to thank several external stakeholders that reviewed draft versions of this standard and assisted in testing technical processes.

CHAPTER 1. Administration, applicability, and limitations

This section provides the prequalification requirements and application procedures for the *IBHS Wildfire Prepared Neighborhood Standard*. The standard mitigation requirements at the *neighborhood* community spatial scale the characteristics of surrounding fuels and of the defined n*eighborhood* itself. It is designed to meaningfully reduce the probability of *conflagration* within the defined *neighborhood* through reducing the probability of initial ignitions where direct flame contact and radiant heat may impact perimeter *structures* from *external fuel* sources and to reduce the probability of ember-driven ignitions from *external fuels* and fuels internal to the neighborhood.

1.1 Applicability

The *IBHS Wildfire Prepared Neighborhood Standard* shall be administered for an area defined by a specific, single, and closed polygon boundary. The provisions set forth in this standard apply to the dwelling types specified in *Section 1.1.1* within the defined boundary. All dwelling units within the defined boundary must be one of the dwelling types defined in *Section 1.1.1*.

The *IBHS Wildfire Prepared Neighborhood Standard* can be applied to a minimum of a single "*cluster*" of *qualified dwelling units* and where 90% or more *structures* have a minimum distance to the nearest surrounding structure of greater than 10 feet within the defined boundary.

The *IBHS Wildfire Prepared Neighborhood Standard's* mitigation requirements are not applicable if 90% or more of the defined neighborhood has a minimum *structure separation* distance of greater than 100 ft. The threat of *conflagration* is diminished, individual parcel level mitigation actions govern ignition probabilities, and dependencies on neighboring *structures* are reduced. This criterion follows the foundational Cohen (2000, 2008) *wildland-urban interface* fire conceptual model and *the Wildfire Mitigation Framework* described in Maranghides et al. (2022).

1.1.1 Qualified dwelling types

Single-family detached home: A freestanding residential building occupied by one family, limited to three stories above grade. This also includes detached single-family factory-built modular homes on a permanent foundation that are designed, built, and sited to meet all local building code requirements. It also includes *accessory dwelling unit(s)* (ADU), *efficiency* co-located with other qualified dwelling types.

Two-family dwelling units (duplex): A freestanding residential building occupied by two families, limited to three stories above grade. Each individual unit must have the same number of stories within the overall structure, limited to three stories above grade. **NOTE:** The entire building, including the dwelling units, must be evaluated under the appropriate requirements and the entire building must meet all requirements specified in the *IBHS Wildfire Prepared Neighborhood Standard*.

Townhouse: A single-family dwelling unit is constructed in a group of three or more attached units in which each unit extends from foundation to roof, has a yard or public way on not less than two sides, and limited to three stories above grade. Mixed use (commercial and residential) buildings are not applicable. **NOTE:** The entire townhouse building, which includes all townhouse units composing the building, must be evaluated under the *IBHS Wildfire Prepared Neighborhood Technical Standard's* requirements and the entire *structure* must meet all requirements.

1.2 Limitations

1.2.1 Building codes

The requirements specified in the *IBHS Wildfire Prepared Neighborhood Technical Standard* currently exceed typical *Wildland-Urban Interface* model building codes (2024 International Wildland-Urban Interface Code – IWUIC, 2022 California Building Code Chapter 7A, 2022 NFPA 1140) through the requirement of a fully *0–5 Foot Noncombustible Zone* in both *neighborhood flame zone* and *neighborhood ember zone* requirements. The *IBHS Wildfire Prepared Neighborhood Standard* is designed to be implemented as a voluntary mitigation standard.

1.2.2 Conflagration

The standard is not intended to prevent large wildfires or eliminate conflagrations in the built-environment. It does seek to mitigate the impact of wildfires and meaningfully reduce the probability of built environment conflagration in neighborhoods where it is applied by establishing minimum requirements for structures, defensible space, and fuel management at a *neighborhood* spatial scale.

1.2.3 Connective fuel management

This standard provides minimum neighborhood requirements for management of fuels (both vegetative and built-environment elements) between structures. It does not seek to characterize vegetative fuels or species that may exhibit reduced combustibility at both the parcel and neighborhood scales.

1.2.4 External fuels

The standard currently assumes, through its processes and subsequent mitigation requirements, that fire can impinge on the neighborhood from all directions and that the worst-case fuels ignite. Currently, structural fuels within what could be a nearby neighborhood that has mitigation elements or another neighborhood which meets this standard are evaluated to the same criteria as if there were no mitigation present. If ignited, these fuels would impart the same flame/radiant heat and ember exposure as an un-mitigated neighborhood.

1.2.5 Fire Response

Advancements in technology, firefighting equipment capabilities, firefighter staffing levels, and training have increased the overall effectiveness of emergency response, structure defense, and wildfire suppression. Data suggests that 90% to 95% of all structures damaged during wildfire are defended, primarily by fire suppression resources. However, when a wildfire enters a vulnerable community under drought and high wind conditions, fire suppression resources cannot be expected to defend every individual structure threatened by embers, flames, and radiant heat. This illustrates the need for homes and communities to have a system of passive mitigations that can significantly aid in increasing the effectiveness of the fire suppression response under extreme conditions. This standard is designed to be applied as a passive mitigation system; therefore, it does not include provisions or requirements for fire service response.

1.2.6 Hazard Mapping

This standard does not provide mapping of *wildland-urban interface* areas, identify the fire hazard potential of locations under consideration, nor provide a specific wildfire risk assessment metric.

1.2.7 Location

The *IBHS Wildfire Prepared Neighborhood Technical Standard* is designed to apply to *neighborhoods* and communities with high to medium structure density, with most *structure separation* distances between 10 to 100 feet. Maranghides et al. (2022) provides a useful definition of the *wildland-urban interface*, *WUI* Types 1-7, that incorporate structure separation distances and if the community is considered wildland "interface" or "intermixed." *WUI* types 1-5, characterized by *structure separation* distances from 6 to 100 feet and typical building densities of less than two *structures* per acre up to eight *structures* per acre, in interface and intermixed areas reflect the *neighborhoods* for which this standard is intended. It is not designed to be used as a construction standard in areas that span the entire built environment and/or large tracts of wildland areas or in dense urban corridors. (For more details see *Appendix B, Section B1.1)*

1.2.8 Maintenance

Buildings, *structures*, landscape materials, vegetation, defensible space or other devices or safeguards required by this standard shall be maintained in conformance to the standard edition under which it is installed.

1.2.9 Structure separation

Experimental research indicates that when *structure separation* is 10 feet or less, fire spread between two structures is highly likely. Therefore, the *IBHS Prepared Neighborhood Standard* contains applicability requirements related to *structure separation* distances. There are neighborhoods/communities that the standard does not apply to, given their small *structure separation* distances. Additional details and scientific reasoning are provided in *Appendix B*.

1.2.10 Topography

Topography is not considered within the *IBHS Wildfire Prepared Neighborhood Standard* in the determination of the *neighborhood flame zone* calculation within *Section 3.3*.

1.2.11 Units of measure

Within the *IBHS Wildfire Prepared Neighborhood Standard,* English units of measure are generally stated and shall be the units used and stated for any mitigation requirement. However, for processes described in *Chapter 3 and* within *Appendix B*, metric units are required for several of those calculations and are therefore presented as such.

1.2.12 Weather

This standard is intended to address wildfire and its impact on the built environment under weather conditions and fuel moisture characteristics typically observed during *conflagration* events. For specific calculations relative to mitigation requirements, an open terrain exposure, peak 3-second gust wind speed at 10 meters (33 ft) height of 70 mph is applied.

CHAPTER 2. Definitions & user guide

2.1 Definitions

0–5 Foot Noncombustible Zone (also referred to as Immediate Zone, Zone 0, or Ember-Resistant Zone). The area which surrounds a structure extending from the base of any exterior wall radially outward along the ground 5 feet and vertically to the sky. In this standard, this shall be referred to as the 0–5 Foot Noncombustible Zone.

Accessory dwelling unit (ADU). An attached or detached residential dwelling unit that provides complete independent living facilities for one or more persons and is located on a lot with a proposed or existing primary residence. It shall include permanent provisions for living, sleeping, eating, cooking, and sanitation on the same parcel as the *single-family* or *multifamily dwelling* is or will be situated (CA Government Code (GOV) 66313). The total floor area for a detached *accessory dwelling unit* shall not exceed 1,200 ft^2 (GOV 66314). A local agency shall not establish by ordinance any of the following: 1) A minimum square footage requirement for either an attached or detached accessory dwelling unit that prohibits an efficiency unit, 2) A maximum square footage requirement for either an attached or detached accessory dwelling unit that is less than either 850 ft^2 or 1,000 ft^2 for an *accessory dwelling unit* that provides more than one bedroom (GOV 66321).

Accessory structure. A detached building or *structure* used to shelter or support any material, equipment, chattel, or occupancy other than a habitable building (i.e., non-dwelling unit). Any detached *structure*, that is accessory and incidental to a *primary dwelling unit* located on the same *parcel* or lot that has a surface area coverage or footprint of greater than or equal to 15 ft^2 and less than 200 ft^2. A structure less than 15 ft^2 is not considered an *accessory structure* for *structure separation* applicability statistics, *structure separation* in the *neighborhood flame zone*, and *cluster* assessments but is considered in the *connective fuel* assessment.

Built environment fuel element. Built environment fuel elements are any combustible material, item, *accessory structure*, etc. An *accessory structure* is considered a *built environment fuel element*. Examples include but are not limited to fences, playhouses, sheds, pergolas, gazebos, detached decks, *accessory structures*, etc.

Cluster. Set of *structures* that are separated from other *structures* in the community by one of the following:
1) The following physical *noncombustible* barriers: any paved, maintained (city, town, county) road, any non-paved but gravel or bare soil roads, or natural barriers that are noncombustible such as creeks, rivers, lakes, ponds etc. with a minimum width of 20 feet.
2) 100 feet or more from other *structures* inside the defined *neighborhood* boundary, or
3) Separated from other *structures* inside the defined *neighborhood* by a combination of barriers or physical distance.
See *section 3.5.1*

Conflagration. Specific to the usage of this term within this standard, an especially large and destructive fire that produces uncontrolled structure-to-structure fire spread and mass *structure* losses.

Connective fuels. *Any fuel element* or group of fuel elements that aid in fire spread between structures.

Connective fuel flag. Assigned to a *cluster* where 10% or more of homes within a *cluster* have more than one *connected fuel pathway* to any neighboring structure.

Connective fuel flagged cluster. An identified *cluster* of *structures* where more than 10% of *structures* have more than one elevation with a *connective fuel pathway* to a neighboring *structure*.

Connective fuel pathway. Series of *fuel elements* or single fuel *elements* that connect two or more neighboring *structures* with no breaks greater than two times the width of the fuel element. If a break in a *fuel element/s* greater than two times the width of the *fuel element* is present, the pathway is considered broken. Any combustible fence which connects to two or more *structures* shall be considered a *connected fuel pathway* independent of other additional *fuel elements*. The presence of *noncombustible* fencing as an element of a *0–5 Foot Noncombustible Zone* shall be considered to have broken the specific *connective fuel pathway* associated with the fence; however other *fuel elements* present shall also be considered in identifying other paths.

Crown fire. Fire that burns canopy forest fuels like foliage, branches, and tall shrubs. Crown fires burn fuels above surface fuels.

Defensible space. An area either natural or man-made where material capable of allowing a fire to spread unchecked has been treated, cleared or modified to slow the rate and intensity of an advancing wildfire and to create an area for fire suppression operations to occur (IWUI 2024).

Dwelling unit, efficiency. *Structure* where all permanent provisions for living, sleeping, eating and cooking are contained in a single room.

Neighborhood ember zone (*NEz*). The area of the defined *neighborhood* determined by the process described in Section 3.4 which has a likelihood of ember exposure.

External fuels. Any *fuel element* or *fuel model type* identified using at a minimum the *LANDFIRE* dataset which is identified within a 4.25-mile buffer beyond the defined *neighborhood* boundary.

External fuel sector. 45° azimuthal sector extending radially outward from the *neighborhood centroid* to a maximum distance of 4.25 miles.

Firebrand. Combustible fragments of material from a fire source with the capacity to ignite other materials. For the purposes of the *IBHS Wildfire Prepared Neighborhood Standard,* ***firebrand*** and ***ember*** terminologies will be used interchangeably, despite technical nuance as described by Manzello and Suzuki (2022).

Firebreak. *Parcels* of land, linear in shape, where all combustible fuels are totally removed down to mineral soil through a combination of physical treatments (thinning, mechanical clearing, prescribed burning, slashing, mastication, mowing, plowing) or pavement such as roads, highways etc. In the case of a boulevard or any divided highway, if the area which is not paved (typically in the center) has no identified *connective fuel nodes*, the entire width of the boulevard and/or divided highway shall be considered a *firebreak*. If this condition is not met and *fuel elements* are present, the roadway width closest to the defined *neighborhood* boundary shall be considered the *firebreak*.

Fire-resistance-rated construction. The use of materials and systems in the design and construction of a building or structure to safeguard against the spread of fire within a building or *structure* and the spread of fire to or from buildings or *structures*. Where this standard requires 1-hour fire-resistance-rated construction, the fire-resistance rating of building elements, components or assemblies shall be determined in accordance with the test procedures set forth in ASTM E119 or UL 263.
Exceptions:

1) The fire-resistance rating of *structure* elements, components or assemblies based on the

designs prescribed in Section 721 of the International Building Code.

2) The fire-resistance rating of structure elements, components or assemblies based on the calculation procedures in accordance with Section 722 of the International Building Code.

Flame fuel assessment zone. Buffer zone that extends 0.25 miles (approximately 300 meters) radially outward from the boundary of the defined *neighborhood*. This area is used to determine fuels that are relevant for the flame fuel assessment process.

Fuel element. Any combustible item such as but not limited to plants, materials (e.g., children's playhouses, racks of firewood, plastic storage bins, etc.), combustible ground cover (i.e., mulch), *structures*, trees, shrubs, sheds, fences, etc. Fuel elements also include any defined vegetative fuel element but do not include grass/vegetation with a height or depth less than 4 inches above the ground. Tree fuel elements, due to their height and canopy have specific requirements. Trees are distinguished as vegetative *fuel element* with a trunk of 4 inches in diameter or greater when measured at a height of 4.5 feet above the ground.

Fuelbreak. Fuelbreaks are *parcels* of land, linear or in blocks, on which the vegetation, debris and detritus have been reduced and/or modified that could control or diminish the risk of the spread of fire crossing the strip or block of land.

Fire behavior fuel model type (also fuel model type). A set of inputs to define a fuel bed for a specific fire behavior model.

IBHS. Insurance Institute for Business & Home Safety.

IBHS Wildfire Prepared Home Standard. The latest version of the *IBHS* Wildfire Prepared Home Technical Standard. (https://wildfireprepared.org/wp-content/uploads/WFPH-Standard.pdf)

Internal neighborhood sector. 45° azimuthal sector extending radially outward from the *neighborhood centroid* of the defined *neighborhood* to its perimeter and constructed using from the same radial lines used to construct the *external fuel sectors*.

LANDFIRE. Landscape Fire and Resource Management Planning Tools is a shared program between the wildland fire management programs of the U.S. Department of Agriculture Forest Service and U.S. Department of the Interior, providing landscape scale geo-spatial products to support cross-boundary planning, management, and operations. *LANDFIRE* began due to an increased concern about the number, severity, and size of wildland fires and the need for consistent national biological/ecological inventory data. *LANDFIRE* identifies areas across the nation potentially susceptible to wildland fire to support community and firefighter protection. *LANDFIRE* has evolved and expanded to include other applications such as habitat research and disturbance maps.

Neighborhood. For the purposes of the *IBHS Wildfire Prepared Neighborhood Standard*, a *neighborhood* is defined as a *cluster* or multiple *clusters* of residential *structures* enclosed by a continuous defined polygon boundary.

Neighborhood centroid. For the purposes of this standard, the position of the center of the defined *neighborhood* can be determined by summing the eastern and western-most longitudes along the perimeter of the *neighborhood* and dividing the result by two to calculate the x-coordinate and then summing the northern and southernmost latitudes along the perimeter of the defined *neighborhood* and dividing the result by two to obtain the y-coordinate.

Noncombustible or Noncombustible element. Made from material of which no part will ignite and burn when subjected to fire. Any material passing ASTM E136 shall be considered noncombustible.

Neighborhood flame zone (*NFz*). An area of the defined *neighborhood* which has a high likelihood of direct flame and radiant heat exposure from *external fuel* sources. This area is located inward from the perimeter of the defined *neighborhood*. The *neighborhood flame zone* is determined using *Equation 3.3* and through the process described in *Section 3.3*.

Parcel. A piece or unit of land, defined by a series of measured straight or curved lines that connect to form a polygon. There are some implications for land ownership. Commonly also called a tract.

Primary dwelling unit. The largest *structure* on a given *parcel* has at least one or more habitable rooms which are designed to be occupied by one family with facilities for living, sleeping, cooking, eating, and sanitation.

Roof assembly. A system designed to provide weather protection and resistance to design loads. The system consists of a roof covering and roof deck or a single component serving as both the roof covering and the roof deck. A roof assembly includes the roof covering, roof deck and may include a vapor retarder, thermal barrier, insulation, or similar substrate.

Roof covering. The material applied to the roof deck to provide weather resistance, achieve fire classification, or enhance appearance.

Roof system. A roof system consists of a roof covering and other interacting roofing components and may include vapor retarder, thermal barrier, insulation or other similar substrate. The system does not include the roof deck unless it is part of a single component serving as the roof covering and the roof deck.

Structure. Any non-commercial building fully enclosed on more than two sides, larger than 200 ft^2 or any *dwelling unit* on a *parcel*. Examples include but are not limited to single family homes, detached garages, recreational vehicle shelters (fully enclosed), *accessory dwelling units*, etc.

Structure separation distance (also referred to as structure separation or SSD). The shortest straight-line distance between a structure's footprint boundary and the footprint boundary of another *structure* that does not cross the following obstacles: any paved, maintained (city, town, county) road, any non-paved but gravel or bare soil roads, or natural barriers that are noncombustible such as creeks, rivers, lakes, ponds etc. with a minimum width of 20 feet.

Vegetative fuel element. A contiguous area bound by a polygon of vegetation consisting of a tree or group of trees, shrubs (bushes), grass/ground cover with a height or depth greater than 4 inches above ground, and/or any other vegetation taller than 4 inches. Trees with canopies less than 10 feet of spacing to the nearest tree canopy shall be considered a single *vegetative fuel element*.

Wildland-Urban Interface (WUI). Across scientific literature there are varying definitions of the *wildland-urban interface*. For the purposes of the *IBHS Wildfire Prepared Neighborhood Standard*, the definition from Johnston et al. (2011) and USDA (2001) is provided. The *WUI* is defined as the geographical area where human development, including structures and other infrastructure, meets or intermixes with undeveloped wildlands. Communities in such areas may be grouped into one of three categories: interface, intermix or occluded (where developed areas surround an area of wildlands that is typically smaller than 1,000 acres) depending on the density of development, coverage of wildland fuels, and population density (Davis 1989).

2.2 User guide

The *IBHS Wildfire Prepared Neighborhood Standard* features both a process to determine mitigation requirements and the requirements themselves that are necessary to address the core principles this standard was built on (see *Chapter 1*). It also has strict applicability requirements. *Chapter 3* provides the process details to determine the mitigation requirements for areas which may have: 1) extreme ember, flame and radiant heat exposure from *external fuels* (e.g., *neighborhood flame zone*), 2) areas which are likely to experience ember attack (e.g., *neighborhood ember zone*) and 3) the *connective fuels* across the *neighborhood*. For detailed information related to the scientific and engineering reasoning used to develop this standard and its processes, please see *Appendix B*.

2.2.1 Applicability

Construction Types: This standard applies to typical single-family, duplex, and townhome construction types.

Structure spacing: This standard can be applied to a defined *neighborhood* when 90% or more of the *structures* are separated by greater than 10 feet and less than 100 feet. The process for *structure separation* assessments is described in *Chapter 3*, *Section 3.1*.

2.2.2 Understanding *neighborhood* requirements

Roof Covering

All *structures* within the defined *neighborhood* must have a Class A roof covering. In addition, no wood roof covering products of any kind are allowed. *Chapter 4, Section 4.1*

The defined *neighborhood* is divided into two primary zones, each with specific mitigation requirements. The processes described in *Chapter 3* are best executed within a geographic information system (GIS) platform.

Neighborhood flame zone

The *neighborhood flame zone* is the area typically located from the boundary of the *neighborhood* inward for up to approximately 450 feet (distances are dependent on fuel characteristics) which has the highest likelihood of experiencing the most severe fire exposure resulting from *external fuels*.

The *neighborhood flame zone* is determined using the processes described in *Chapter 3*. It accounts for *external fuels* within 0.25 miles of the *neighborhood* boundary. For each sector, a "worst-case" distance into the *neighborhood i*s determined using the processes described in *Chapter 3*, *Sections 3.1* and *3.2*. The *structure* requirements for this zone are provided in *Chapter 4, Section 4.3.* It is possible that *external fuels* and/or *fuelbreak/firebreak* features can result in the *neighborhood flame zone* not being needed.

Connective fuel pathways in the *neighborhood flame zone*: For *structures* located inside the *neighborhood flame zone*, there can be no *connective fuel pathway* to any neighboring *structures*.

Neighborhood ember zone

The *neighborhood ember zone* is the area, typically the remainder of the *neighborhood* not within the *neighborhood flame zone* which has a high likelihood of experiencing ember attack from *external fuels* and/or *structures* within the *neighborhood* should fire enter. It is determined by the processes described in *Chapter 3*, *Section 3.4* and considers *external fuels* within 4.25 miles of the defined *neighborhood*. It is possible the *neighborhood ember zone* will not cover the entire *neighborhood*; this is contingent on *neighborhood* size and fuel characteristics. The requirements for *structures* in this zone are provided in *Chapter 4*, *Section 4.4*.

***Connective fuels* in the *neighborhood ember zone* and remainder of the *neighborhood*:** *Connective fuels* are evaluated across *clusters* of *structures* as described in *Chapter 3*, *Section 3.5.1*. The *connective fuel* requirements for the full *neighborhood* are provided in *Chapter 4*, *Section 4.*2.

2.2.3 New *neighborhood* construction recommendations

The 100% application of *IBHS Wildfire Prepared Home Plus* construction across a new *neighborhood* development, provided the *structure separation* applicability criteria is met, will generally meet the requirements of this standard except in special cases related to *ADUs*, *auxiliary structures*, and *connective fuel pathways*.

For a decision-tree graphical depiction of the *IBHS Wildfire Prepared Neighborhood* processes and requirements, see *Appendix C*.

CHAPTER 3. Processes

3.1 *Structure separation* assessment

For any defined *neighborhood*, the distribution of the shortest separation distance from each *structure* to any neighboring *structures* shall be determined. To calculate the minimum *structure separation distance*, distribution datasets such as the Microsoft Building Footprint database or similar shall be considered sufficient for use. The *IBHS Wildfire Prepared Neighborhood* standard shall be considered applicable if 90% or more of the *structures* contained within the *neighborhood* boundary have a minimum *structure separation* distance greater than 10 feet and less than or equal to 100 feet.

To calculate the *neighborhood structure separation* statistics, count the number of *structures* for which the smallest *structure separation* measurement is equal to or less than 10 feet and divide that number by the total number of *structures* in the defined *neighborhood*.

The next step in the process is to calculate the full designated *neighborhood structure separation* statistics, count the number of *structures* that have a measurement equal to or less than 10 feet and divide this by the total number of *structures* in the defined *neighborhood*. The standard is considered applicable if this value is 10% or less as stated in *Chapter 1*. The *structure separation* procedure is also used within *Chapter 3, Section 3.5* for determining *clusters* and the *connective fuel* assessment.

3.2 *External fuel* assessment

External fuels surrounding a community drive the exposure risk for any community. To determine the *neighborhood flame zone* and *neighborhood ember zone* widths, *external fuels* and their associated *fire behavior fuel type models* surrounding the defined *neighborhoo*d are identified.

External fuels assessment shall include the area 4.25 miles (6.84 km) radially outward from the specified *neighborhood* exterior boundary in all directions around the assessed *neighborhood*. The *LANDFIRE* fuel type models described in Scott and Burgan (2005) shall be the minimum required dataset for the *external fuel* assessments. Other datasets can be used, provided their resolution is equivalent or finer in spatial resolution than the *LANDFIRE* 30 meter grid spacing and such that fuel types/classifications can be condensed into the 40 fuel models described by Scott and Burgan (2005). Those can be found in *Appendix A, Table A3.2*.

The *centroid* of the defined neighborhood will be determined to set external fuel assessment sectors. From the *neighborhood centroid*, eight 45° azimuthal fuel sectors will be determined. Fuels will be assessed for each using a 0.25-mile buffer extending outward in each sector from the *neighborhood* boundary for determining the *neighborhood flame zone* and a buffer of 4.25 miles outward in each sector will be used in assessing *external fuel* characteristics to determine the *neighborhood flame zone (Figure 3.1)* and *neighborhood ember zone (Figure 3.2, Figure 3.3)*.

Within each *external fuel sector* of the *flame fuel assessment zone*, the flame intensity shall be determined for any *fuel type model* classification that is present (Scott and Burgan 2005; *Appendix A*) as shown in *Figure 3.1*.

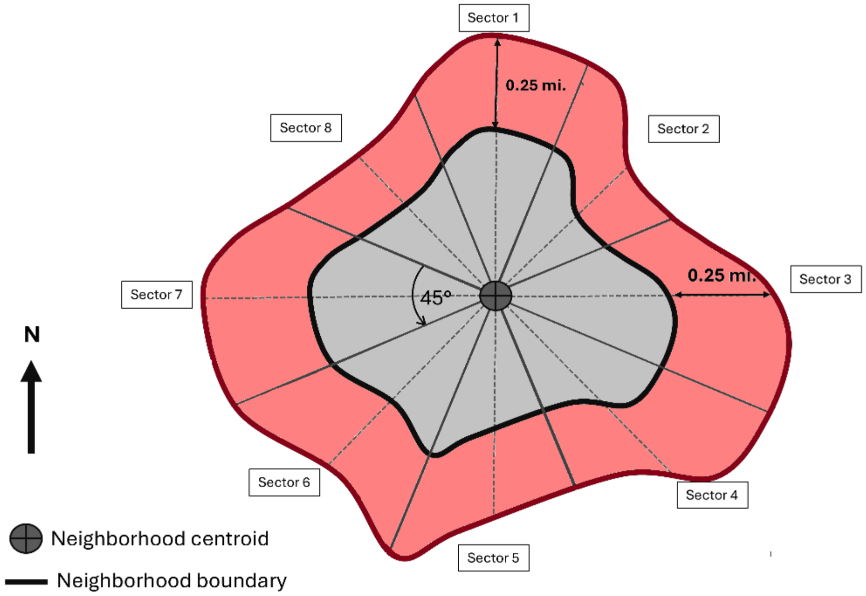


Figure 3.1. Idealized schematic illustrating how external fuel sectors are determined. The area shaded in gray represents the interior of the neighborhood. The red shaded areas represent the 0.25-mile buffer / flame fuel assessment zone that is used to determine the neighborhood flame zone (Equation 4-1). The neighborhood ember zone is not depicted but is shown in Figure 3.2 below. The schematic is not to scale and intended for illustrative purposes only.

Within each *external fuel sector,* the ember transport distance shall be determined for any *fuel type model* that represents 10% or greater of the fuel types present within the *external fuel sector* as shown in *Figure 3.2* and *Figure 3.3*.

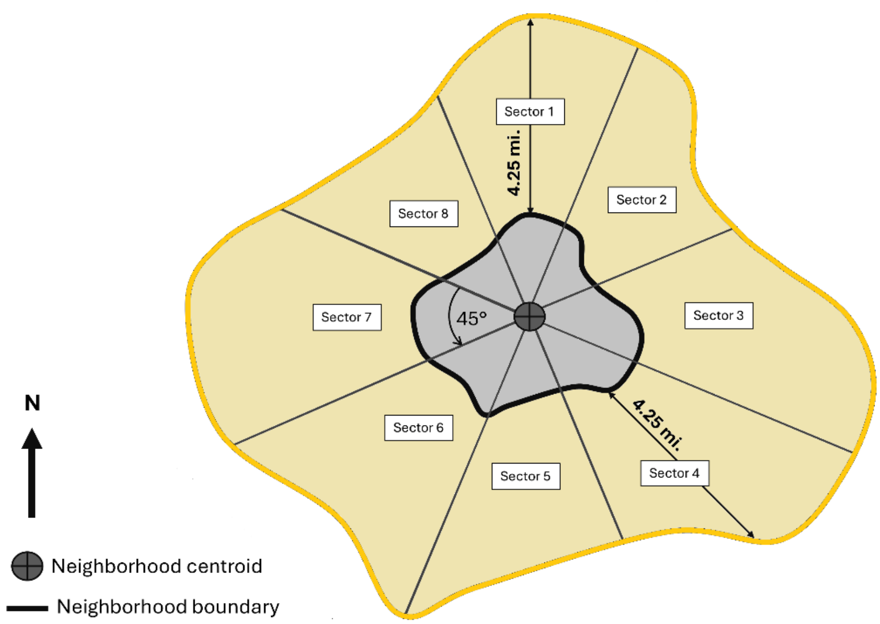


Figure 3.2. Idealized schematic illustrating how external fuel sectors are determined. The area shaded in gray represents the interior of the neighborhood. The beige shaded areas represent the 4.25-mile buffer region where external fuels will be evaluated for use in the neighborhood ember zone. The flame fuel assessment zone is not depicted but is shown in Figure 3.1 above. The schematic is not to scale and intended for illustrative purposes only.

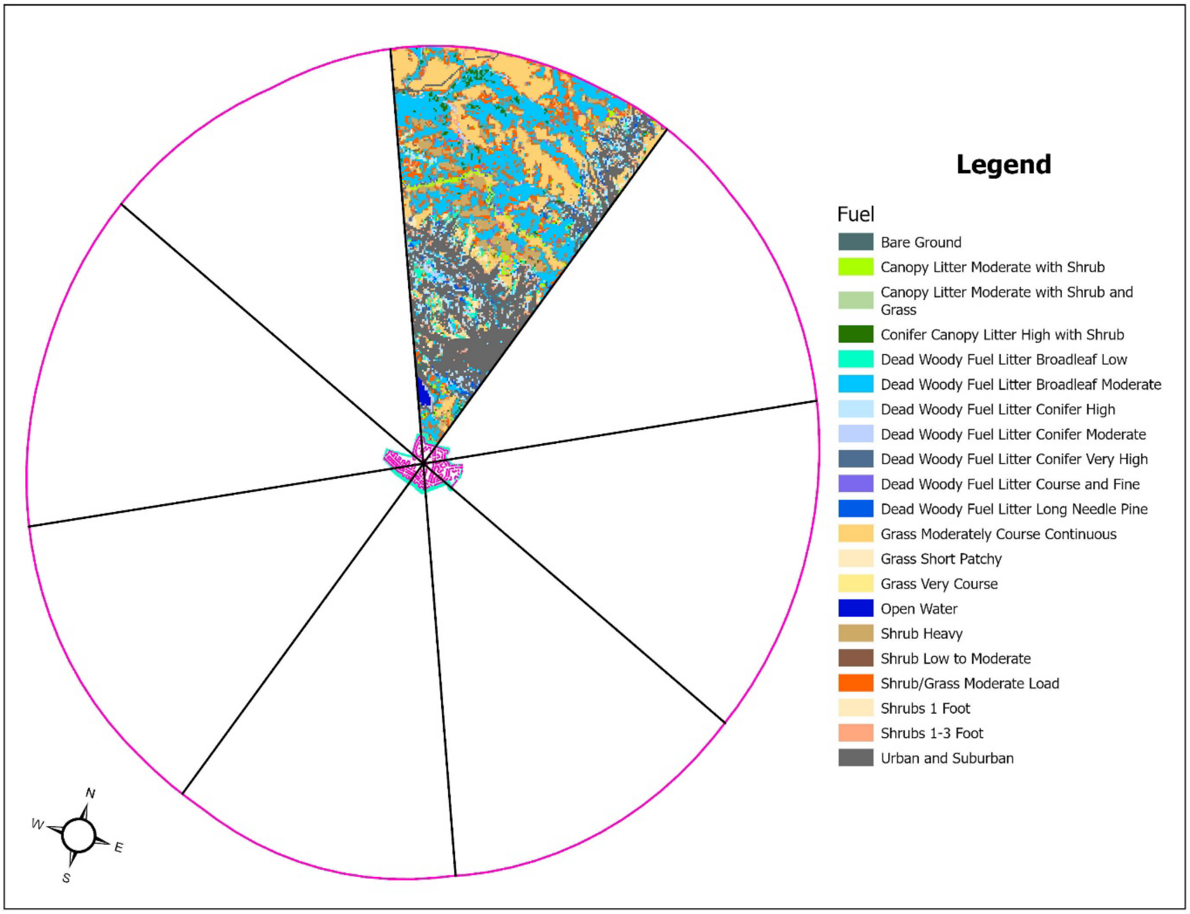


Figure 3.3. Example LANDFIRE fuel model type example for a specific external fuel sector.

3.3 Calculating the *neighborhood flame zone*

The *neighborhood flame zone* calculation method assesses the potential for direct flame contact and heat transfer from fuels adjacent to the defined *neighborhood* under common fire weather conditions observed during *conflagration* events. The calculation of the *neighborhood flame zone* is determined by:

1) Identify all *fuel model types* present in each of the eight *fuel assessment sectors* using the 0.25-mile buffer distance.
2) Determine for each sector the percentage tree coverage. If 10% or more is covered, then a canopy provision is applied in determining the *neighborhood flame zone*. This is to account for the potential for *crown fire* which could increase exposure.
3) Use *Table 3.2* and *Table 3.3* (for structural fuels) to determine the distance inward from the *neighborhood* boundary for each *fuel model type* present. The longest distance for any identified *fuel model type* shall be used to determine the boundary of the *neighborhood flame zone* for each sector (*FZ*, shown in *Equation 3-1*). If the canopy provision in step 2 is not met, then use *Column 2* of *Table 3.2* or *Table 3.3 (for structural fuels)*. If the canopy provision is met, then use *Column 4* of *Table 3.2* or *Table 3.3 to set FZ*.
4) Determine if a *fuelbreak* or *firebreak* is present and its width within the 0.25 mi *flame fuel assessment* buffer in each sector which will be applied to the final *neighborhood flame zone*

calculation (*Equation 3-1*). The *fuelbreak, firebreak* must be 20 feet or wider and span the width of the individual sector within the 0.25 mi buffer. If these conditions are met, the width of the *fuelbreak* or *firebreak* shall be accounted in the final *neighborhood flame zone* calculation for a given sector by:

$$Neighborhood\ flame\ zone\ width\ (NFz) = FZ - fuel/fire\ break\ width \qquad \textit{Equation 3-1}$$

If the *neighborhood flame zone* width is less than or equal to zero for all sectors, there is no *neighborhood flame zone* for the sector.

The final *neighborhood flame zone* shall be determined by the following procedure: use the same radial lines emanating from the *neighborhood* sector developed in the external fuel process to create 8 interior neighborhood sectors. Each sector is bound by two consecutive radial lines and the section of the neighborhood perimeter connecting those lines. Each of these *interior sectors* corresponds to the one of the 8 *exterior fuel sectors* (*Figure 3.4*). For a given *interior sector*, identify the corresponding *NFz* width and create a buffer around the perimeter portion of its bounds equal to that width. Then determine the intersection of that buffer and the corresponding interior sector, effectively clipping the buffer by the *interior sector's* bounds. Repeat this with each of the eight *interior sectors*, creating the appropriate *NFz* for each sector.

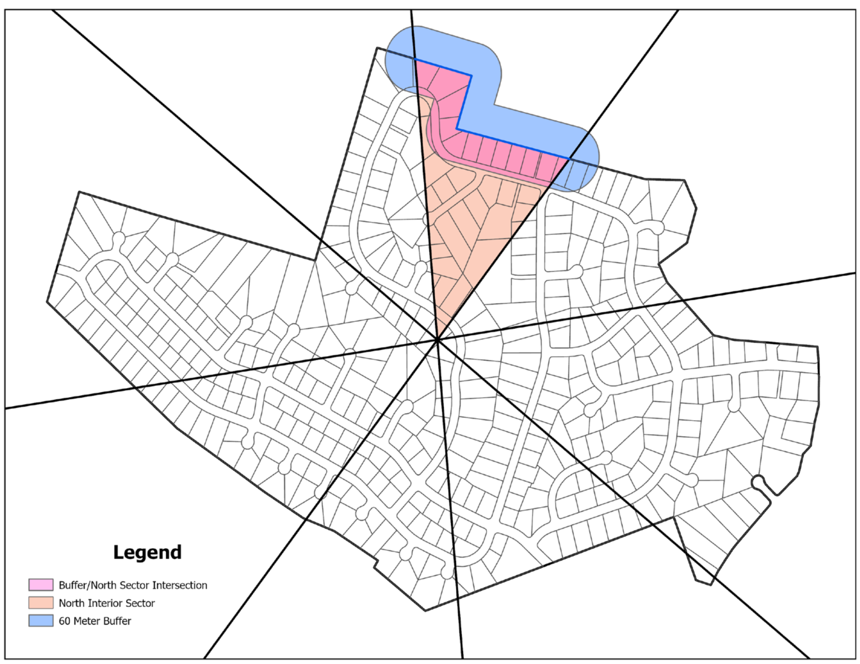


Figure 3.4. In this idealized example, the northern sector has an NFz of 60 m (197 ft) and so a buffer of 60 m is drawn around that portion of the neighborhood perimeter that binds the northern sector. This buffer is then clipped by the bounds of the northern sector. In this example, the final determined NFz boundary for the northern sector is shown in pink. Any parcel that falls on or within this boundary is considered part of the neighborhood flame zone.

Table 3.1. Neighborhood flame zone distances by fuel model type and if the canopy fuel threshold was met. Distances are provided in units of both meters and feet.

***Fire behavior fuel model* type identifier**	**Column 1** (m)	**Column 2** (ft)	**Column 3** Column 1 + Canopy fuel provision (m)	**Column 4** Column 2 + Canopy fuel provision (ft)
GR1	3	10	73	240
GR2	6	20	76	249
GR3	8	26	78	256
GR4	12	39	82	269
GR5	23	75	93	305
GR6	37	121	107	351
GR7	45	148	115	377
GR8	55	180	125	410
GR9	68	223	138	453
GS1	8	26	78	256
GS2	13	43	83	272
GS3	22	72	92	302
GS4	60	197	130	427
SB1	15	49	85	279
SB2	31	102	101	331
SB3	44	144	114	374
SB4	46	151	116	381
SH1	8	26	78	256
SH2	33	108	103	338
SH3	10	33	80	262
SH4	19	62	89	292
SH5	32	105	102	335
SH6	30	98	100	328
SH7	44	144	114	374
SH8	47	154	117	384
SH9	67	220	137	449
TL1	3	10	73	240
TL2	5	16	75	246
TL3	5	16	75	246
TL4	6	20	76	249
TL5	9	30	79	259
TL6	13	43	83	272
TL7	9	30	79	259
TL8	19	62	89	292
TL9	29	95	99	325
TU1	9	30	79	259
TU2	11	36	81	266

***Fire behavior fuel model* type identifier**	**Column 1** (m)	**Column 2** (ft)	**Column 3** Column 1 + Canopy fuel provision (m)	**Column 4** Column 2 + Canopy fuel provision (ft)
TU3	22	72	92	302
TU4	39	128	109	358
TU5	51	167	121	397

Table 3.2. Neighborhood flame zone distance for any structural fuels identified in the flame fuel assessment zone with 10% or more coverage in each sector. Distances are provided in units of both meters and feet.

***Fire behavior fuel model* type identifier**	**Column 1** (m)	**Column 2** (ft)	**Column 3** Column 1 (m)+ Canopy fuel provision (m)	**Column 4** Column 2 + Canopy fuel provision (ft)
NB1	21.7	71	91.7	301

Once the *neighborhood flame zone* is determined, the minimum structure separation distance for structures in this zone is determined for use in the *neighborhood ember zone* calculation using the same procedure as described for the full *neighborhood structure separation* assessment.

3.4 Calculating *neighborhood ember zone*

3.4.1 Ember loft

For the *IBHS Wildfire Prepared Neighborhood*, the Himoto and Iwami (2021) model for firebrand (ember) transport is used for its simplicity and because it provides conservative estimates for maximum ember transport distances.

For each *external fuel* sector, fuel model types with 10% or greater spatial coverage (i.e., 10% or more *LANDFIRE* grid boxes) in each sector are evaluated for ember transport considering the variables shown in *Figure 3.5*. The *fuel model types* obtained from the external fuel assessment (*Section 3.2.1*) are condensed into the three categories shown in *Table 3.4*. The Himoto and Iwami (2021) model uses a log-normal distribution to represent the statistical distribution of ember transport. A cumulative density function is obtained by integrating the log-normal probability density function. For the *IBHS Wildfire Prepared Neighborhood Standard*, the 80th percentile transport distance for a 10 meter open terrain exposure, peak 3-second gust wind speed of 70 miles per hour is used to calculate transport distances.

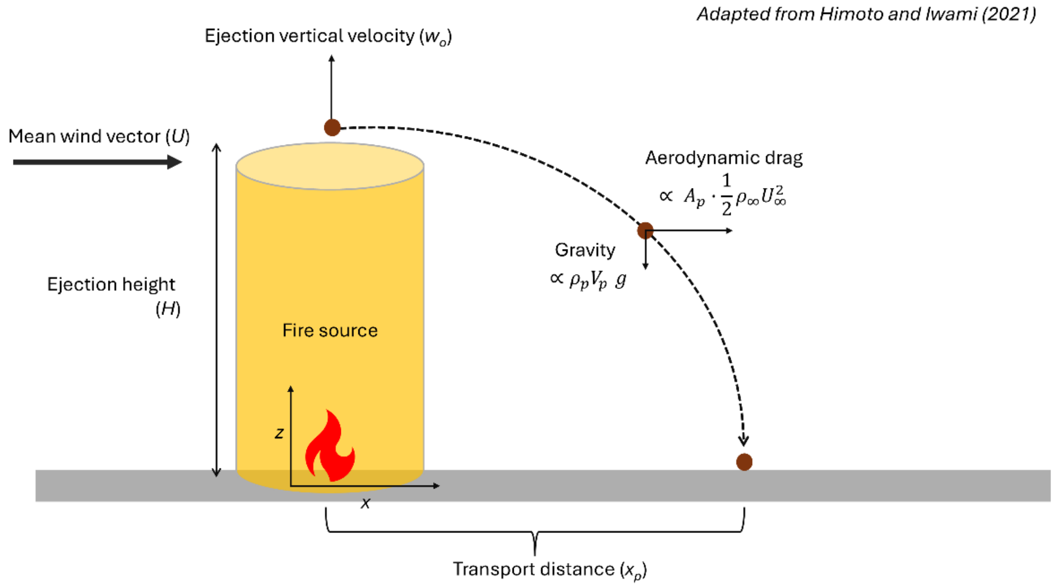


Figure 3.5 Conceptual diagram of the inputs to the Himoto and Iwami (2021) ember transport model (adapted from Himoto and Iwami 2021).

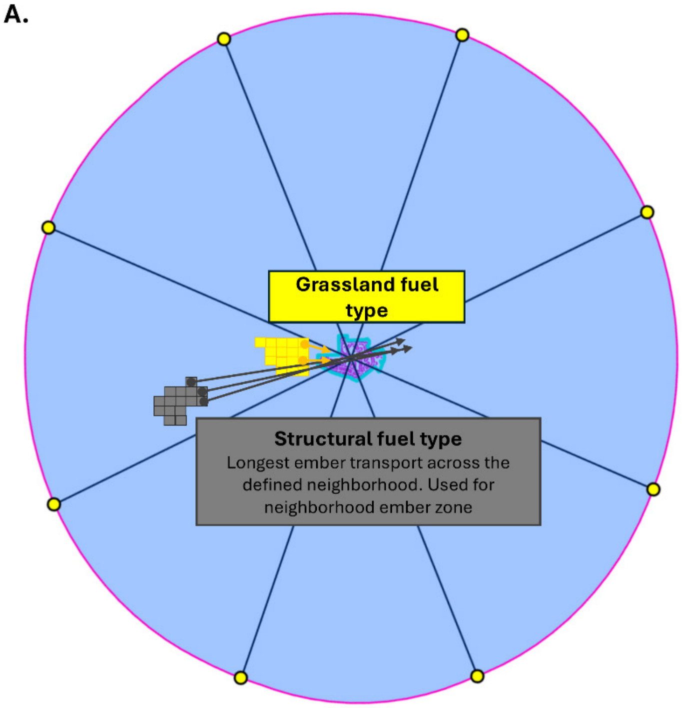
Table 3.4 Ember transport distances using the Himoto and Iwami (2021) model. For determining the neighborhood ember zone, the distances for a 70-mph wind shall be used and are provided in this table. See Appendix A, Table A3.2 for the full list of fuel model types.

Fuel type	***Column 1*** *Transport distance at 70 mph winds*	***Column 2*** *Total vector length if neighborhood flame zone structure separation conditions are present that require additional ember transport distance.*
Grassland/Fine Fuels LANDFIRE fuel model types: ***GR1-GR9 GS1-GS4***	3783 ft (0.72 mi)	25791 ft (4.88 mi)
Trees and Shrubs LANDFIRE fuel model types: ***SH1-SH9 TU1-TU5 TL1-TL9 SB1-SB4***	15158 ft (2.8 mi)	37166 ft (7.03 mi)
Structural fuels LANDFIRE fuel model types ***NB1***	22,008 ft (4.2 mi)	44,016 ft (8.4 mi)

3.4.2 Ember transport vectors and determining the *neighborhood ember zone*
Within each sector ember, transport vectors are directed toward the *neighborhood centroid* from the grid point for any *fuel model type* with 10% or more coverage in each sector. The vector length for each *fuel model type* is determined by using *Column 1* or *Column 2* of *Table 3.4. Column 1* is used for all sectors to determine ember transport vector lengths if 90% or more *structures* inside the *neighborhood flame zone* are separated by 30 feet or more. If not, *Column 2* is used for ember transport vector lengths. An example is shown in *Figure 3.6A*.

If any ember transport vector crosses more than one of the defined boundaries of the *neighborhood* and the length of that vector within the *neighborhood* boundary is greater than the width of the *neighborhood flame zone* in that sector, the entire *neighborhood*, excluding the *neighborhood flame zone* when present, shall be considered in the *neighborhood ember zone*. If all vectors do not meet this condition, then the *neighborhood ember zone* shall be drawn as a polygon connecting the endpoints of the eight ember transport vectors that extend the furthest inward from the defined *neighborhood* boundary. If this boundary falls across a specific *parcel* boundary, that *parcel* shall be considered part of the *neighborhood ember zone*. An example is provided in *Figure 3.6B.*

A.



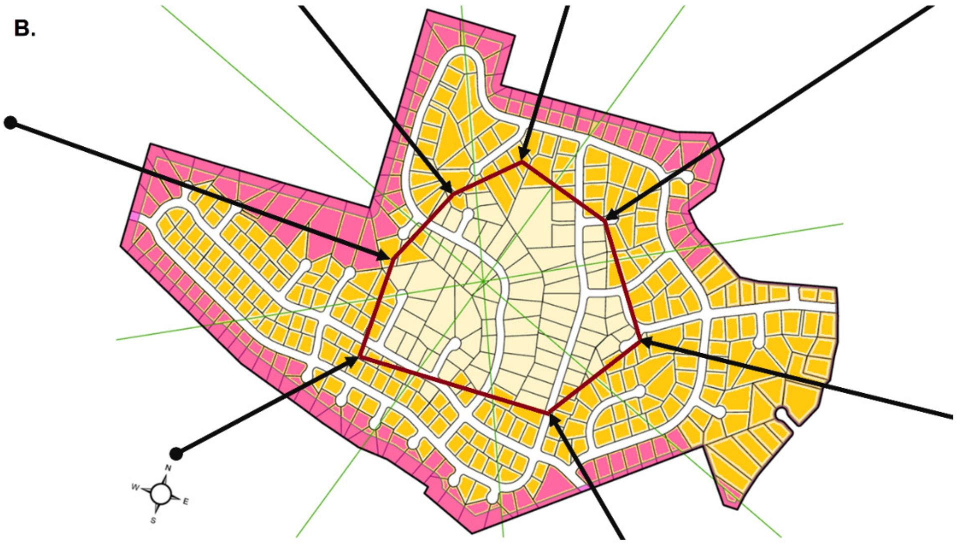


Figure 3.6. An idealized diagram of (A) ember transport vectors which cross the defined neighborhood and (B) where no vector crosses the neighborhood. In (A), the structural fuel ember transport vector produces the longest vector across the neighborhood despite being further away than the grassland fuels. Since the structural fuel transport distance is the worst-case scenario, it is used for the NEz determination. For (B) the neighborhood ember zone is defined by the area between the neighborhood flame zone (if present) or the defined neighborhood boundary (if no neighborhood flame zone is present) and the vector end points (black arrows). In the example shown in (B), the parcels included in the NFz are shaded orange, while the physical boundary is determined by the ember transport vector end points denoted by the red line. Parcels which fall into the neighborhood flame zone are shaded pink.

3.5 *Connective fuels*

The *connective fuel* characteristics of a defined *neighborhood* are determined by evaluating potential fire pathways through *clusters* of *structures*. The *clusters* are defined using break points which would alter the path of fire and where each *structure's* ignition potential would not be immediately influenced by other nearby *structures*. It is in these areas where *connective fuels* create the pathways for fire to easily move through direct flame contact and/or radiant heat exposure. For details on the *connective fuels* philosophy employed in this standard, see *Appendix B*, *section B4.2*.

Connective fuel pathways are evaluated within the defined *neighborhood* using the following process:

3.5.1 Cluster identification process

A *cluster* is one or more *structures* within a *neighborhood* separated in all directions from other *structures* within the *neighborhood* by one or more obstacles to structure-to-structure fire transmission.

1) any paved, maintained (city, town, county) road, any un-paved gravel or bare soil road, natural barriers that are noncombustible such as creeks, rivers, lakes, ponds etc. with a minimum width of 20 feet, or
2) 100 feet (approximately 30 m) or more from all other structures inside the defined neighborhood boundary.

The following process is best executed within a geographic information systems (GIS) platform and accompanying aerial imagery.

Identifying *clusters* for the *connective fuel node* evaluation: identify collections of *structures* that are completely bound by the barriers described in 1 and 2 above. Determining the extent of a given *cluster* is an iterative process that follows:

A) Start with a single *structure* and identify all other *structures* for which a measurement of 100 feet or less can be made without crossing one of the obstacles identified above and group them with the initial *structure*.

B) For each of the additional *structures* identified in step A, identify any other *structures* for which a measurement of 100 feet or less can be made without crossing one of the obstacles identified above and add these to the *cluster*. Continue expanding this process outward until no other additional *structures* can be added to the group of structures without crossing one of the obstacles cited above. The group of *structures* defined to its maximum extent shall be considered a unique *cluster* of *structures*. Each identified *cluster* shall be given a unique integer identifier. It is recommended for data schema purposes (see *Appendix A*), those *structures* within each *cluster* should be assigned to their specific *cluster* identifier.

The first *cluster* may or may not include all the *structures* within the defined *neighborhood*. If it does not include all the *structures* in the *neighborhood*, select another *structure* within the *neighborhood* not yet assigned to a *cluster* and repeat this process. Continue until every *structure* in the *neighborhood* has been assigned to a *cluster*. Note that it is possible for *structures* to be completely separated from all other *structures* in a *neighborhood* by one or more of the obstacles cited above, which means *neighborhoods* may contain *clusters* as small as one unit or *structure*. *Figure 3.7* provides an example of identified *clusters* for a test *neighborhood*.

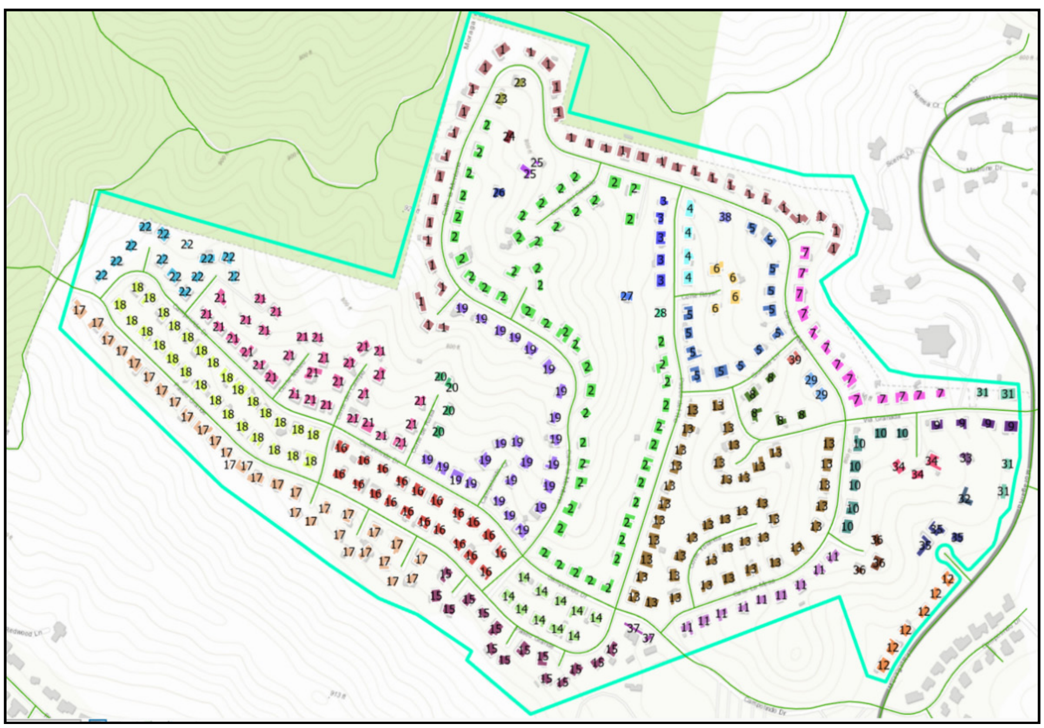


Figure 3.7. Example of a completed cluster analysis. Each identified cluster is indicated by an integer identifier and specific color.

3.5.2 *Connective fuel pathway* identification and evaluation

To determine whether an identified *cluster* of *structures* is compliant or flagged for *connective fuel pathways,* each individual *structure* within an identified *cluster* will be evaluated for *connective fuel pathways* to neighboring *structures*. *Connective fuel pathways* are identified through spatial analysis of *fuel elements* and whether adequate spacing is present such that the *connective fuel pathway* is broken.

All *fuel elements* will be identified across the defined *neighborhood*. *Fuel elements* shall be bound by a polygon that represents their surface area coverage.

For tree *fuel elements* with a trunk of 4 inches in diameter or greater when measured at a height of 4.5 feet above the ground the tree, per requirements stated in the *IBHS Wildfire Prepared Home Standard*. Other vegetative *fuel elements* including bushes, shrubs, and other vegetation shall also be treated by the definitions and requirements stated in the *IBHS Wildfire Prepared Home Standard*.

For *built environment fuels* that are not considered *structures* their surface area shall be used in the connective fuel assessment.

For fences or other *built-environment fuels* which extend vertically and the vertical surface area of which is two times or larger than their surface footprint, the *connective fuel pathway* shall be considered a straight line along the fence or other feature. This type of *fuel pathway* is considered broken by a compliant *0–5 Foot Noncombustible Zone* and/or ensuring that any fencing or similar *fuel element* that is parallel to a structure and within 5 feet is noncombustible. Combustible fences shall be considered a complete *connective fuel pathway* regardless of the overlap or proximity of other *fuel elements*. However, the use of a *0–5 Foot Noncombustible Zone* which includes the use of *noncombustible* fence materials in the 5-foot area extending outward from any *structure* results in a break of the *connective fuel pathway* associated with just the fence. In this case, the fence shall not be *considered a connective fuel pathway*.

Connected fuel pathways shall be evaluated for individual *structures* within each denoted *cluster*. The identified *fuel elements are* used to determine if a *connective fuel pathway* exists to each elevation (i.e., front, rear, right, left) of a *structure* to a neighboring *structure*. The *connective fuel pathway* is considered connected to the *structure* if a series of *fuel elements or a single element* connects the evaluated *structure* to one or more neighboring *structures* with no identified breaks greater than two times the height of the *fuel element* (excluding fences, see fence provisions below) along the fuel pathway. *Fuelbreaks and firebreaks*, as defined, shall be considered to have broken a *connective fuel pathway.* If along the *connected fuel pathway*, a break in *fuel elements* greater than two times the height of the *fuel element/s* is present, the pathway is also considered broken. For each *structure* the number of *connected fuel pathways* is found and used in the analysis of *connective fuels* for the *neighborhood flame zone* and the identified *clusters*. For each *cluster*, a *connective fuel flag* is assigned if more than 10% of *structures* have more than one *connective fuel pathway*.

After all *clusters* have been evaluated, the total number of *structures* within those *clusters* that have been assigned a *connective fuel flag* shall be calculated. If the total number of *structures* within flagged *clusters* represents 10% or less of the total *structures* within the entire defined *neighborhood* then the *neighborhood* shall be considered compliant with the *IBHS Wildfire Prepared Neighborhood Standard* for *connective fuels*. If the total number of *structures* within *clusters* with *connective fuel flags* is greater than 10% of the total *structures,* the *neighborhood* shall be considered non-compliant for *connective fuels*.

CHAPTER 4. Neighborhood mitigation requirements

4.1 Roof covering

Within the defined *neighborhood*, regardless of *external fuel* characteristics or *structure separation* distributions, all *structures* shall have a Class A rated *roof covering* (see *Appendix B, Section B2* for additional scientific reasoning). Wood shakes and shingles or fire-retardant-treated, fire-resistant pressure-treated or any other wood *roof covering* within any *roof assembly* or *roof system* are prohibited regardless of *roof covering* fire classification.

4.2 *Connective fuels*

The defined *neighborhood* shall be segmented into *clusters* using the process described in *Chapter 3 Section 3.5.1*. Each *cluster* shall be given a numeric integer identifier.

> **4.2.1 *Connective fuels* in the *neighborhood flame zone*.** All *structures* within the boundaries of the *neighborhood flame zone* shall have no *connective fuel pathways* to any neighboring *structures*.
>
> **4.2.2 *Connective fuels* across the defined *neighborhood*.** If 10% or more of *structures* within each determined *cluster* have more than one side/elevation with a *connected fuel pathway* to any neighboring *structure*, the *cluster* is assigned a *connective fuel "flag"* for exceeding the *connective fuel pathway* tolerance. If the number of flagged *clusters* produces a total of greater than 10% of the total *structures* in the defined *neighborhood*, the *neighborhood* must remediate the *connective fuels*. The *IBHS Wildfire Prepared Neighborhood Standard* does not provide prescriptive *connective fuels* remediation requirements or guidance. Remediation shall meet the *neighborhood* requirement through any means determined by the defined *neighborhood*.
>
> If the number of *connective fuels flagged clusters* is zero and all *structures* within the *neighborhood flame zone* have zero *connective fuel pathways*, then no *connective fuels* remediation is required, and the defined *neighborhood* shall be considered compliant.
>
> If the total number of *structures* located in *connective fuel flagged clusters* is 10% or less than the total number of *structures* in the defined *neighborhood,* and all *structures* within the *neighborhood flame zone* have zero *connective fuel pathways*, no *connective fuels* remediation is required, and the defined *neighborhood* shall be considered compliant.

The *neighborhood ember zone* dimensions shall be determined using the processes described in *Chapter 3, Section 3.4* and *Equation 3-1*.

4.3 *Neighborhood flame zone structures*

The *neighborhood flame zone* width (in feet) shall be calculated to determine *structures* at risk from direct flame/radiant heat contact from surrounding *external fuels* for each *external fuel sector* considering the presence of *fuelbreaks and firebreaks* that are within the 0.25-mile *flame fuel assessment* buffer and meet the conditions described in *Chapter 3, Section 3.3*.

The *neighborhood flame zone* shall be determined using the processes defined in *Chapter 3, Section 3.3* and by applying *Equation 4-1*. If the *neighborhood flame zone* (NFz) is present in any sector, any *structures* and/or *parcels* within the defined *neighborhood* boundary and the determined *neighborhood flame zone* shall meet the minimum mitigation requirements prescribed within the latest available *IBHS Wildfire Prepared Home Standard* for a "Plus" level of mitigation (henceforth referred to as *IBHS WFPH Plus*). These minimum requirements provide ignition protection from high radiant heat, direct flame contact, and ember exposure. If any part of a *parcel* falls within the *neighborhood flame zone*, any *structure* on that *parcel* shall be considered part of the *neighborhood flame zone* and must meet the specific requirements for this zone.

If there is no designated *neighborhood flame zone* for a specific sector, mitigation requirements move to ember protection and the *neighborhood ember zone* requirements.

Table 4.3 Neighborhood flame zone (NFz) construction requirements correspond to those requirements specified by the 2025 IBHS WFPH Plus requirements. Other select codes and standards provisions are provided for reference.

Structural component	Construction requirements	2025 *IBHS* WFPH Plus[1]	2024 IWUIC IR1[2]	2022 CBC[3]	2018 NFPA 1140[4]
Roof	Class A roof covering	✓	X	~	~
Gutters, Gutter Protection, and Downspouts	Noncombustible gutters, gutter protection, and downspouts	✓	✓	~	✓
Protection of Eaves	1. Noncombustible materials, or 2. 1-hour fire-resistance-rated construction, or 3. 2-inch nominal dimension lumber	✓	✓	✓	✓
Vents	1. Corrosion-resistant vents conforming with ASTM E2886 (flame- and ember-resistant), or 2. Noncombustible corrosion-resistant mesh with openings not to exceed 1/8-inch in diameter (ember-resistant)	✓	✓	✓	✓
Exterior Wall Covering	Noncombustible building material	✓	~	~	~
6-inch Noncombustible Vertical Clearance	Applied vertically on the exterior base of the wall measured from the grade and the nearest horizontal surface (e.g., decks and patios)	✓	✓	~	✓
Exterior Glass	1. Multipaned glass with at least two tempered panes, or 2. 20-minute fire-resistance rating when tested in accordance with NFPA 257, or 3. Glass blocks (windows only), and 4. Operable skylights protected by a noncombustible 1/8-inch mesh screen	✓	✓	✓	✓
Exterior Doors	The exterior doors shall be constructed with a noncombustible threshold and 1. Noncombustible construction, or 2. Solid-core wood not less than 1 ¾-inches thick, or 3. 20-minute fire-resistance rating when tested according to NFPA 252, or 4. Doors made of combustible material are permissible provided a noncombustible exterior storm door is installed as the outermost door	✓	✓	~	✓
Underfloor Area Construction	Fully enclosed to the ground with noncombustible corrosion-resistant mesh with openings not to exceed 1/8-inch in diameter.	✓	~	~	~

Structural component	Construction requirements	2025 *IBHS* WFPH Plus[1]	2024 IWUIC IR1[2]	2022 CBC[3]	2018 NFPA 1140[4]
	Exception: Complete enclosure shall not be required where underfloor areas are elevated more than 4 feet above the ground. In such a case, a minimum of 6-inches of noncombustible material or metal flashing shall be extended vertically from grade on the exterior of columns and supporting walls.				
Appendages and Projections (Decks)	Noncombustible building material	✓	~	~	~
Fences and Retaining Walls	Noncombustible fence and retaining walls within 5 feet of primary dwelling unit and attachments. No combustible parallel fences.	✓	X	X	X
Detached *Accessory Structures* and *ADUs*	*All detached ADUs and accessory structures* with a footprint greater than or equal to 15 square feet shall be located a minimum of 30 feet away from the *primary dwelling unit* and attachments	✓	~	~	~

1. *IBHS Wildfire Prepared Home Standard*, Plus level [https://wildfireprepared.org/wp-content/uploads/WFPH-Standard.pdf]
2. 2024 International Wildland-Urban Interface Code, Ignition Resistant Construction Class 1
3. 2022 California Building Code, Title 24, Part 2 (Volumes 1 & 2) with July 2024 Supplement updated
4. 2018 NFPA 1144, Standard for Reducing Structure Ignition Hazard from Wildland Fire

Green (✓) – Construction requirements referenced as one of the acceptable methods in this standard or by another code
Gray (~) – Construction requirements partially addressed by the code
Orange (X) – Construction requirements not referenced by the code

4.4 *Neighborhood ember zone structures*

The *neighborhood ember zone* width (in feet) shall be calculated to determine *structures* at risk from ember exposure from surrounding *external fuels* for each *external fuel* sector as well as possible ignitions in other areas of the defined *neighborhood*. The *neighborhood ember zone* dimensions shall be determined using the processes described in *Chapter 3, Section 3.4 (see process step 4)*.

Any *structures* and/or *parcels* within the defined neighborhood boundary or, when present inside the *neighborhood flame zone* boundary, and the determined *neighborhood ember zone* shall meet the minimum mitigation requirements prescribed within the latest available *IBHS Wildfire Prepared Home Standard* "Base" level (hereafter referred to as *IBHS WFPH Base*). These minimum requirements provide ignition protection from ember attack exposure. If any part of a *parcel* falls within the *neighborhood ember zone*, any *structure* on the *parcel* shall be considered part of the *neighborhood ember zone* and is required to meet the specified requirements for this zone.

If *structures* are present within the defined boundaries of the defined *neighborhood* and are not included in the *flame and/or neighborhood ember zones*, there are no additional mitigation requirements except for meeting roof cover material requirements and *connective fuel pathway* requirements.

Table 4.4. Neighborhood ember zone construction requirements correspond to those requirements specified by the 2025 IBHS WFPH Base. Other current codes and standards and how their provisions relate are provided for reference.

Structural component	**Construction requirements**	**2025 *IBHS* WFPH Base[1]**	**2024 IWUIC IR3[2]**	**2022 CBC[3]**	**2018 NFPA 1140[4]**
Roof	Class A roof covering	✓	X	~	~
Gutters and Downspouts	Noncombustible gutters and downspouts	✓	✓	~	✓
Vents	1. Corrosion-resistant vents conforming with ASTM E2886, or 2. Noncombustible corrosion-resistant mesh with openings not to exceed 1/8-inch in diameter	✓	X	✓	✓
6-inch Noncombustible Vertical Clearance	Applied vertically on the exterior base of the wall measured from the grade and the nearest horizontal surface (e.g., decks)	✓	X	~	✓
Underfloor Area Construction	Fully enclosed to the ground with noncombustible corrosion-resistant mesh with openings not to exceed 1/8-inch in diameter. **Exception:** Complete enclosure shall not be required where underfloor areas are elevated more than 4 feet above the ground. In such a case, a minimum of 6-inches of noncombustible material or metal flashing shall be extended vertically from grade on the exterior of columns and supporting walls.	✓	X	~	~
Fences and Retaining Walls	Noncombustible fence and retaining walls within 5 feet of *primary dwelling unit* and attachments.	✓	X	X	X
Detached Accessory Structures and ADUs	Shall have no more than 3 detached *accessory structures* and *ADUs* with a footprint greater than or equal to 15 square feet located between 10-30 feet of the *primary dwelling unit* and attachments.	✓	~	~	~

1. *IBHS Wildfire Prepared Home Standard*, Base level [https://wildfireprepared.org/wp-content/uploads/WFPH-Standard.pdf]
2. 2024 International Wildland-Urban Interface Code, Ignition Resistant Construction Class 3
3. 2022 California Building Code, Title 24, Part 2 (Volumes 1 & 2) with July 2024 Supplement updated
4. 2018 NFPA 1144, Standard for Reducing Structure Ignition Hazard from Wildland Fire

Green (✓) – Construction requirements referenced as one of the acceptable methods in this standard or by another code
Gray (~) – Construction requirements partially addressed by the code
Orange (X) – Construction requirements not referenced by the code

CHAPTER 5. References for *Chapters 1-4*.

Andrews, P. L., and C.D. Bevins. (2003). BehavePlus fire modeling system, version 2.0: User's guide [Computer software]. USDA Forest Service, Rocky Mountain Research Station. https://www.firelab.org/project/behaveplus.

ASTM E119—20: Standard Test Methods for Fire Tests of Building Construction and Materials, *ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959*.

ASTM E136—22: Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750 Degrees C, *ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959*.

Baum, Howard R., and B. J. McCaffrey, (1989). Fire induced flow field-theory and experiment. *Fire Safety Science,* **2, 129**-148.

Cohen, J. D. (2000). Preventing disaster: home ignitability in the wildland-urban interface. Journal of Forestry, 98(3), 15-21.

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

Davis J.B. (1989). Demography: A Tool for Understanding the Wildland-Urban Interface Fire Problems. *Proceedings of the Symposium on Fire and Watershed Management*, General Technical Report PSW109, ed. Berg N.H., 38–42.

Himoto, K., and T. Iwami (2021). Generalization framework for varying characteristics of the firebrand generation and transport from structural fire source. *Fire safety journal* **125,** 103418.

International Code Council (2024). *2024* International Building Code. *Falls Church, VA: International Code Council*.

International Code Council (2024). *2024* International Wildland-Urban Interface Code. *Falls Church, VA: International Code Council*.

Insurance Institute for Business & Home Safety (2024). IBHS Wildfire Prepared Home Technical Standard. *Insurance Institute for Business & Home Safety*, Richburg, SC, 9 pp. https://wildfireprepared.org/wp-content/uploads/WFPH-Standard.pdf.

Johnston L., Blanchi R., Jappiot M. (2019). Wildland-Urban Interface. In: Manzello S.L. (ed) Encyclopedia of Wildland-Urban Interface (WUI) Fires. Springer, Cham. https://doi.org/10.1007/978-3-319-51727-8_130-1.

Manzello, S.L. and S. Suzuki, (2022). The world is burning: What exactly are firebrands and why should anyone care?, *Frontiers in Mechanical Engineering*, **8**, 1-18. https://doi.org/10.3389/fmech.2022.1072214.

Maranghides, A., E.D. Link, S. Hawks, J. McDougald, S.L. Quarles, D.J. Gorham and S. Nazare. (2022). WUI Structure/Parcel/Community Fire Hazard Mitigation Methodology, *National Institute of Standards and Technology*, NIST Technical Note 2205, 77 pp. https://doi.org/10.6028/NIST.TN.2205.

National Fire Protection Association (2018). *NFPA 1144 standard for reducing structure ignition hazards from wildland fire*. NFPA Standards council, Quincy MA.

Rothermel, R.C., (1972). A mathematical model for predicting fire spread in wildland fuels. Rocky Mountain Research Station. *United States Department of Agriculture*. Res. Pap. INT-115, 40 pp.

Scott, J. H., and R. E. Burgan (2005). Standard fire behavior fuel models: A comprehensive set for use with Rothermel's surface fire spread model. *USDA Forest Service*, General Tech. Rep. RMRS-GTR-153, 72 pp. https://doi.org/10.2737/RMRSGTR-153.

Stratton, R. (2004). FlamMap: Fire mapping and analysis system (version 5.0) [Computer software*]. USDA Forest Service, Rocky Mountain Research Station*, Fire Sciences Laboratory. https://www.firelab.org/project/flammap.

UL 263—2011: Fire Tests of Building Construction and Materials—with Revisions through August 2021, *UL LLC, 333 Pfingsten Road, Northbrook, IL 60062-2096.*

US Department of Agriculture, US Department of Interior (2001). Urban Wildland Interface Communities Within the Vicinity of Federal Lands That Are at High Risk from Wildfire. Federal Register **66**(3), 751-777. https://www.federalregister.gov/d/01-52.

APPENDIX A
Minimum data requirements, additional data and recommendations, data schema

The following appendix includes the minimum data requirements to determine compliance with the *IBHS Wildfire Prepared Neighborhood Standard* as well as recommendations for both additional data and data schema.

A1 Formats

A1.1 Date

The date shall be entered as a string using the form YYYY-MM-DD.

A2 *Neighborhood* applicability and governance

A2.1 *Neighborhood* design and applicability requirements

Table A2.1 provides the minimum required data fields and variables for determining the applicability of the IBHS Wildfire Prepared Neighborhood Standard. Within the data schema, roof compliance with the Class A requirement is considered part of the neighborhood compliance variables.

Variable	**Variable name**	**Type**	**Description**	**Options**
Roof	Neighborhood_roof_compliance	string	Are 100% of roofs Class A across the entire defined *neighborhood*?	Binary 0=True/Yes/Complaint 1=No/Noncompliant
Construction type	Construction_type	string	Are all *structure* types within the defined *neighborhood* boundary compliant by those listed in Chapter 1?	Binary 0=True/Yes/Compliant 1=No/Noncompliant
Structures	Total_structures	integer	Total number of *structures* identified in the defined *neighborhood*	integer
Parcels	Total_parcels	integer	Total number of *parcels* in the defined *neighborhood*	integer
Structure separation	Structure_separation	string	Are 90% or more of *structures* separated by a minimum distance greater than 10 feet to the closest neighboring *structure*?	Binary 0=True/Yes/Compliant 1=No/Noncompliant
Mean structure separation	Structure_separation_mean	float	Mean *structure* separation for the defined *neighborhood*	Float
Median structure separation	Structure_separation_median	float	Median *structure separation* distance for the defined *neighborhood*	Float
Standard deviation of *structure separation*	Structure_separation_stdev	float	Standard deviation of the distribution of *structure separation* distances for the defined *neighborhood*	Float

A2.1 Covenants, Conditions & Restrictions (CC&R)
Any *Covenants, Conditions and Restrictions* documents that are active and enforced are recommended to be submitted as a .pdf document if provided.

A2.2 FIREWISE
Neighborhoods, communities, etc. which hold an NFPA *FIREWISE USA* recognition are encouraged to provide proof of their recognition to accompany any *neighborhood* specific data in instances when the standard is being applied towards mitigation assessments or any designation program.

A3 Fuel assessment data requirements

A3.1 External fuels
Fuels surrounding the defined neighborhood govern the mitigation requirements for the *neighborhood flame zone* and the *neighborhood ember zone*. The *external fuel* type models listed in *Table A3.2* (Scott and Burgan 2005) are used in fuel models to identify fire and ember behavior and are derived from those included in the *LANDFIRE* dataset. *External fuel* type models/classifications which have 10% or greater coverage by surface area in each *external fuel* assessment sector shall be identified using the variable structure defined in *Table A3.1*. Additional supplemental data can be used to identify fuels and/or to augment the time lag between *LANDFIRE* updates where land-use surrounding the defined *neighborhood* may have changes if the spatial resolution is finer than that used by *LANDFIRE* (30 m by 30 m grid) and can be integrated under the 40 different fuel model types from Scott and Burgan (2005). *Tables A3.2, A3.3* provide the data structure for the identified fuel type models for each sector that are used within *Chapter 3*, to determine the *neighborhood flame zone* and *neighborhood ember zone* distances for each sector. See *Figures 3.1* and *3.2* for sector identification provisions.

Table A3.1. The following table provides the data variable structure for external fuel model types for all detected (depicted as the N-number of fuel types) fuels with 10% or more *coverage in each 45° north-relative external fuel assessment sector for 4.25 miles radially outward from the defined neighborhood boundary.*

Variable	**Variable name**	**Type**	**Description**	**Options**
Sector 1	Fuel_type_[1...N]_sector1	string	Fuel type present in sector 1	See fuel type options below in Table A3.3
Sector 2	Fuel_type_[1...N]_sector2	string	Fuel type present in sector 2	See fuel type options below in Table A3.3
Sector 3	Fuel_type_[1...N]_sector3	string	Fuel type present in sector 3	See fuel type options below in Table A3.3
Sector 4	Fuel_type_[1...N]_sector4	string	Fuel type present in sector 4	See fuel type options below in Table A3.3
Sector 5	Fuel_type_[1...N]_sector5	string	Fuel type present in sector 5	See fuel type options below in Table A3.3
Sector 6	Fuel_type_[1...N]_sector6	string	Fuel type present in sector 6	See fuel type options below in Table A3.3

Variable	Variable name	Type	Description	Options
Sector 7	Fuel_type_[1...N]_sector7	string	Fuel type present in sector 7	See fuel type options below in Table A3.3
Sector 8	Fuel_type_[1...N]_sector8	string	Fuel type present in sector 8	See fuel type options below in Table A3.3

Table A3.2. This table provides the data variable structure for the flame model types which represent the worst-case flame intensity and ember transport distances and are used in calculating the neighborhood flame zone and neighborhood ember zone (Chapter 3, Sections 3.3 and 3.4).

Variable	Variable name	Type	Description	Options
Neighborhood flame zone				
Neighborhood flame zone fuel model type sector 1	FRz_fueltype_sector1	string	Worst case fuel type for *neighborhood flame zone* in sector 1	See fuel model types in Table A3.3
Neighborhood flame zone fuel model type for sector 2	FRz_fueltype_sector2	string	Worst case fuel type for *neighborhood flame zone* in sector 2	See fuel model types in Table A3.3
Neighborhood flame zone fuel model type for sector 3	FRz_fueltype_sector3	string	Worst case fuel type for *neighborhood flame zone* in sector 3	See fuel model types in Table A3.3
Neighborhood flame zone fuel model type for sector 4	FRz_fueltype_sector4	string	Worst case fuel type for *neighborhood flame zone* in sector 4	See fuel model types in Table A3.3
Neighborhood flame zone fuel model type for sector 5	FRz_fueltype_sector5	string	Worst case fuel type for *neighborhood flame zone* in sector 5	See fuel model types in Table A3.3
Neighborhood flame zone fuel model type for sector 6	FRz_fueltype_sector6	string	Worst case fuel type for *neighborhood flame zone* in sector 6	See fuel model types in Table A3.3
Neighborhood flame zone fuel model type for sector 7	FRz_fueltype_sector7	string	Worst case fuel type for *neighborhood flame zone* in sector 7	See fuel model types in Table A3.3

Variable	Variable name	Type	Description	Options
Neighborhood flame zone fuel model type for sector 8	FRz_fueltype_sector8	string	Worst case fuel type for *neighborhood flame zone* in sector 8	See fuel model types in Table A3.3
Neighborhood ember zone				
Neighborhood ember zone fuel model type for sector 1	ERz_fueltype_sector1	string	Worst case fuel type for *neighborhood ember zone* in sector 1	See fuel model types in Table A3.3
Neighborhood ember zone fuel model type for sector 2	ERz_fueltype_sector2	string	Worst case fuel type for *neighborhood ember zone* in sector 2	See fuel model types in Table A3.3
Neighborhood ember zone fuel model type for sector 3	ERz_fueltype_sector3	string	Worst case fuel type for *neighborhood ember zone* in sector 3	See fuel model types in Table A3.3
Neighborhood ember zone fuel model type for sector 4	ERz_fueltype_sector4	string	Worst case fuel type for *neighborhood ember zone* in sector 4	See fuel model types in Table A3.3
Neighborhood ember zone fuel model type for sector 5	ERz_fueltype_sector5	string	Worst case fuel type for *neighborhood ember zone* in sector 5	See fuel model types in Table A3.3
Neighborhood ember zone fuel model type for sector 6	ERz_fueltype_sector6	string	Worst case fuel type for *neighborhood ember zone* in sector 6	See fuel model types in Table A3.3
Neighborhood ember zone fuel model type for sector 7	ERz_fueltype_sector7	string	Worst case fuel type for *neighborhood ember zone* in sector 7	See fuel model types in Table A3.3
Neighborhood ember zone fuel model type for sector 8	ERz_fueltype_sector8	string	Worst case fuel type for *neighborhood ember zone* in sector 8	See fuel model types in Table A3.3

Table A3.3. This table provides the LANDFIRE fuel type models used in Chapters 3 and 4 in determining neighborhood flame zone and neighborhood ember zone and for use in the variables described in Table A3.1. Adapted from Scott and Burgan (2005). Rows shaded in light brown represent fuels in arid to semiarid climates with rainfall deficient summer months and extinction moisture content of 15%. Those rows shaded in light green represent subhumid to humid climates with extinction moisture contents of 30%–40%.

Class	Type ID	Description
1. Grass		
	GR1	Short or patchy or heavily grazed grass
	GR2	Moderately coarse continuous grass with average height 1 feet
	GR3	Very coarse grass with average height 2 feet
	GR4	Moderately coarse continuous grass with average height 2 feet
	GR5	Dense, coarse grass with mean height 1-2 feet
	GR6	Dryland grass with average height 1-2 feet
	GR7	Moderately coarse continuous grass with average height 3 feet
	GR8	Heavy, coarse continuous grass with average height 3-5 feet
	GR9	Very heavy, coarse, continuous grass with average height 5-8 feet
2. Grass & Shrub Mix (Up to 50% shrub coverage)		
	GS1	Shrubs height about 1-foot, low grass load
	GS2	Shrubs height about 1 to 3 feet, moderate grass load
	GS3	Moderate grass/shrub load, average grass/shrub height less than 2 feet
	GS4	Heavy grass/shrub load, average height greater than 2 feet
3. Shrubs coverage 50% or greater; grass sparse or less		
	SH1	Low shrub fuel load, fuelbed depth about 1-foot; some grass may be present
	SH2	Moderate fuel load (higher than SH1), average height about 1-foot, no grass fuel present
	SH3	Moderate shrub load, possibly with pine overstory or herbaceous fuel, fuel bed depth 2 to 3 feet
	SH4	Low to moderate shrub and litter load, possibly with pine overstory, fuel bed depth about 3 feet
	SH5	Heavy shrub load, average height 4 - 6 feet
	SH6	Dense shrubs, little or no herb fuel, average height about 2 feet
	SH7	Very heavy shrub load, average height 4 - 6 feet
	SH8	Dense shrubs, little or no herb fuel, average height about 3 feet
	SH9	Dense, finely branched shrubs with significant fine dead fuel, average height about 4 - 6 feet; some herbaceous fuel may be present

Class	Type ID	Description
4. Grass or shrubs mixed with litter from forest canopy		
	TU1	Fuelbed is low load of grass and/or shrub with litter
	TU2	Fuelbed is moderate litter load with shrub component
	TU3	Fuelbed is moderate litter load with grass and shrub components
	TU4	Fuelbed is short conifer trees with grass or moss understory
	TU5	Fuelbed is high load conifer litter with shrub understory
5. Dead & down woody fuel beneath forest canopy		
		Recently burned but able to carry wildland fire
	TL1	Light to moderate load, fuels 1 to 2 inches deep
		Fuelbed not recently burned
	TL2	Broadleaf, hardwood litter, low load and compact
	TL3	Moderate load conifer litter and does not include coarse fuels
	TL4	Moderate load, includes small diameter downed logs. Includes both fine and coarse fuels
	TL5	High load conifer litter; light slash or mortality fuel. Does not include coarse fuels
	TL6	Moderate load, less compact broadleaf, hardwood litter
	TL7	Heavy load includes larger diameter downed logs includes both fine and coarse fuels. Not composed of broadleaf or long-needle pine litter
	TL8	Moderate load of long-needle pine litter. Compactness may include small amount of herbaceous load
	TL9	Very high load, fluffy composed of broadleaf, hardwood litter
6. Activity fuel or debris from wind damage		
		Fuelbed is activity fuel
	SB1	Fine fuel load is 10 - 20 tons/acre, weighted toward fuels 1 - 3 inches diameter class, depth is less than 1-foot
	SB2	Fine fuel load is 7 - 12 tons/acre, evenly distributed across 0 - 0.25, 0.25 - 1, and 1 - 3 inches diameter classes, depth is about 1 foot
	SB3	Fine fuel load is 7 to 12 tons/acre, weighted toward 0 - 0.25-inch diameter class, depth is more than 1-foot
		Fuelbed is blowdown
	SB2	Blowdown is scattered, with many trees still standing
	SB3	Blowdown is moderate, trees compacted to near the ground
	SB4	Blowdown is total, fuelbed not compacted, foliage still attached
7. Built environment or fire resistant agricultural (maintained)		*Note: The "NB" LANDFIRE fuel classes are considered unable to carry wildland fire. However, built environment fuels (NB1) are considered and used in both ember transport and flame intensity processes. They are considered combustible and are treated as such.*

Class	Type ID	Description
	NB1	Urban or suburban development
	NB2	Snow/ice
	NB3	Maintained agricultural field
	NB8	Open water
	NB9	Bare ground/soil

A3.3 *Flame & neighborhood ember zones* required data fields

Table A3.4 provides the minimum required data fields/variables for the *neighborhood flame* zone and *neighborhood ember zone* distances for each *external fuel sector*.

Table A3.4. Variable structure for the final flame resistance and neighborhood ember zone distances for each sector. The values for each variable listed in this table shall be calculated using the processes described in Chapter 3, Section 3.3 (neighborhood flame zone), Equation 4-1 (for FRz*), and Section 3.4 (neighborhood ember zone). Values can be rounded to the nearest foot.*

Variable	Variable name	Type	Description	Options
Neighborhood flame zone				
Neighborhood flame zone distance sector 1	Fz_distance_sector1	integer	*neighborhood flame zone* distance for sector 1	Value in feet. 0 if there is no *neighborhood flame zone*
Neighborhood flame zone distance for sector 2	Fz_distance_sector2	integer	*neighborhood flame zone* distance for sector 2	Value in feet. 0 if there is no *neighborhood flame zone*
Neighborhood flame zone distance for sector 3	Fz_distance_sector3	integer	*neighborhood flame zone* distance for sector 3	Value in feet. 0 if there is no *neighborhood flame zone*
Neighborhood flame zone distance for sector 4	Fz_distance_sector4	integer	*neighborhood flame zone* distance for sector 4	Value in feet. 0 if there is no *neighborhood flame zone*
Neighborhood flame zone distance for sector 5	Fz_distance_sector5	integer	*neighborhood flame zone* distance for sector 5	Value in feet. 0 if there is no *neighborhood flame zone*
Neighborhood flame zone distance for sector 6	Fz_distance_sector6	integer	*neighborhood flame zone* distance for sector 6	Value in feet. 0 if there is no *neighborhood flame zone*
Neighborhood flame zone distance for sector 7	Fz_distance_sector7	integer	*neighborhood flame zone* distance for sector 7	Value in feet. 0 if there is no *neighborhood flame zone*

Variable	Variable name	Type	Description	Options
Neighborhood flame zone distance for sector 8	Fz_distance_sector8	integer	*neighborhood flame zone* distance for sector 8	Value in feet. 0 if there is no *neighborhood flame zone*
Neighborhood flame zone structure separation	Fz_structure_separation	string	Are 10% or more structures in the *neighborhood flame zone* separated by less than 30 feet?	Binary 0 = Yes/True/Additional ember transport distance added to *Ez* 1= No/False
Neighborhood ember zone				
Neighborhood ember zone distance for sector 1	Ez_distance_sector1	integer	*neighborhood ember zone* distance for sector 1	Value in feet
Neighborhood ember zone distance for sector 2	Ez_distance_sector2	integer	*neighborhood ember zone* distance for sector 2	Value in feet
Neighborhood ember zone distance for sector 3	Ez_distance_sector3	integer	*neighborhood ember zone* distance for sector 3	Value in feet
Neighborhood ember zone distance for sector 4	Ez_distance_sector4	integer	*neighborhood ember zone* distance for sector 4	Value in feet
Neighborhood ember zone distance for sector 5	Ez_distance_sector5	integer	*neighborhood ember zone* distance for sector 5	Value in feet
Neighborhood ember zone distance for sector 6	Ez_distance_sector6	integer	*neighborhood ember zone* distance for sector 6	Value in feet
Neighborhood ember zone distance for sector 7	Ez_distance_sector7	integer	*neighborhood ember zone* distance for sector 7	Value in feet
Neighborhood ember zone distance for sector 8	Ez_distance_sector8	integer	*neighborhood ember zone* distance for sector 8	Value in feet

A3.4 Additional data fields

A3.2.1 Fuel Treatment activities

The following do not require data fields but are available for entry and logging should the user of the *IBHS Wildfire Prepared Neighborhood Standard* wish to include these data. These focus on treatments within three miles of the defined *neighborhood* boundary within the previous three years.

Table A3.5. The following shall be completed for any fuel treatment data entry.

Name	Type	Description	Options
Treatment_ID	String or integer	A unique integer identifier for the treatment within a project (for that organization), usually a number or an alpha-numeric code, rather than a full name. Preferred that it does not include text that identifies which organization, in case that must be kept private	
Treatment_name	string	Project or fuel treatment name	
County	string	County name where treatment was completed	
Neighborhood	string	Neighborhood name/identifier	
Neighborhood_ID		Account identifier	Identifier if applying for, or have an active *IBHS* designation
Primary_objective	string	The primary goal of the treatment (see options).	Ex: Broadcast Burn, Fuel Reduction, Fuelbreak, Roadway Clearance
Secondary_objective	string	The secondary goal of the treatment (see options). **Optional field**.	Ex: Broadcast Burn, Fuel Reduction, Fuelbreak, Roadway Clearance
Tertiary_objective	string	The tertiary goal of the treatment (see options). **Optional field.**	Ex: Broadcast Burn, Fuel Reduction, Fuelbreak, Roadway Clearance
Retreatment_date	date	Approximate estimated date at which the treatment will need to be performed again	
Treatment_status	string	Treatment status	Ex: Planned, Active, Complete
Treatment_start_date	date	Date the treatment started, usually the date of the first activity	
Treatment_end_date	date	Date all treatment activities were completed.	
Treatment_area	integer	Area of treatment in acres (nearest integer)	
Ownership_group	string	Agency or organization	Federal, State, Local, Private, Other, HOA, Firewise, etc.
Activity_description	string	The practice used to achieve management objectives.	
Broad_vegetation_type	string	Identify the primary broad vegetation type for the activity area	Forest, Woodland, Shrubland, Grass, etc.

Table A3.6 Objective descriptions

Objective	Objective definition
Biomass utilization	Work conducted in an area where the secondary or tertiary objective is to utilize woody biomass for wood products, and/or generate energy through combustion or gasification, and/or utilize woody biomass to help develop markets for beneficial uses of the material
Burned area restoration	Work conducted in a recently burned area intended to promote recovery and ecological stability
Carbon storage	Work conducted to improve carbon storage or carbon stability in forests, shrubs and grasslands
Climate adaptation	Work conducted to increase the ability of an ecosystem to be resilient to or resist climate change. Resilience is the ability to recover from a climate change-related event, while resistance is the ability to withstand that event unchanged

Objective	Objective definition
Cultural burn	Application of fire to the environment predominantly to achieve cultural objectives
Ecological restoration	Work conducted to re-establish the composition, structure, pattern, integrity, and ecological processes necessary to facilitate terrestrial and Wildfire & Landscape Resilience Interagency Tracking System – August 2023 9 aquatic ecosystem sustainability, resilience, and health under current and future conditions
Fire prevention	Activities were conducted to help educate the public about Fire Prevention. Includes CWPP, public education events, placement of prevention signs, and community meetings related to fire prevention
Forest pest control	Work conducted to control the spread of active forest pest and diseases, typically used during active infestations such as Sudden Oak Death and Gold Spotted Oak Borer outbreaks
Forestland stewardship	Work conducted to encourage private and public investments in forestlands and resources within the state to ensure adequate future high quality timber supplies, related employment, and other economic benefits, and to protect, maintain, and enhance the forest resource for the benefit of present and future generations
Fuelbreak	Work conducted to modify flammable vegetation to create defensible space to reduce fire spread to structures and/or natural resources, and to provide a safer location to fight the fire. Fuelbreaks are strategically placed along a ridge, valley bottom, access road, or around a subdivision
Habitat restoration	Work conducted to improve or protect wildlife habitat
Land protection	Protection of natural and working lands against conversion to other land cover types, such as developed or cropland, that would result in the loss of natural vegetation. Often through the establishment of easements, acquisitions, fee title, or other activities
Mountain meadow restoration	Work conducted to restore mountain meadow lands
Non-timber products	Work conducted to collect, propagate, or preserve non-timber products, including food, medicinal, cultural, spiritual, or other materials from an ecosystem
Other forest management	Precommercial forest management treatment activities. Or work conducted in an area to improve stand structure or composition
Other fuels reduction	Work conducted in an area where the primary objective is to reduce fuel loads. While this can be accomplished through Fuel Break and Broadcast Burn objectives, this should be used when Fuel Break and Broadcast Burning objectives are not being utilized
Prescribed fire	Work conducted in an area where the primary objective is reducing fuel loads through broadcast burning and pile burning
Recreation	Work conducted to improve or maintain recreation opportunities
Reforestation	Work conducted to promote the reforestation of non- or understocked forestland and areas burned by wildfire, drought, pests, or other natural disturbances to increase carbon sequestration and rebuild natural habitats and ecosystems. Tree planting associated with timber harvest operations is not tracked because these activities are legally required to meet minimum stocking standards following timber operations
Riparian restoration	Work conducted to improve riparian habitat or stream channel function
Roadway clearance	Work conducted along the right of way of fire roads, county roads, or highways for purposes of improved ingress and egress. This includes the removal of dead trees resulting from insects or drought. Right of Way Clearance is not done with the intent of stopping a fire at the location of work but instead focuses on ingress and egress enhancement
Site Preparation for Planting, Seeding, or Natural Regeneration	Manipulation of a site to enhance the success of regeneration, including through the completion of activities such as broadcast burning, mastication, mowing, dozer, or herbicide application
Timber harvest	Work conducted in an area where the primary objective is to harvest timber to produce wood products
Utility right of way clearance	Work conducted along the right of way of Electric Utility lines. This includes the removal of dead trees resulting from insects or drought. Right of Way Clearance is not done with the intent of stopping a fire at the location of work but instead focuses on keeping trees from hitting powerlines and/or high fuel loads from forming under powerlines

Objective	Objective definition
Watershed restoration	Work conducted in uplands and/or riparian areas to restore watershed function, including improvements in water quantity, water quality, habitat, and other ecological characteristics
Wetland restoration	Work conducted on land that is covered or saturated by water for all or portions of a year (excluding mountain meadows and riparian areas), to improve ecosystem function, including water quality, habitat, and other ecological characteristics

A4 *Parcel* Level Variables

A4.1 Required *parcel* level variables

The following variables represent the minimum requirements that shall be collected and submitted for each *parcel* and subsequent *structures* within the *neighborhood* being evaluated. Tables are broken down into parcel-level subsystems. The following are the sub-systems used in the data dictionary and minimum requirements as developed by *IBHS* in support of the *IBHS Wildfire Prepared Home Standard*. The *parcel*-level data fields can be obtained through any means such as ground-based inspections, *aerial imagery* etc. but must meet the minimum data requirements specified here.

Table A4.1. Home inspection details subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Value
address	address	string		Physical address	Home Inspection Details	
latitude	lat	float		Latitude in decimal degrees	Home Inspection Details	
longitude	lon	float		Longitude in decimal degrees	Home Inspection Details	
Single family home	single_family_home_present	string	Single Family Home Present?	Is the home a single-family home (no townhomes / condos) with three stories or less? Binary True/False	Home Inspection Details	0=True /compliant 1=False
Stories	number_of_stories	integer	Number of stories	How many stories does the home have (not including a walk-out basement)?	Home Inspection Details	
Neighborhood flame zone	flame_resistance_zone	string	Neighborhood flame zone	Is the parcel/home a part of the *neighborhood flame zone*	Home Inspection Details	0=True/Yes 1=False/No
Neighborhood ember zone	ember_resistance_zone	string	Neighborhood ember zone	If the parcel/home is not part of the neighborhood flame zone, is it part of the *neighborhood ember zone*	Home Inspection Details	0=True/Yes 1=False/No

Table A4.2 General parcel subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Value
Accessory structure/s	accessory_structures_properly_distanced_from_home	string	*Accessory structure* spacing	Are all additional *structures* larger than 15 square feet. more than 30 feet from the house or not present? Note: If	General	0=True/Compliant 1=False

				not present, select yes. (Structure examples sheds, hot tubs, propane tanks, pergolas, ADUs, playsets) Binary Yes/No		
Accessory structure/s inside 30 feet	accessory_structures_present	string	*Accessory structures* inside 30 feet from the house	If the property has additional *structures* larger than 15 ft^2 within 30 feet of home, are there three or fewer structures? **Additional data requirements:** Photo of each *accessory structure* present showing distance from home for reference.	General	0=True/Compliant 1=False

Table A4.3 Accessory structure compliance subsystem (for 3 accessory structures, not required if not present).

Variable	**Data name**	**Variable type**	**Title**	**Description**	**Subsystem**	**Value**
Accessory structure compliance 1	accessory_structure_compliance_1	String	*Accessory structure* 1 compliance	For the *accessory structure* 1, does it meet all of the same requirements as the home? Binary Yes/No **Additional data requirements:** Photos of the 5 feet buffer zone all the way around the structure.	Accessory structure compliance	0=True/Yes/Compliant 1=False
Accessory structure compliance 2	accessory_structure_compliance_2	String	*Accessory structure* 2 compliance	For the *accessory structure* 2, does it meet all of parcel requirements? Binary Yes/No **Additional data requirements:** Photos of the 5 feet buffer zone all the way around the *structure*.	Accessory structure compliance	0=True/Yes/Compliant 1=False
Accessory structure compliance 3	accessory_structure_compliance_3	String	*Accessory structure* 32 compliance	For the *accessory structure* 3, does it meet all of the parcel requirements? Binary Yes/No **Additional data requirements:** Photos of the 5 feet buffer zone all the way around the structure.	Accessory structure compliance	0=True/Yes/Compliant 1=False

Table A4.4. External propane tank (not required if not present).

Variable	**Data name**	**Variable type**	**Title**	**Description**	**Subsystem**	**Value**
External propane tank compliance	propane_tank_compliance	string	External fixed propane tank	If a stationary propane tank is present, is it at least 10 feet from with house with the additional clearance requirements or placed 30 feet away from the home? **Additional data requirements:** Photos of the	Propane tank	0=True/Compliant 1=False

				5 feet buffer zone all the way around the propane tank.		

Table A4.5. Hot Tub/Spa (not required if not present).

Variable	Data name	Variable type	Title	Description	Subsystem	Value
Hot tub/spa compliance	hot_tub_complia nce	string	Hot tub/spa	If applicable, is the hot tub placed at least 10 feet from the home, on a noncombustible surface (no wood decks) and not under a covered porch or pergola? Binary Yes/No **Additional data requirements:** Photos of the 5 feet buffer zone all the way around the hot tub.	Hot tub	0=True/Compliant 1=False

Table A4.6. General roof condition subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Value
Roof debris	roof_clear_of_de bris	string	Roof debris	Is the roof clear of debris Binary True/False. **Additional data requirements:** Presence of debris shall be documented with photo/s	Home Inspection Details	0=True/Compliant 1=False

Table A4.7. Dominant roof cover subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Value
Dominant roof cover percentage	dominant_roof_ cover_percenta ge	integer	Dominant Roof Cover Percentage	Percentage of coverage for the dominant roof cover material	Dominant roof cover	Range: 50%-100%
*Dominant roof cover material type	dominant_roof_ cover_material	string		What is the dominant roof covering material? **Additional data requirements**: Photo requirement: 6 photos showing all roof faces.	Dominant roof cover	See sub-table for minimum required roof cover types

Table A4.8. Secondary roof cover subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Value
Secondary roof cover percentage	secondary_roof_c over_percentage	integer	Dominant Roof Cover Percentage	Percentage of coverage for the dominant roof cover material	Dominant roof cover	Range: <50%
*Secondary roof cover material type	secondary_roof_c over_material	string		What is the secondary roof covering material? **Additional data requirements:**	Dominant roof cover	See sub-list for minimum required roof cover types

				Photo requirement: 6 photos showing all roof faces.		

**The following provides the minimum required roof cover types to be evaluated and listed in required parcel-level data for both dominant and secondary roof cover materials:*
Asphalt shingle
Standing seam metal
Metal with exposed fasteners
Discontinuous metal
Clay tile with bird stops
Clay tile without bird stops
Concrete tile with bird stops
Concrete tile without bird stops
Slate
Composite shingle/Plastic Panel
Wood shake shingle
Low slope/flat membrane
Low slope/flat built-up/TPO
Low slope/flat modified bitumen
Low slope/flat ballasted
Unknown steep slope
Unknown low slope/flat

Table A4.9. Gutters, downspouts subsystem.

Variable	**Data name**	**Variable type**	**Title**	**Description**	**Subsystem**	**Value**
Metal gutters downspouts	metal_gutter_downspouts_present	string	Metal gutters and downspouts	Are the gutters and downspouts made of metal Binary True/False **Additional data requirements:** Photos required of gutters and downspouts	Gutters & downspouts	0=True/Compliant 1=False
Gutter debris	gutters_downspouts_clear_of_debris	string	Debris in gutters	Are the gutters and downspouts clear of debris. **Additional data requirements:** Photos required of inside gutter condition	Gutters & downspouts	0=True/Compliant 1=False
Gutter guards	metal_gutter_guard_present	String	Presence of gutter guards	Are gutter guards present and completely made of metal? **Additional data requirements:** If true a photograph is required	Gutters & downspouts	0=True 1=False

Table A4.10. Vents subsystem.

Variable	**Data name**	**Variable type**	**Title**	**Description**	**Subsystem**	**Value**
Roof vent compliance	roof_vents_compliance	string	Roof vent compliance	Are all roof vents (except plumbing vents) flame- and ember-resistant or covered with 1/8" metal mesh or finer? Binary True/False	Vents	0=True/Compliant 1=False

Variable	Data name	Variable type	Title	Description	Subsystem	Value
				Additional data requirements: Close-up photo of every vent with mesh in view (to observe size).		
Under eave vents	vents_under_eaves_compliance	string	Vents_under_eaves_compliance	If present: Are the open eave vents flame- and ember-resistant or covered with 1/8" metal mesh or finer? Binary True/False **Additional data requirements:** Photos require close-up of every vent with mesh in view (to observe size).	Vents	0=True/Compliant 1=False
Roof vent type	roof_vents_type	string	Roof vent types	Identify and list all vents visible that are present on the roof. **Additional data requirements:** Provide photographs of each	Vents	*See sub-list below for minimum vent type requirements
Eave attic vents	eave_attic_vents_compliance	string	Eave attic vents	If present: Are under eave vents that enter directly into the attic space flame- and ember-resistant or covered with 1/8th inch metal mesh or finer? Binary True/False	Vents	0=True/Compliant 1=False
Gable end vents	gable_end_vents_compliance	string	Gable end vents	If present: Are the gable end vents flame- and ember-resistant or covered with 1/8" metal mesh or finer? Binary True/False **Additional data requirements:** Photos must be provided of each visible vent with close-up of mesh	Vents	0=True/Compliant 1=False
Crawl space vents	crawl_space_vents_compliance	string	Crawl space vent compliance	If present: Are the crawl space vents flame- and ember-resistant or covered with 1/8" metal mesh or finer? **Additional data requirements:** A close-up photo of every vent with mesh in view (to observe size).	Vents	0=True/Compliant 1=False
Forced air vent louver flap	dryer_vent_louver_flap_present	string	Forced air vent louver flap present	Do forced air vents have a louver or flap? Binary True/False **Additional data requirements:** A close-up photo of the vent.	Vents	0=True/Compliant 1=False
Forced air vent and flap material	metal_dryer_vent_present	string	Forced air vent louver flap material	Is the dryer vent assembly made of metal? **Additional data requirements:** A close-up photo of the vent/s.	Vents	0=True/Compliant 1=False

The following provides the minimum required roof vent types to be listed in required parcel-level single-family home data.
Ridge-cap vent
Off-ridge vent
Turbine vent

Table A4.11. Eave/Soffit subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Value
Eave/soffit materials	eave_soffits_materials_compliance	string	Eave soffit materials	Are the eaves enclosed on the underside with soffits made of noncombustible material, have at least a 1-hour fire-resistance-rating, material, or 2-inch dimension lumber (no plywood or vinyl)? Binary True/False **Additional data requirements:** A close-up photo/s of the eaves.	Dominant roof cover	0=True/Compliant 1=False

Table A4.12. General exterior walls subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Value
Exterior walls material and 6- inch vertical clearance	exterior_walls_material_compliance	string	Exterior Walls Material(s) Compliance	Noncombustible 6-inch vertical clearance. Do all exterior walls have a minimum of 6 vertical inches (measured from the ground up and from any attached horizontal surface like a deck or patio) of noncombustible siding material around the home such as fiber-cement, brick, stone, stucco, or exposed concrete foundation?	General exterior walls	0=True/Compliant 1=False

Table A4.13. Dominant wall subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Value
Dominant wall cover material	dominant_wall_cover_material	string	Dominant wall cover material	*Please select the dominant wall cover material(s). **Additional data requirements:** A close-up	Dominant walls	*see list below for minimum wall material types

				photo/s of materials used on all wall coverings.		
Dominant wall cover material coverage	dominant_wall_cover_cover_percentage	integer	Dominant wall cover material coverage percentage	What is the dominant wall cover percentage of coverage on the structure	Dominant walls	>50%

Table A4.14. Secondary wall subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Value
Secondary wall cover material	secondary_wall_cover_material	string	Secondary wall cover material	*Please select the secondary wall cover material(s). **Additional data requirements:** A close-up photo/s of materials used on all wall coverings.	Secondary walls	*See list below for minimum wall material types
Secondary wall cover material coverage	secondary_wall_cover_cover_percentage	integer	Secondary wall cover material coverage percentage	What is the secondary wall cover percentage of coverage on the structure?	Secondary walls	<50%

**The following provides the minimum required wall material types to be listed in required parcel-level single-family home data.*

Stucco
Vinyl siding
Fiber cement siding
Wood panel/wood-based composite siding
Wood shake
Plastic composite siding
Brick or brick veneer
Stone or stone veneer
Concrete
Other
Unknown

Table A4.15. Foundation subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Value
				Photos required	Foundation	

Table A4.16. Shutters subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Value
Functional shutters	functional_shutters_present	string	Presence of functional shutters	Are functional noncombustible shutters present on all windows? Binary True/False	Shutters	0=True/Yes 1=False

Variable	Data name	Variable type	Title	Description	Subsystem	Value
				Additional data requirements: Close-up photos showing the shutters/shutter system.		
Decorative shutters	secondary_wall_cover_cover_percentage	string	Presence of decorative shutters	If present, are decorative shutters made of noncombustible material? Binary True/False **Additional data requirements:** Close-up photo/s of the materials used.	Shutters	0=True/Yes 1=False

Table A4.17. Exterior glass and doors.

Variable	Data name	Variable type	Title	Description	Subsystem	Value
Exterior glazing	windows_skylights_glazed_glass	string	Windows / Skylights / Glazed Glass	Do all windows, skylights, and glazed openings within doors meet ONE of the following requirements: Multipaned glass with at least two tempered panes (etched), have a 20-minute fire-resistance rating, or glass blocks (windows only)? **Additional data requirements:** Photos of the tempered glass etched label (bug), located on the inside of each tempered pane in one of the four corners, meeting AMMA labeling requirements.	Exterior glazing, doors, bay windows	0=True/Yes/ Compliant 1=False
Exterior doors	exterior_door_material_compliance	string	Exterior door materials compliance	Are all exterior doors solid, have a noncombustible threshold and ONE of the following: 1) Door surface/cladding made of noncombustible or ignition-resistant material (e.g., metal, solid hardwood, fiberglass), or 2) a noncombustible storm door as the outermost door? **Additional data requirements:** A photo of every exterior door.	Exterior glazing, doors, bay windows	0=True/Yes/ Compliant 1=False
Skylight type	skylight_type	string	Skylight glass type	If skylights are present, are they made of flat glass (rather	Exterior glazing,	0=True/Yes/ Compliant

Variable	Data name	Variable type	Title	Description	Subsystem	Value
				than domed plastic)? Binary Yes/No	doors, bay windows	1=False
Skylight mesh	Skylight_mesh	string	Skylight mesh protection	If skylights are operable, is the opening protected by a noncombustible mesh screen where the dimensions of the mesh shall not exceed 1/8-inch in diameter? Binary Yes/No	Exterior glazing, doors, bay windows	0=True/Yes/ Compliant 1=False

Table A4.18. Primary deck/covered porch subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Values
Area around deck	deck_area_noncombustible_space_present	string	Deck area noncombustibles	Does the area around the footprint of all decks / covered porches, including under stairs, have at least 5 feet of noncombustible space? Binary Yes/No	Primary deck/covered porch	0=True/Yes/Compliant 1=False
Decks and porches condition	decks_covered_porches_clear_of_debris	string	Decks covered porches clear of debris	Is the top surface of all decks / covered porches clear of yard debris? Binary Yes/No **Additional data requirements:** Photo/s of the deck / porch deck surface.	Primary deck/covered porch	0=True/Yes/Compliant 1=False
Deck or porch type description	deck_covered_porch_type	string	Type of porch/deck	What type of deck / covered porch is present? **Additional data requirements:** Photos of each side of the deck / porch and include the base of the structure (see subsystem photo requirements for additional details)	Primary deck/covered porch	*See sublist below for minimum porch/deck descriptors
Deck and porch vegetation condition	decks_covered_porches_clear_of_excessive_vegetation	string	Porch/deck vegetation condition	Is the top surface of all decks / covered porches completely free from trees and shrubs, with no more than 10 potted plants / flowers in noncombustible planters? Binary Yes/No	Primary deck/covered porch	0=True/Yes/Compliant 1=False
Underneath deck area condition assessment	underneath_decks_covered_porches_clear_of_vegetation	string	Under deck condition assessment	Is underneath all decks / covered porches including stairs free from any vegetation (including wood piles, plants, grass, weeds,	Primary deck/covered porch	0=True/Yes/Compliant 1=False

Variable	Data name	Variable type	Title	Description	Subsystem	Values
				etc.)? Binary Yes/No Noncombustible materials like concrete, rock, or dirt are permitted. **Additional data requirements:** Photo/s of underneath the deck / porch of the ground and substructure (including any mesh or lattice used to enclose it.)		
Decks/porches under 4 feet elevation	decks_porches_less_than_4ft_to_ground_properly_enclosed	string	Deck/porches below 4 feet elevation	Decks / porches 4 feet or less from walking surface to ground: Is it fully enclosed underneath with 1/8-inch or finer metal mesh with no combustible material such as lattice installed over the mesh? Binary Yes/No **Additional data requirements:** Photo/s of the covering.	Primary deck/covered porch	0=True/Yes/Compliant 1=False
Auxiliary deck structures	decks_w_additional_structure_compliance	string	Decks with additional structure/s attached	Attached decks with an additional structure (like a pergola or gazebo): Is it made of metal, with no solid roof cover, free from all vegetation, and without curtains / drapes / screens? **Additional data requirements: Photo**/s of the structure.	Primary deck/covered porch	0=True/Yes/Compliant 1=False
Deck stairs materials	decks_stairs_construction_materials_compliance	string	Deck stair materials	Are all decks, including stairs, entirely constructed with noncombustible materials such as metal / lightweight concrete OR retrofitted with noncombustible materials for no-gap walking surfaces and railing within 5 feet of home? Binary Yes/No. **Additional data requirements:** minimum of 2 photos of underdeck structure materials and a close-up of the walking surface.	Primary deck/covered porch	0=True/Yes 1=False

Table A4.19. Secondary deck/covered porch subsystem – provides data requirements for additional decks and porches.

Variable	**Data name**	**Variable type**	**Title**	**Description**	**Subsystem**	**Values**
Area around deck	secondary_Deck_area_noncombustible_space_present	string	Deck area noncombustible	Does the area around the footprint of all decks / covered porches, including under stairs, have at least 5 feet of noncombustible space? Binary Yes/No	Secondary deck/covered porch	0=True/Yes/Compliant 1=False
Decks and porches condition	secondary_decks_covered_porches_clear_of_debris	string	Decks covered porches clear of debris	Is the top surface of all decks / covered porches clear of yard debris? Binary Yes/No **Additional data requirements:** Photo/s of the deck / porch deck surface.	Secondary deck/covered porch	0=True/Yes/Compliant 1=False
Deck or porch type description	secondary_deck_covered_porch_type	string	Type of porch/deck	What type of deck / covered porch is present? **Additional data requirements:** Photos of each side of the deck / porch and include the base of the structure (see subsystem photo requirements for additional details)	Secondary deck/covered porch	*See sublist below for minimum porch/deck descriptors
Deck and porch vegetation condition	secondary_decks_covered_porches_clear_of_excessive_vegetation	string	Porch/deck vegetation condition	Is the top surface of all decks / covered porches completely free from trees and shrubs, with no more than 10 potted plants / flowers in noncombustible planters? Binary Yes/No	Secondary deck/covered porch	0=True/Yes/Compliant 1=False
Underneath deck area condition assessment	secondary_underneath_decks_covered_porches_clear_of_vegetation	string	Under deck condition assessment	Is underneath all decks / covered porches including stairs free from any vegetation (including wood piles, plants, grass, weeds, etc.)? Binary Yes/No Noncombustible materials like concrete, rock, or dirt are permitted. **Additional data requirements:** Photo/s of underneath the deck / porch of the ground and substructure (including any mesh or lattice used to enclose it.)	Secondary deck/covered porch	0=True/Yes/Compliant 1=False

Variable	Data name	Variable type	Title	Description	Subsystem	Values
Decks/porches under 4 feet elevation	secondary_decks_porches_less_than_4ft_to_ground_properly_enclosed	string	Deck/porches below 4 feet elevation	Decks / porches 4 feet or less from walking surface to ground: Is it fully enclosed underneath with 1/8-inch or finer metal mesh with no combustible material such as lattice installed over the mesh? Binary Yes/No **Additional data requirements:** Photo/s of the covering.	Secondary deck/covered porch	0=True/Yes/Compliant 1=False
Auxiliary deck structures	secondary_decks_w_additional_structure_compliance	string	Decks with additional structure/s attached	Attached decks with an additional structure (like a pergola or gazebo): Is it made of metal, with no solid roof cover, free from all vegetation, and without curtains / drapes / screens? **Additional data requirements: Photo**/s of the structure.	Secondary deck/covered porch	0=True/Yes/Compliant 1=False
Deck stairs materials	secondary_decks_stairs_construction_materials_compliance	string	Deck stair materials	Are all decks, including stairs, entirely constructed with noncombustible materials such as metal / lightweight concrete OR retrofitted with noncombustible materials for no-gap walking surfaces and railing within 5 feet of home? Binary Yes/No. **Additional data requirements: minimum** of 2 photos of underdeck structure materials and a close-up of the walking surface.	Secondary deck/covered porch	0=True/Yes 1=False

Table A4.20. 0–5 Foot Noncombustible Zone: 0–5 foot subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Values
0-5 Foot Noncombustible Zone ground cover assessment	hiz_ground_cover_noncombustible	string	Ground cover assessment	Is the ground cover in the 0-5-Foot Noncombustible Zone hardscaped with bare dirt, gravel, pavers, river rocks, DG base, steppingstones, or concrete and free from debris? No combustible	*0-5 Foot Noncombustible Zone*	0=True/Yes/Compliant 1=False

Variable	Data name	Variable type	Title	Description	Subsystem	Values
				ground covers such as wood or rubber mulch are allowed. Binary Yes/No		
0-5 Foot Noncombustible Zone vegetation assessment	hiz_clear_of_vegetation	string	Vegetation assessment	Is the 0-5-Foot Noncombustible Zone free from all vegetation? This means no bushes, grass/artificial turf, flowers, trees, succulents, including no overhanging tree branches? Binary Yes/No	*0-5 Foot Noncombustible Zone*	0=True/Yes/Compliant 1=False
0-5 Foot Noncombustible Zone combustible items	hiz_clear_of_combustible_items	string	Combustible items assessment	Is the 0-5-foot noncombustible buffer free from all combustible items such as furniture, firewood, sheds, storage units, hot tubs, etc.? Binary Yes/No	*0-5 Foot Noncombustible Zone*	0=True/Yes/Compliant 1=False
0-5 Foot Noncombustible Zone Vehicles	hiz_clear_of_vehicles	string	Vehicles	Is the 0-5-foot noncombustible buffer free of stored boats, RVs, trailers, or ATVs? Binary Yes/No	*0-5 Foot Noncombustible Zone*	0=True/Yes/Compliant 1=False
Yard vegetation debris	hiz_clear_of_debris_accumulation	string	Yard vegetation debris	Is the entire yard free of accumulated fallen pine needles, leaves, and other debris? Binary Yes/No	*0-5 Foot Noncombustible Zone*	0=True/Yes/Compliant 1=False
Tree spacing canopy	trees_spaced_pruned	String	Tree spacing/canopy spacing	Are all trees with trunks 4+ inches spaced apart / pruned to a canopy-to-canopy distance of at least 10 feet and limbs pruned to a minimum of 6 feet off the ground? Binary Yes/No	*0-5 Foot Noncombustible Zone*	0=True/Yes/Compliant 1=False
Tree to shrubs/bush spacing	trees_vegetation_properly_spaced	string	Tree to shrub-bush spacing	Are the trees with trunks 4+ inches properly spaced? (Spacing between the tree canopy and the next closest shrub / bush / tree must be at least twice the height of the shrub / bush / tree or 10 feet.) Binary Yes/No	*0-5 Foot Noncombustible Zone*	0=True/Yes/Compliant 1=False
Shrubs and bushes spacing	shrubs_bushes_trees_spaced_properly	string	Shrub/bushes spacing	Do all the shrubs / bushes / trees with trunks less than 4 inches have proper spacing between them? Spacing distance must be at least twice the height of the tallest	*0-5 Foot Noncombustible Zone*	0=True/Yes/Compliant 1=False

Variable	Data name	Variable type	Title	Description	Subsystem	Values
				bush / shrub present and privacy bushes or rows of shrubs are not allowed. (Example: 3 feet bush + 4 feet bush (tallest) = spaced 8 feet apart.) Binary Yes/No		
Dead vegetation	dead_vegetation_removed	string	Dead vegetation maintenance	Has all dead vegetation been removed? Binary Yes/No	*0-5 Foot Noncombustible Zone*	0=True/Yes/Compliant 1=False

Table A4.21. 5–30-foot subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Values
Trees properly pruned	thirty_feet_hiz_trees_pruned	string	Trees pruned	Do all trees within 30 feet, have branches removed from the ground up to 6 feet and upper branches trimmed to ensure 10 feet of space from neighboring trees? Binary Yes/No	HIZ 5-30	0=True/Yes/Compliant 1=False
Tree spacing canopy	thirty_feet_hiz_vegetation_spaced	string	Tree spacing 5-30 feet	Trees with trunk 4 inches or larger: Have spacing between the tree canopy and the next closest shrub/bush/tree with a trunk diameter of less than 4 inches at least twice the height of the bush/shrub/tree (or 10 feet, whichever is less)? Binary Yes/No	HIZ 5-30	0=True/Yes/Compliant 1=False
Shrub/bushes spacing	thirty_feet_hiz_shrubs_spaced	string	Spacing of shrubs and bushes	Are all shrubs within 30 feet, removed from under trees, have space between grouping of a 10-foot area of 10 feet apart, AND all privacy hedges and rows of bushes have been removed? Binary Yes/No	HIZ 5-30	0=True/Yes/Compliant 1=False
Yard debris Zone 1	thirty_feet_hiz_vegetation	string	Yard debris 5-30 foot area	Within 30 feet of the home, is the yard free of accumulated fallen pine needles, leaves, and other debris? Binary Yes/No	HIZ 5-30	0=True/Yes/Compliant 1=False
Dead vegetation and firewood stacks	thirty_feet_hiz_vegetation_firewood	string	Dead vegetation and	Has all dead vegetation and firewood stacks been	HIZ 5-30	0=True/Yes/Compliant 1=False

Variable	Data name	Variable type	Title	Description	Subsystem	Values
			firewood 5–30-foot area	removed or placed at least 30 feet away from the home?		

Table A4.22. Fences subsystem.

Variable	Data name	Variable type	Title	Description	Subsystem	Values
Back-to-back fencing	back_to_back_fencing_compliance	string	Back-to-back fence sections	If fences are back-to-back within 30 feet, is there at least 5 feet between them? Binary Yes/No **Additional data requirements:** Photos of any fencing within 30 feet.	Fences	0=True/Yes/Compliant 1=False
Home fencing	fencing_distance	string	Fencing near or within the HIZ	Is fencing within 5 feet of the home, including any part that attaches to the home? Binary Yes/No **Additional data requirements:** Photos of any fencing near or within 5 feet/HIZ of the home.	Fences	0=True/Yes/Compliant 1=False
0-5 Foot Noncombustible Zone fencing	fence_material_noncombustible	string	0-5 Foot Noncombustible Zone fencing	If fencing, posts or gates are present within 5 feet of the home, are they made of *noncombustible* materials, such as metal (aluminum, chain link, or iron) or concrete blocks? No vinyl or wood fences allowed. Binary Yes/No	Fences	0=True/Yes/Compliant 1=False

A4.2 *Parcel* level additional data requirements

The following represent the minimum subsystem photograph requirements that shall be collected for each *parcel/single family structure* and subsystem variable if the variable feature is present. See *Section A6* for photograph/image format requirements, metadata requirements and recommendations.

Table A4.23 Parcel level additional data requirements.

Subsystem	Variable	Data name	Photograph minimum requirements
Home Inspection Details	Address numbers	address_numbers_photo	1 photo of the address numbers on the home / mailbox.
Home Inspection Details	Left elevation photographs	left_yard_photos	2 photographs of the yard area in its entirety

Subsystem	Variable	Data name	Photograph minimum requirements
Home Inspection Details	Back/rear of house photographs	back_of_the_house_photos	3 photos of the back of the property in landscape mode/orientation.
Home Inspection Details	Front elevation of the property photographs	front_of_the_house_photos	3 photos of the front of the property in landscape mode/orientation.
Home Inspection Details	Front yard photographs	front_yard_photos	2 photos of the yard in its entirety.
Home Inspection Details	Left Side of the House Photos	left_side_of_the_house_photos	3 photos of the left side of the property in landscape mode/orientation.
Home Inspection Details	Right Side of the House Photos	right_side_of_the_house_photos	3 photos of the right side of the property in landscape mode/orientation.
Home Inspection Details	Right Yard Photos	right_yard_photos	2 photos of the yard in its entirety.
General	*Accessory structures* within 30 feet	accessory_structures_present	Photo/s required of each *accessory structure* present showing distance from home for reference.
***Accessory structure* 1**	*Accessory structure* compliance 1	accessory_structure_compliance_1	Photos of the 5 feet buffer zone all the way around the *structure*
***Accessory structure* 2**	*Accessory structure* compliance 3	accessory_structure_compliance_2	Photos of the 5 feet buffer zone all the way around the *structure*
***Accessory structure* 3**	*Accessory structure* compliance 3	accessory_structure_compliance_3	Photos of the 5 feet buffer zone all the way around the *structure*
Hot Tub/Spa	Hot tub/spa	hot_tub_compliance	Photos of the 5 feet buffer zone all the way around the hot tub
Exterior Propane Tank	Exterior fixed propane tank	propane_tank_compliance	Photos of the10 feet buffer zone all the way around the propane tank.
Dominant Roof Covering	Dominant roof cover material	dominant_roof_covering_material	6 photos showing all roof faces
Secondary Roof Covering	Secondary roof cover materials	secondary_roof_covering_material	6 photos showing all roof faces
Roof	Roof clear of debris	roof_clear_of_debris	Photo/s of any areas of visible built-up debris on any roof face. Close-up photographs if possible
Gutters and Downspouts	Gutters and downspout materials	metal_gutter_downspouts_present	1 close-up photo of gutter, 1 close-up photo of downspout
Gutters and Downspouts	Gutters and downspout debris accumulation	gutters_downspouts_clear_of_debris	Photo/s of any areas of debris in gutter systems

Subsystem	Variable	Data name	Photograph minimum requirements
Gutters and Downspouts	Gutter guard	metal_gutter_guard_present	Close-up photo/s of gutter guard material (if present)
Vents	Roof vent compliance	roof_vents_compliance	Close-up photo of every vent with mesh in view (to observe size)
Vents	Roof vent types	roof_vents_type	Close-up wide-angle photo of every vent with mesh in view (to observe size)
Vents	Forced air vent assembly	dryer_vent_louver_flap_present	1 photo of the vent assembly including the louver flap (if present)
Vents	Dryer vent material	metal_dryer_vent_present	1 close-up photo of the vent
Vents	Eave attic vents	eave_attic_vents_compliance	A close-up photo/s of every vent with mesh in view (to observe size)
Vents	Gable-end attic vents	gable_end_vents_compliance	A close-up photo/s of every vent with mesh in view (to observe size)
Vents	Crawl space vents	crawl_space_vents_compliance	A close-up photo/s of every vent with mesh in view (to observe size)
Eaves & Soffits	Eave/soffit material compliance	eaves_soffits_materials_compliance	Close up photo of the eaves for all 4 elevations (4 total photos, minimum requirement)
Dominant Walls	Dominant wall cover material	dominant_wall_cover_material	Close up photo of material used on dominant percentage wall coverings
Secondary Walls	Secondary wall cover material/s	secondary_wall_cover_material	Close up photo/s of material/s used on any secondary wall coverings
Foundation	Foundation	foundation_photos	Photos of all sides of the foundation, including the deck (if present). Minimum of 4 photos total, 1 for each elevation clearly showing foundation ground/foundation interface.
Shutters	Functional shutters	functional_shutters_present	Close-up photo showing the shutters
Shutters	Decorative shutters	decorative_shutters_material_non_combustible	Close up photo/s of the decorative shutter material/s
Exterior glazing, windows, doors, bay windows	Windows, skylights compliance	windows_skylights_glazed_glass	Photo of the tempered glass etched labels for all accessible windows.
Exterior glazing, windows, doors, bay windows	Exterior Door Material(s) Compliance	exterior_door_material_compliance	Photo of every exterior door
Exterior glazing, windows, doors, bay windows	Bay window	bay_window_non_combustible_wall_present	Photo/s of any bay window and area underneath and surrounding the window feature.
Primary Deck / Covered Porch	Deck / Covered porches clear of debris	decks_covered_porches_clear_of_debris	Photo/s of the deck / porch deck surface
Primary Deck / Covered Porch	Deck / Covered porch type	deck_covered_porch_type	Photos (minimum 3) of each side of the deck / porch and include the base of the structure.

Subsystem	Variable	Data name	Photograph minimum requirements
Primary Deck / Covered Porch	Under deck/porch area	underneath_decks_covered_porches_clear_of_vegetation	Photo/s of underneath the deck / porch of the ground and substructure (including any mesh or lattice used to enclose it.)
Primary Deck / Covered Porch	Decks below 4 feet elevation	decks_porches_less_than_4ft_to_ground_properly_enclosed	Photo of the covering surrounding deck (less than 4 feet elevation)
Primary Deck / Covered Porch	Decks with additional structure/s	decks_w_additional_structure_compliance	Photo/s of the structure/s
Primary Deck / Covered Porch	Deck/stairs materials	decks_stairs_construction_materials_compliance	2 photos of underdeck structure materials and 1 close-up photograph of the walking surface
Secondary Deck / Covered Porch	Secondary deck/porch debris condition	secondary_decks_covered_porches_clear_of_debris	Photo of the deck / porch deck surface
Secondary Deck / Covered Porch	Secondary deck / Covered porch type	secondary_deck_covered_porch_type	Photos (minimum 3) of each side of the deck / porch and include the base of the structure.
Secondary Deck / Covered Porch	Secondary deck underneath area	secondary_underneath_decks_covered_porches_clear_of_vegetation	Photo of underneath the deck / porch of the ground and substructure (including any mesh or lattice or other materials used to enclose it.)
Secondary Deck / Covered Porch	Secondary decks below 4 feet elevation	secondary_decks_porches_less_than_4ft_to_ground_properly_enclosed	Photo of the covering surrounding deck (less than 4 feet elevation)
Secondary Deck / Covered Porch	Secondary decks with additional structure/s	secondary_decks_w_additional_structure_compliance	Photo/s of the structure/s
Secondary Deck / Covered Porch	Secondary decks/stairs materials	secondary_decks_stairs_construction_materials_compliance	2 photos of underdeck structure materials and a close-up of the walking surface
0-5 Foot Noncombustible Zone	0-5 Foot Noncombustible Zone Photos	hiz_photos	Please take photos showing the 0–5-Foot Noncombustible Zone surrounding the entire house. Photos must capture all four elevations, front, rear, left and right sides
5-30 Foot Defensible Space Zone	5-30 Foot Defensible Space Zone Photos	thirty_feet_hiz_photos	Please take photos showing the 5–30 Foot Defensible Space Zone surrounding the entire house for reference. Photos must capture all four elevations, front, rear, left and right sides
Fences	Fencing	back_to_back_fencing_compliance	Photos of any fencing within 30 feet
Fencing	0-5 Foot Noncombustible Zone Fencing	fencing_distance	Photos of any fencing near the home

A4.3 *Connective fuel parcel* level requirements

A4.3.1 Required data

Connective fuel assessment is required for all structures within the designated neighborhood/community and the following data fields are required. See *connective fuel node* definition.

Table A4.24. Connective fuel pathways.

Subsystem	Variable	Data name	Description	
Connective fuels	Cluster identifier	Cluster_id	Which cluster of *structures* does this parcel belong to	ID integer
Connective fuels	Front elevation connective fuel	front_elevation_connective_fuel	Does the front elevation have a connected fuel node pathway to a neighboring *structure*?	0= Yes 1= No
Connective fuels	Left elevation connective fuel	left_elevation_connective_fuel	Does the left elevation have a connected fuel node pathway to a neighboring *structure*?	0= Yes 1= No
Connective fuels	Back/rear elevation connective fuel	back_elevation_connective_fuel	Does the back/rear elevation have a connected fuel node pathway to a neighboring *structure*?	0= Yes 1= No
Connective fuels	Right elevation connective fuel	right_elevation_connective_fuel	Does the right elevation have a connected fuel node pathway to a neighboring *structure*?	0= Yes 1= No

A4.4 Additional data

Intentionally left blank for future standard revisions and the identification of additional relevant data sources

A4.5 Additional optional neighborhood to parcel data

A4.5.1 Neighborhood "as built" site and structure plan drawing sets

"As built" site and individual *structure* drawing sets can be submitted as a .pdf document.

A4.5.2 Local defensible space ordinance

A .pdf file of any local ordinance in place and enforced for *defensible space* requirements.

A5 *Structure cluster* and *neighborhood connective fuel* minimum data requirements

See *structure cluste*r definition and *Chapter 3* for *structure* identification and connective fuel processes and *Chapter 4* for defined *neighborhood* requirements.

Table A5.1. Contiguous cluster required variables and connective fuel flags.

Variable	Data name	type	Description	Value
Cluster identifier	cluster_id	integer	Integer number identifier for each contiguous *structure cluster* identified within the boundaries of the *neighborhood*	i.e. 1, 2, 3, … N block. Each block can reuse integer IDs
Total homes within the *cluster*	cluster_homes	integer	Number of homes/units within the identified contiguous *cluster*	Numeric integer values

Total homes pass connective fuels	cluster_homes_pass	integer	Total number of homes/units which passed *connective fuel node* criteria in *cluster*	Numeric integer values
Total homes flagged for connective fuels	cluster_homes_flagged	integer	Total number of homes/units which failed *connective fuel node* criteria in *cluster*	Numeric integer values
Cluster compliance	cluster_compliance	string	Was the cluster flagged for connective fuels?	0=No/Compliant 1=Yes/Flagged for connective fuels

Table A5.2. Neighborhood connective fuel compliance.

Variable	Data name	type	Description	Value
Neighborhood connective fuel compliance	neighborhood_connect_fuel	integer	Does the *neighborhood* meet all connective fuel requirements?	Binary 0=Yes/Compliant 1=No/False/Non-Compliant

A6 *Neighborhood flame zone* and *neighborhood ember zone* mitigation compliance

Table A6.1. Flame and neighborhood ember zones mitigation compliance.

Variable	Data name	type	Description	Value
Neighborhood flame zone compliance	flame_resistance_zone	string	Does the parcels within the *neighborhood flame zone* meet all mitigation requirements including connective fuel provisions	Binary 0=Yes/Compliant 1=No
Neighborhood flame zone percentage mitigated	flame_resistance_zone_ percent	percentage	Percentage of mitigated *parcels* meeting *neighborhood flame zone* requirements	Percentage (if compliant, percentage = 100%)
Neighborhood ember zone compliance	ember_resistance_zone	string	Does the *parcels* within the *neighborhood ember zone* meet all mitigation requirements	Binary 0=Yes/Compliant 1=No
Neighborhood ember zone percentage mitigated	ember_resistance_zone_percent	percentage	Percentage of mitigated *parcels* meeting *neighborhood ember zone* requirements	Percentage (if compliant, percentage = 100%)

A7 Imagery minimum requirements

A7.1 Ground-level imagery photograph requirements

The following provides requirements and recommendations for *ground level imagery* and photographs used to assess, verify, validate, and/or monitor any element required by the *IBHS Wildfire Prepared Neighborhood Standard*.

A7.1.1 Camera specifications

Resolution: Any submitted ground-based imagery shall use a minimum resolution of 12 megapixels.
Lens: It is recommended to use wide-angle lenses to capture more of the scene; a focal length of 24mm-35mm is recommended but not required.

A7.1.2 Image format

File Format: Images shall be saved and submitted in RAW format.
Color Depth: Images shall use a minimum 16-bit color depth setting.

A7.1.3 Geotagging and metadata

All submitted images shall contain the following minimum metadata:
Time, Latitude, Longitude, Camera settings (i.e., aperture and focal length settings)

A7.1.4 Temporal requirements

Ground-based imagery shall be collected within 60 days of any defined neighborhood evaluation, verification and/or monitoring.

A7.2 Ground level imagery recommendations

The following are recommendations and best-practices for ground-level imagery and are not considered to be requirements for ground-based imagery use for any element and/or requirement of the *IBHS Wildfire Prepared Neighborhood Standard*.

A7.2.1 Recommended imaging conditions

Time of Day: For the best image quality, photos should be taken during the "golden hours," however it is understood that these times are not ideal for typical inspection activities.

A7.2.2 Weather conditions

Avoid rainy or completely overcast days, if possible, to minimize reflections, issues with water droplets, distortion from rain/moisture, and shadows that might not show details.

A7.2.3 Photographic techniques

Exposure: It is recommended to use HDR techniques to manage high-contrast scenes but not required
Focus: Ensure the entire scene is in focus.

A7.2.4 Coverage

360-Degree Views: Each required image location could also include a 360-degree series of photos. For 360-degree image processing, the process will require taking multiple photos in a circle around a central point. 360 imagery is not required (see imagery requirements).

A7.2.5 Panoramic shots

Use panoramic shots for open areas to get a wider perspective of the landscape and community layout, which can be useful for understanding potential fire spread.

A7.2.6 Overlapping fields of view

Each photo should overlap with the previous by approximately 30% to ensure complete coverage when stitching images together or when analyzing spatial relationships.

A7.2.7 Consistent height

Establish a consistent height at which photos are taken by using a tripod to standardize the angle of capture across different photographers and locations. While not required, the use of a tripod at a consistent height for all ground-based images is recommended.

A7.2.8 Distance from subject
Standardize the distance from which photos are taken to maintain consistency across different images and scenes.

A7.2.9 Positioning and reference points
Use reference points or markers in photos to help align shots taken from different angles or at different times. Mark specific spots for repeated photography. It's useful for monitoring changes over time.

A7.2.10 Macro and micro scales
Instruct photographers to take both wide-angle shots for overall views and closer, detailed shots of specific features like building materials, vegetation types, and ground cover for assessing fire risk.

A7.2.11 Angle grids
Create a grid system for larger areas, specifying the exact points and angles from which photos should be taken. This can guide photographers and ensure that all necessary perspectives are covered.

A7.3 *Aerial imagery* requirements
This section provides the minimum requirements for aerial imagery used for assessment, verification, validation, and/or monitoring of any requirement specified in the *IBHS Wildfire Prepared Neighborhood Standard*.

A7.3.1 General *aerial imagery* requirements. Aerial imagery collected from any fixed-wing aircraft, unmanned aerial vehicle, drone, quadcopter etc. for use in assessing roof cover type, connective fuels, defensible space, and fuelbreak characterization shall meet the following:

A7.3.1.1 Digital file format
Aerial imagery may be supplied using one of the following file formats: ECW, geoTiff, GeoJSON, TIFF, MrSID, MRF or HDF. Other file formats not listed here require additional approval for use.

A7.3.1.2 Spectral resolution
Photogrammetric digital camera providing 3-bands, red, green, blue, and panchromatic if available.

A7.3.1.3 Temporal resolution
Aerial imagery used to provide an evaluation and determination of mitigation requirements specified in *Chapter 4* using the processes described in *Chapter 3* shall have been collected within one calendar year. Imagery used for verification of mitigation actions and/or monitoring of mitigation actions described in *Chapters 3* and *4* shall be collected within 6 months of its use in verifying actions.

A7.3.1.3 Spatial resolution shall be 15 cm or finer.

A7.3.1.4 Image compression shall not exceed 15 times and should minimize image quality loss.

If imagery must be converted follow these recommendations for the specific data type (recommendations courtesy of ESRI).

Table A7.1

Data Type	**Recommendations**
8-bit or 16-bit, 1-,3-, or 4-band rasters where lossy compression is not suitable	Use MRF with LERC compression or TIF with LZW/Deflate compression. These formats include tiling with tiles of size 512, 256 or 128. Smaller tile sizes work best for scientific data where access to temporal profiles is more common.
8-bit, 3-band natural color imagery already preprocessed by orthorectification, color balanced, mosaicked, and cut into tiles	This imagery is generally used as background imagery and should be converted directly to a tile cache or stored as MRF or TIFF with JPEG YCbCr compression. Typically, a quality value of around 80 is used, which provides approximately 8-times compression. YCbCr-based JPEG compression internally converts the image to a different spectral domain, improving the compression.
16-bit or 32-bit, 1-band elevation data	Use MRF with LERC compression or TIFF, LZW/Deflate compression, tiled 128 or 256. For 16-bit elevation, be sure that JPEG is not used.
8- or 16-bit imagery where lossy compression is suitable	Use MRF or TIF with JPEG (YCbCr) compression. The quality should be checked by testing some sample imagery. In many cases, a quality factor of 90 is suitable. Note that ArcGIS supports a 12-bit version JPEG. Therefore, when compressing 16-bit pan imagery using JPEG, only the first 12 bits of the imagery will be used. Many modern sensors have a sensitivity in the range of 11 - 14 bits, and using 12-bit compression maintains much of the image content but excludes the last (often noisy) bits.
8-bit or 16-bit, 3-band, non-natural-color imagery when lossy compression is suitable	Examples of this kind of imagery include false color imagery or scanned maps. Use MRF or TIFF, with JPEG (RGB) compression. In RGB JPEG compression, each band is compressed separately.
8-bit or 16-bit, 4-band RGB-IR	This is the format often captured by modern digital sensors. If the data has been orthorectified and enhanced, then some of the original image information has been lost, potentially limiting its use for some forms of analysis. For such imagery, lossy compression may be suitable, but care should be taken to quantify the effects on any intended future analysis. It is then recommended to convert such imagery into a 3-band RGB and 1-band NIR image and use the above recommendations for compressing each. Splitting into a separate RGB image enables better compression, and most users will likely access the RGB component more than the NIR. In ArcGIS, one can virtually merge the two files to create an RGB-IR image suitable for displaying as false color or computing NDVI. Typically for such imagery, the compression quality is set higher, to 90 or 95, so that compression does not add significant artifacts to NDVI. When using JPEG compression, the recommended quality values to use can range from 80 to 95. It is best to try different factors on sample images and review the differences to determine an optimal value.

Data Type	Recommendations
8-bit or 16-bit, 5-band RGB-IR with a panchromatic band	Many sensors include 4-band multispectral imagery and 1-band higher-resolution panchromatic imagery. If you are maintaining the IR band, it is recommended to not pre-pansharpen such imagery. The pan-image changes the multispectral properties of the bands, and the pan-sharpening process will significantly increase the file sizes, reducing the suitability of the imagery for analysis. Instead, maintain the 4-band multispectral and 1-band panchromatic as separate rasters, and use the capability of ArcGIS to pan-sharpen on the fly, which is performed very fast and ensures that the integrity of the spectral bands is not lost. If you need to compress the imagery to reduce size, the panchromatic band should use JPEG compression, as the panchromatic band is typically much larger than the multispectral image and is not used for spectral analysis. Limited JPEG compression (for example, Q90) has minimal effect on visual interpretation or computation of tie points or DSM generation. When using JPEG compression, the recommended quality values to use can range from 80 to 95. It is best to try different factors on sample images and review the differences to determine an optimal value. Another option that can be used is to pansharpen and store the 3band RGB image with lossy JPEG compression. This image can be used for visual interpretation. Then store the lower resolution multispectral red and IR bands separately for use in analysis.

A7.3.2 *Aerial imagery* requirements for connective fuel assessment.

For *aerial imagery* to be used in *connective fuel* assessments it must be orthorectified for use in Geographic Information Systems (GIS) platforms.

It is important to collect ortho-rectified imagery so ground features/connective fuel elements can be measured, and other data layers can be created from the data source which has a strong relationship to ground control. The data required for ortho-rectification include orientation parameters for the source image(s) and a digital elevation model (DEM) of the geographic area to be covered by the imagery. Ortho-rectification corrects for tip and tilt of the aircraft and displacement in the photograph caused by changes in the ground elevation. Generally, the development of ortho-rectified imagery requires the acquisition of overlapping photography of the same geography and some combination of surveyed ground control and airborne (Global Positioning System) GPS collection at the time of photography. A photogrammetrist performs image correlation techniques and aero-triangulation on the resulting block of photographs to establish the orientation parameters of the individual image. Using the most recent DEM source or new LiDAR DEM provides the base for which the new imagery is rectified. Orth-rectified imagery allows for detailed connective fuel features to be accurately mapped and measured. The requirements specified here provide a consistent structure for data providers and users to ensure compatibility of datasets within the same framework layer. The requirements integrate with existing standards such as the American Society for Photogrammetry and Remote Sensing (ASPRS) standards.

A8 Definitions specific to this appendix

Accuracy, horizontal. A measure of the horizontal distance on a photograph within defined tolerances.

Accuracy, vertical. Vertical (elevation) accuracy of a rectified image and associated digital elevation models. Vertical measurements are usually expressed as contour lines or spot heights.

Aerial imagery. Any image taken from an airborne craft.

Band. A range of wavelengths of electromagnetic radiation.

Covenants, Conditions, and Restrictions (also referred to as CC&R). A recorded document that contains a legal description of the development and a statement that it is a community apartment project, condominium project, planned development, or stock cooperative. The declaration must additionally set forth the name of the association and the restrictions on the use or enjoyment of property. Unlike bylaws, which address the governance of an association, CC&Rs describe property rights and obligations of the membership, such as 1) restrictions on the use of property, 2) member and association maintenance duties, 3) enforcement powers, 4) lender protection provisions, 5) assessments obligations and lien/collection rights, 6) duty to insure, and 7) dispute resolution and attorneys' fees provisions.

Datum. The description of the shape of the earth as defined by the National Geodetic Survey; usually referred to as NAD27 or NAD83 for the horizontal datums and NAVD29 or NAVD88 for the vertical datums. NAD27 uses surface reference points, whereas NAD83 uses the center of the earth as the reference point.

Digital elevation model (DEM). A Digital Elevation Model (DEM) is a representation of the bare ground (bare earth) topographic surface of the Earth excluding trees, buildings, and any other surface objects.

Forward lap or End lap. The extent to which sequential exposures in a flight line overlap, typical end lap for stereo photography is 60%.

Ground sample distance (GSD). The area of ground represented in each pixel in x and y components.

Ground-based imagery. Any imagery taken or collected from the ground.

Side Lap. The extent to which the exposures of adjacent flight lines overlap, typical side lap for a block of stereo photography is 30%.

Pixel. The smallest cell size with a uniform value of an image. This digital image cell is produced in varying sizes, usually referred to in ground units such as 6 inches, 1 foot, 3 meters, etc. Pixels are created during the scanning of the aerial imagery and are key to establishing the resolution of the orthophotograph.

Map or Cartographic scale. The relationship between a given distance on the ground and the corresponding distance on a photograph or image. Scale is expressed in at least two different ways. Both are ratios. In the first, commonly used measuring systems are compared; for example, 1" = 100' (1 inch on the map equals 100 feet on the earth). In the second, the map unit is arbitrary; for example, 1:100 means that one of anything (an inch, a foot, a centimeter, etc.) on the map equals 100 of that same unit on the earth. (1"=100' is the same scale as 1:1200). Scale is presented in several ways: as a bar at the bottom of the map, as a ratio (1:100), or as an equation (1"=100').

Orthorectified. The process of geometrically correcting an image to remove relief distortions, sensor artifacts, earth curvature and other perspective distortions, and align the image with coordinates on the ground, restoring geometric integrity. Ground control points, tie points, and elevation data are used to correct perspective and terrain distortion in aerial, drone, and satellite imagery.

Projection. Methods of presenting the earth (a three-dimensional object) on a plane, (a two-dimensional object) with as little distortion as possible.

Root-mean-square error (RMSE). Square root of average squared error.

Scanning. The process of converting analog photographs or hard copy maps into a digital form.

Spatial accuracy. Distance from true ground location.

Spatial resolution. Pixel.

APPENDIX B
Commentary

B1 Administrative commentary

The *IBHS Wildfire Prepared Neighborhood Standard* was developed to provide a means for community-scale wildfire mitigation through a system of requirements that could build upon the growing body of science. The goals of this standard are to provide a system of mitigation requirements that account for varying external fuel exposures, structure spacing, and connective fuel conditions to address the following core principles:

- Reduce the probability of *structure* ignition from flames, radiant heat, and ember exposures that are closest to or in direct contact with the specific external fuels that surround the defined neighborhood.
- Holistically reduce the probabilities of ember-driven ignitions across the defined neighborhood.
- Slow or halt structure-to-structure fire spread within the defined neighborhood should ignitions occur.

By addressing each of these elements, the probability of a *conflagration* occurring can be reduced and allow the neighborhood to function more as a *fuelbreak* rather than a fuel source.

The *IBHS Wildfire Prepared Neighborhood Standard*, like any building code, ordinance, or standard, has its limitations which are governed by practical application and limits to scientific and engineering understanding. It is designed to provide a system of mitigation elements that are generally more stringent than those administered under current *WUI* building code provisions. The *IBHS Wildfire Prepared Neighborhood Standard* is intended to be applied as a voluntary standard that enables a neighborhood and/or community to increase its resilience to wildfires and reduce the probabilities that a built-environment *conflagration* occurs. It is meant to defend against fire entering the defined neighborhood from all directions.

The current state of wildfire science does not provide the practical ability to reduce *structure* ignition probabilities to zero, even in a neighborhood which meets the provisions of this standard. The scientific reasoning behind the provisions included in this standard are targeted to contain *structure* ignitions to 10% or less within a compliant neighborhood. This is accomplished through bulk *parcel* level requirements, management of *connective fuels*, and evaluating the presences of *fuelbreaks* and *firebreaks*. Like all codes, ordinances, and standards, the maintenance of the required provisions is critical to ensuring the effectiveness of the mitigation system.

It is well understood that wildland fire behavior is governed by fuel, weather, and topography. The *IBHS Wildfire Prepared Neighborhood Standard* seeks to affect fuels and account for typical weather conditions that occur during built-environment conflagrations. Topography, however, is not included as a critical variable. While different slope configurations can be diagnosed, the small-scale changes in topography present practical challenges for designing and implementing a technical mitigation standard such as this. The focus on *connective fuels* and the *parcel*-level mitigation elements specified in this standard should also account for fuels across topographic features which could influence fire spread toward *structures*. The *IBHS Wildfire Prepared Neighborhood Standard* uses a 10 m, 70 mph 3-second gust wind for open terrain conditions as its wind-design level. Using the extreme value analysis of wind return intervals used in the ASCE 7-22 standard, this value generally represents an annual exceedance probability of 0.25% – 1% across much of the Western United States. It is noted that this design wind speed is higher than the 90th percentile of peak gusts observed in downsloping wind events across the Pacific Coast states of California, Oregon, and Washington (56 mph; Garner and Kovacik 2022). However, it is below extremes that have been observed, such as the peak gust observed in Arvada, Colorado of 115 mph during the Marshall Fire (2021) and those estimated to have occurred within meso- and micro-scale features such as the tornado-like vortex seen during the Carr Fire (2018) (Lareau et al. 2018).

B1.1 Applicability

The applicability of the standard and the areas in which it can be applied was determined through synthesizing the body of research regarding w*ildland-urban interface* fires, beginning with Cohen's (2008) conceptual model of *wildland-urban interface* fire spread through Maranghides et al.' s framework for mitigation. It also leverages improved understanding, through experimental testing, of how fire spreads between structures. The *IBHS Wildfire Prepared Neighborhood Standard* was designed to serve typical communities near or within the *WUI*. Its system of actions is generally designed for and applicable to WUI types 1-5 developed by Maranghides et al. (2022) and shown in *Table B1*. The standard also follows a similar approach to Maranghides et al. (2022) of segregating perimeter areas from areas interior to the defined *neighborhood*. It is noted that the *IBHS Wildfire Prepared Neighborhood Standard* is more conservative with *structure separation* in types 1 and 2 (see *Table B1.1*) due to recent experimental testing results described in *Section B2*. The *IBHS Wildfire Prepared Neighborhood Standard* only can apply if at least 90% of the *structures* within the defined *neighborhood* have more than 10 feet and less than 100 feet of *structure separation* distance.

Table B1.1. WUI types classified by structure separation and typical parcel/lot size as developed by Maranghides et al. (2022). The green shaded rows are the classes where the IBHS Wildfire Prepared Neighborhood Standard is generally applicable. It is noted that the IBHS Wildfire Prepared Neighborhood Standard applies 10 feet as the lower bound for structure separation distance whereas Maranghides et al. (2022) uses 6 feet, applying a 3 feet setback distance.

Type	WUI Type Name	Structure separation (feet)	Typical parcel/lot size (acres)	Typical housing density (structures per acre)
*1	High density intermix – perimeter	6-30 feet	< 0.5	2 – 8+
*2	High density intermix - interior	6-30 feet	< 0.5	2 - 8+
*3	Medium density intermix – perimeter	30-100 feet	0.5 – 1+	< 2
*4	Medium density – intermix – interior	30-100 feet	0.5 – 1+	< 2
*5	Medium density intermix	30-100 feet	0.5 – 1+	< 2
6	Low density interface	> 100 feet	> 1	< 1
7	Low density intermix	> 100 feet	> 1	< 1

**WUI types in which the IBHS Wildfire Prepared Neighborhood Standard is generally applicable are shaded green. For types 1 and 2, the classification assumes a 3 feet setback. For type 2, the interior of the community is defined as located more than 0.25 miles from wildland fuel sources.*

B1.2 Mitigation approach and framework

To develop the mitigation approach at a neighborhood-scale used in this standard, *IBHS* synthesized the body of scientific literature including post-event analyses, experimental testing, and dynamical modeling. The *IBHS Wildfire Prepared Neighborhood Standard* was developed as a system of protection which accounts for different characteristics of external fuels, how different parts of a *neighborhood* could experience different exposure from flames, radiant heat, and embers, as well as how the *neighborhood* is designed and the fuel characteristics across it.

Across the history of conflagrations in the built environment from urban fires, to fires following earthquakes, to wildfire-driven conflagrations five commonalities have emerged:

- Presence of drought conditions, at any time scales

- Presence of strong winds, typically above 20-30 mph
- Ignition mechanism, typically human-caused
- Dense construction with materials that have little to no fire resistance
- Dense combustible elements surrounding and between *structures*

The details behind the characteristics of wildfire-driven conflagrations are well summarized within Giammanco et al. (2023). The *IBHS Wildfire Prepared Neighborhood Standard* seeks to address the last two critical factors related to hardening of *structures* with more fire resistance characteristics and materials and helping remove pathways for fire to spread between and to neighboring *structures*. The controllable factors within a community are parcel level mitigation, distribution of density of ladder and connective fuels, building codes/ordinances/HOA *CC&Rs*, vegetative fuel types, presence of *fuelbreaks* and existing or in-place preparedness programs. The standard presented here is configured as a system to slow fire spread and reduce the probability of conflagration. To develop the system of requirements shown here, the following questions had to be addressed in some manner to identify a practical system for a *neighborhood* spatial scale:

1) What degree of parcel level mitigation/hardening could slow fire spread to a rate where conflagration was not a certainty?
2) How much *connective fuel* mitigation was needed with no parcel level hardening? With some hardening measures? With maximum protection that wildfire science could practically offer?

B1.2.1 Experimental simulations

To begin to address these questions to understand what mitigation approach should be taken and how to understand the influence of mitigation actions in larger scales, *IBHS* partnered with the University of Buffalo to conduct a series of idealized dynamical model simulations and two "hind-cast" simulations (Marshall Fire and Camp Fire) to understand what degree of mitigation through parcel level actions and connective fuel remediation is needed to slow fire spread and meaningfully lower the probability of a built-environment conflagration. Given the lack of post-fire observations of the impact of community-scale mitigation, dynamical modeling has helped fill the gap in designing the framework of this standard. The simulations were designed to bring together the known understanding of built-environment conflagrations, experimental test results and post-fire investigations.

The dynamical modeling study used the SWUIFT model (Streamlined Wildland-Urban Interface Fire Tracing) to conduct the hindcast and idealized neighborhood experiments using various levels of hardening, connective fuel conditions, and different wind speed exposures (Masoudvaziri et al. 2021). Inputs to the SWUIFT model were *LANDFIRE* for landcover, Microsoft building footprints, WRF-LES model for wind conditions, and WRF-Fire for wildland fire spread. The structure hardening conditions were designed to mimic the reduction in ember and direct flame/radiant heat ignition probabilities and designed to serve as proxies for the *IBHS Wildfire Prepared Home* (WFPH) requirements. The hindcast of the Marshall Fire (2021) using 70% of *structures* within the fire boundary hardened to a level that is considered a proxy for the *IBHS WFPH Plus* level of mitigation was shown to reduce fire spread within the built environment. However, at this same level of mitigation, it did not make a detectable difference in fire spread rates and destroyed structures for the Camp Fire (2018) hindcast. The *connective fuels*, in this case mostly vegetative, were too densely connected and enabled fire to continue to propagate despite the simulated mitigation efforts. The result suggested that a combination of both structure hardening, *parcel* level fuel management and overall *connective fuel* management is crucial to ensure the mitigation system can accomplish the goals set forth in this standard.

To test the framework of the system employed in this standard, two idealized communities were defined as a high and a medium density interface community (see *Table B1*) covering approximately 0.75 mi^2 with two different *structure spacing* distances (4 meters and 20 meter), 33 feet (10 meter) wide streets and different *connective fuel* and *parcel* level mitigation levels. Five different wind environments were also tested from winds of 5 to 25 ms^{-1} (11–56 mph). This yielded 110 independent dynamical simulations. Conflagration was defined as greater than 10% structure loss in a 12-hour time window. In both communities, with *connective fuels* connecting all four sides of each *structure* and in any wind conditions conflagration occurred easily as no mitigation elements were present. In the most densely spaced community, even with 0% connected fuel coverage, once fire entered the modeled community conflagration occurred. Simulations at low wind speeds showed that by reducing *connective fuels* to only two *connective fuel paths* per *structure* reduced the number of *structures* burned and slowed fire spread but still met the conflagration criteria (> 10% *structures* ignited). When combining *parcel* level mitigation on 70% of *structures* (a proxy for *IBHS WFPH Plus* construction) and reducing connective fuel pathways to just one side of each *structure*, conflagration was avoided, and fire spread rates were greatly reduced.

The results were in general agreement with the wildfire mitigation framework within these types of communities discussed in Maranghides et al. (2022) and provided support for a framework which accounted for parcel level actions (both *structure* hardening and fuel management) and overall management of *connective fuels* into and within the defined *neighborhood*. The *IBHS Wildfire Prepared Neighborhood Standard* applies a modified hardening approach to utilize maximum protection elements in areas which may see a greater likelihood of direct flame and radiant heat exposure and fill the remaining ember protection gaps using those measures described in the base level of protection of the *IBHS Wildfire Prepared Home Standard*. This allows for greater flexibility in structure spacing applicability and in *connective fuel pathways*. It is noted that in each case, a *0–5 Foot Noncombustible Zone* remains a cornerstone of mitigation actions. It is also noted that the 30% *connective fuel* coverage configuration on each parcel used in the dynamical simulations was nearly identical to the *connective fuel node* and *pathway* requirements stated in *Chapter 4*. The *IBHS Wildfire Prepared Neighborhood Standard* also uses a more stringent wind design environment (70 mph 3-second gust wind speed at 10 m (33 feet) height for open terrain exposure conditions) compared to the highest wind conditions used in the idealized *neighborhood* simulations (56 mph). In this Appendix, *sections B2 through B6* provide additional details to support the scientific and engineering decision made regarding structure separation applicability requirements, roof cover requirements, *connective fuels*, and the requirements of the *flam*e and *neighborhood ember zones*.

B2 Roof provisions

The *IBHS Wildfire Prepared Neighborhood Standard* requires that all roof covering materials in the defined neighborhood carry a Class A fire rating based on the ASTM E108 (ASTM 2020) testing standard regardless of whether the home falls outside the *flame* or *neighborhood ember zones*. The requirement is more stringent than what is currently specified in Chapter 7A of the California Building Code and the 2021 International Wildland Interface Code (IWUIC). The *IBHS Wildfire Prepared Neighborhood Standard* specifically requires a Class A roof covering material and does not permit Class A by assembly. Regardless of their fire classification, any wooden roof covering product including but not limited to fire-retardant treated and fire-retardant coated wood shakes and shingles are not permitted.

Wind patterns near buildings heavily influence ember distribution patterns and accumulation locations. Because roofs are a large, elevated surface with complex geometry and a range of slopes, they are prone to ember accumulation during ember storms. The regions on the rooftop where embers reach stability and rest are also a complex function of roof geometry, particularly roof valleys. Roof valleys are often covered with organic vegetative debris, which is particularly susceptible to ignition from embers (Nguyen and Kaye

2021). Standard test methods such as ASTM E108 and UL 790 (Underwriters Laboratories 2022; ASTM 2020) evaluate the fire performance of different roof covering materials.
The vulnerability of roofs to ember storms is well studied. Several retrospective studies have reported a statistical correlation between wood coverings and building losses due to ember exposure (Davis 1990; Foote et al. 2011). Moore (1981) reported that out of 1,850 homes, 50% of homes with wooden roof covering within 30 feet of burning vegetation ignited while only 24% of homes with fire-resistant roofs ignited in the 1961 Bel Air Fire in Southern California. Foote (1994) found the degree of flammability of the roof had a significant impact on home survival where homes with nonflammable roofs had a 70% survival rate compared to 19% for homes with flammable roofs. After the 1991 Oakland Hills Fire in California, it was estimated that each burning home with a non-fire-retardant-treated wood shake roof contributed to the ignition of ten other homes (Bryner 2000). Hedayati et al. (2024) also identified during the Lahaina Fire that roof performance was nearly binary. Non-Class A roofs had an ignition rate greater than 80% and the roof was a critical variable in ignition probabilities. However, for *structures* with a Class A roof covering, the roof was a far less critical variable in explaining ignition potential.

Wood shake and/or wood shingle roofs have been identified as one of the most susceptible roof covers to ember attack and ignition. These materials, when new or at a later point in their lifetime, are often treated with fire retardant material or ignition-resistant coatings, sprays, paints, etc. to allow the material to have some degree of ignition resistance. Quarles and Standohar-Alfano (2017) investigated the aged performance of several fire-retardant coatings, and their relative ignition resistance compared to untreated wood surfaces. Degradation for some began as soon as three months, and by a year of exposure to typical weather conditions the ignition performance was no different than an untreated specimen. When considering fire-retardant coatings, Koo et al. (2001) also found highly variable performance of different fire-retardant coatings on wood specimens even in newly applied conditions.

Östman and Tsantaridis (2016) explored how treated wood products performed over a 10-year window of natural weathering. While they found some products that could retain their treatment compounds could maintain performance over time, others after 10 years showed no performance benefit compared to untreated products. Zhou et al. (2018) specifically examined a fire-retardant treated cedar shake shingle and how its ignition performance degraded using three accelerated weathering tests. While the fire-retardant treated wood performed better than its untreated counterpart, it was observed that ignition times decreased with added artificial aging. The result was sufficient to indicate a decrease in fire resistance performance as the treated wood aged.

While new coatings, treatments, and formulations continue to be developed and are emerging into the marketplace that show promise, there remains little new literature on how their performance changes over time under natural aging/weathering conditions; nor are there any operational testing standards that evaluate changes over time in performance. The uncertainties surrounding adhesion, compatibility of materials, and long-term durability are well described in Albert and Liew (2023).

Given the potential service life uncertainties of both ignition resistant treatments and applied ignition-resistant coatings, the use of wood shake, wood shingle, or any wood roofing materials regardless of test rating as a new product in the *IBHS Wildfire Prepared Neighborhood Standard* is prohibited. This follows that stated in Chapter 7A of the California Building Code (Section 703A.5.3). While new coatings, treatments, and formulations continue to be developed that show promise, there remains little new literature on how the performance changes over time under natural aging/weathering conditions. Additionally, there are no operational testing standards and associated product approvals that account for changes over time in performance.

B3 Structure separation

Laboratory experiments and post-fire investigations show a direct link between thermal exposure and the structure hardening needed for fire resilience (Maranghides et al. 2022). Effective wildfire mitigation balances both factors. Embers are the primary ignition source, starting small fires that, under favorable conditions, spread to larger fuels like fences, sheds, and vehicles. This escalation, combined with strong winds, often leads to rapid, building-to-building fire spread. Spot fires rely on nearby fuels to reach *structures*, with these fuels radiating heat and accelerating fire growth. Denser *neighborhoods*, with more fences and vehicles, amplify this risk. Thus, greater structure spacing is crucial to reducing vulnerability and preventing catastrophic conflagrations in the built environment.

The built environment, specifically where high-density construction is built with little to no fire-resistance, has minimal resistance time against potential flame exposure. Once ignited, the fuel load of a typical single-family home is easily sufficient to produce a flame and radiant heat exposure on a nearby *structure* to ignite it, even with some degree of hardened or fire-resistant materials, especially in the presence of wind which helps stretch flame lengths.

IBHS is studying wind-driven fire spread from a source building to a target building which represents a typical *primary dwelling unit (30-feet by 40-feet in size, and 1.5 stories in height)*. *Figure B3.1* provides a photograph of an active test at the *IBHS* Research Center. In the first phase, the source building was a large burning shed, while the second phase uses a 625 ft^2 *accessory dwelling unit* as the source. Results from the first phase show that heat intensity on the target building depends on the source-target orientation, wind speed, and separation distance. When the target building absorbs thermal energy from the fire, energy is dissipated through the complex turbulent flow, some is reflected away from the *structure*, and the rest is absorbed, raising the temperature of the building envelope. The thermal response varies by component: annealed glass may shatter in place, tempered glass might fall out depending on its frame, combustible siding and open eave can ignite, and noncombustible siding may buckle. These illustrate the diverse damage modes under fire exposure. While some of these damages are not catastrophic, nearly all can compromise the building's envelope through large openings or ignitions, significantly increasing the likelihood of complete destruction in the absence of fire-service intervention.

Figure B3.1. Photograph of wind-driven flame spread testing at the IBHS Research Center in Richburg, South Carolina.

The first phase of the project was able to demonstrate that even under non-extreme wind conditions, the energy accumulated at a 10-foot separation is sufficient to ignite combustible siding and open eaves. Even with noncombustible siding or enclosed eaves, other vulnerable components of the building remain at risk at a 10-foot separation distance. In experimental tests, double-pane tempered windows with vinyl frames—a product with a 20% US market share and likely to remain popular due to its affordability—failed under similar energy accumulation rate. This suggests the fire intensity at 10 feet or closer is sufficient to overwhelm the resilience of many common building materials, even those compliant with modern WUI codes.

Therefore, based on the initial results from this experimental testing program, *the IBHS Wildfire Prepared Neighborhood Standard* uses the 10-foot minimum spacing benchmark as the smallest structure-to-structure spacing extent to which the standard is applicable.

B4 Connective fuels

The importance of fuels between and around structures has been a critical variable in built-environment *conflagrations* dating back to the first urban fires of the 1600s. Dense combustible fuels between *structures* create fire paths in which fire can easily spread through direct flame and radiant heat-driven ignition from structure-to-structure. In wildland fires, these types of fuels are commonly referred to as ladder fuels and are typically vegetative, which allow fire to spread both laterally and vertically. Within the context of a *WUI* fire or built environment *conflagration*, *connective fuels* are both *vegetative* and *built-environment fuels*. They play a critical role in whether a wildfire entering a *neighborhood* becomes a catastrophe. For example, wooden privacy fences served as a dominant fire pathway between *structures* during the Marshall Fire (2021) (FEMA 2023; Giammanco et al. 2023; Juliano et al. 2022).

B4.1 Fuel continuity

The arrangement and continuity of fuel can affect the fire's ability to spread, influencing the intensity of the flames. The arrangement and distribution of fuel, both vertically and horizontally, is referred to as fuel continuity. This continuity or connectivity describes the degree to which fuels are interconnected to provide a continuous path for fire to spread. Within the *IBHS Wildfire Prepared Neighborhood Standard*, these are referred to as *connective fuels* and *connective fuel pathways*. In terms of fire behavior, fuel continuity plays a significant role in determining the rate and intensity of fire spread. High fuel continuity, where fuels are densely distributed and interconnected, can promote the rapid spread of fire, as flames can easily propagate from one fuel source to another. In general, live vegetation exhibits gaps between needles, shrubs, or trees, and clumps of trees, arguing that understanding continuity of fuels is critical for fire suppression and fuel management (Hurley et al. 2015). Even at small scales, the separation between fuel particles has been shown to create critical conditions for fire spread on both natural and artificial fuel beds. (Vogel 1970; van Wagner 1970; Weber 1990; Di Christina et al. 2021; Bu et al. 2021). This concept of critical conditions or thresholds also applies to larger scales, where discontinuity occurs between plants rather than individual particles (Cheney et al 1998; Marden-Smedley et al. 2001; Weise et al. 2005). In either case, the fire spread threshold is determined by fuel characteristics and environmental factors such as wind, slope, and fuel moisture content.

Over the past few years, *IBHS* has collaborated with the United States Forest Service (USFS) to investigate and identify the critical physical processes that drive ignition, considering the spatial distribution of fuel and a range of environmental conditions. As a result of this collaborative effort, valuable insights have been gained, particularly regarding the threshold separation distance between pine needle fuel beds for continuous flame spread under various wind conditions. As can be seen in *Figure B4.1*, the findings have demonstrated the separation distance required for sustained flame spread varies depending on wind speed and moisture content conditions. Understanding this threshold separation distance is crucial for effectively predicting fire behavior and implementing appropriate fire management strategies such as the *connective fuel* provisions described in this standard in *Chapters 3* and *4*.

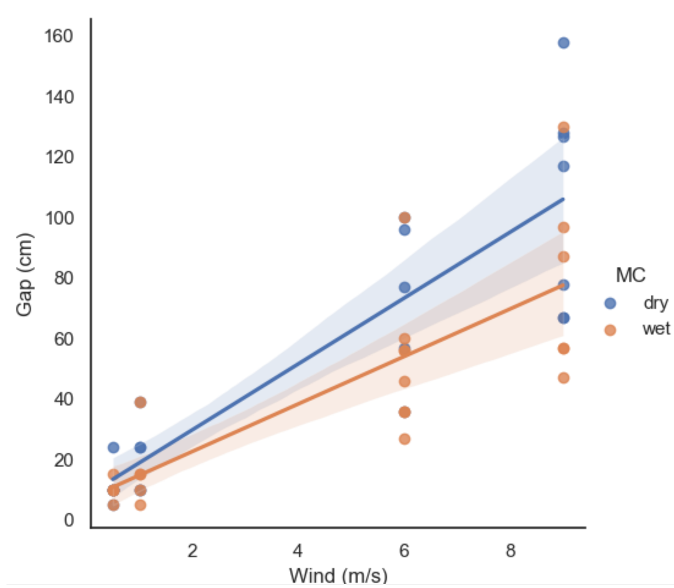


Figure B4.1. Maximum separation distance required for sustaining flame spread. Fuelbreak gap distances shown as a function of wind speed for fine fuels at two different moisture content levels at the IBHS Research Center.

The concept of fuel connectivity observed in vegetation fuels can also be extended to structural fuels such as fences, sheds, *accessory dwelling units*, and other similar objects. The underlying mechanism driving fire spread remains the same: when these structural fuels are closely spaced or connected, heat transfer between burned and unburned particles occurs at a high rate, leading to rapid fire spread (Shields 2008). Understanding the role of fuel connectivity in structural fuels is essential for assessing fire risk and implementing appropriate fire mitigation strategies. It emphasizes the importance of maintaining adequate spacing and reducing fuel continuity to minimize the potential for fire spread and mitigate the risks associated with structural fires

In the case of nonhomogeneous fuel, such as a mixture of different structural/*built environment and vegetative fuels*, details of the fire spread mechanisms are not yet well understood due to the interactions and complexities arising from the combination of different types of fuels. When low density fuels such as leaves meet larger fuels, such as building components, qualitative observations suggest a more rapid rate of fire growth. This fuel configuration can create a vertical fuel ladder that allows the fire to jump from the ground and engulf different building components in flames (Menning and Stephens 2007). According to post-fire investigations, discontinuities between trees, bushes and *structures* can reduce the threat of tall, high-intensity flames, which are strongly correlated with building damage. An analysis of Ramsay et al.'s (1970) post-Ash Wednesday bushfire damage in Australia found that damage to homes was affected by the amount and type of vegetation around them. Dense vegetation around houses aided in connecting the fire to other nearby homes, making it less likely they would survive. During the Witch Creek Fire (2007), when evaluating the vegetation within the first 30 feet of houses in San Diego County, California, Maranghides et al. (2013) found that 67% of homes with unmaintained vegetation were destroyed, whereas only 32% of homes with maintained defensible spaces were destroyed. The importance of fuel discontinuity was found to be even more important near buildings. Syphard et al. (2014), after analyzing more than 2,000 structures in San Diego County, concluded *structures* with defensible space that contained spaced vegetative fuels "immediately adjacent" survived more fires. Additionally, it was also found that reducing woody vegetation by up to 40% immediately adjacent to *structures* and preventing vegetation from overhanging or touching structures were the most effective measures (Syphard et al. 2014). A fence or deck attached to the house can also facilitate the spread of fire or radiate enough heat to ignite the building's cladding. *Figure B4.2* provides a photograph illustrating fire spread along a wooden fence following the Mountain Fire in Camarillo California in 2024. Both post-event investigations and laboratory experiments show that these components, especially if they are in the vicinity or in contact with vegetation, can ignite *structures*.

Figure B4.2. Photograph of a fence, following the 2024 Mountain Fire in Camarillo, CA, which had ignited adjacent to a home where fire spread to the wall of the structure. In this case fire service intervention and the presence of noncombustible wall cladding (stucco) helped avoid ignition of the structure. The window frame on the right side of the image was damaged, and there was evidence of sufficient radiant heat to damage the paint in the eaves of this home. Photograph by Evan Sluder.

B4.2 Connective fuel mitigation approach

The mitigation approach taken by the *IBHS Wildfire Prepared Neighborhood Standard* leans heavily on the defensible space provisions of the *IBHS Wildfire Prepared Home Standard* but takes a fire pathway approach toward evaluating the defined neighborhood and determining what conditions it must meet. *Connective fuels* are evaluated across contiguous *clusters* of *structures*, where fire can most easily spread from structure-to-structure via *connective fuels* and direct flame / radiant heat. This will manifest itself more readily across *clusters* of homes that do not have barriers that help break the chain of fire. Across those *clusters* the coverage of connective fuels is evaluated. Within the *neighborhood flame zone* where the most severe fire exposure from external fuels is most likely, *structures* cannot be connected by any fuel pathway. This area is the first step in minimizing initial ignitions in the area where fire is likely to enter the defined neighborhood through external fuels. Across the remainder of the defined *neighborhood* and the identified *clusters*, it is acceptable to have a single *connective fuel pathway*. Given the hardening provisions specified for *structures*, this flexibility would enable more practical landscape options while keeping the probability of *conflagration* low. It is noted in most cases, *structures* that comply with the *IBHS WFPH Plus*, will not have any connective fuel pathways. However, complications could arise with the use of accessory structures and the parcel configuration; where an *accessory structure* could act as a *connective fuel pathway* or complete a pathway to a neighboring *structure* while complying with the parcel-level provisions of the *IBHS Wildfire Prepared Home Standard*. If the defined *neighborhood* is large enough, or external fuels do not necessitate a *neighborhood ember zone,* the *connective fuel* provisions combined with the Class A compliant roof will still provide measures to defend against the lower probability of fire entering the area, representing a factor of safety.

B5 *Neighborhood flame zone*

The *neighborhood flame zone* encompasses the perimeter of the defined *neighborhood* where *structures* are near *external fuels* that could impart direct flame contact and radiant heat exposure on *structures* within the zone. It is in this area where protection from ember attack, direct flame contact and radiant heat is required to reduce the probability of ignitions should fire reach the defined *neighborhood* boundary.

The method can be broken down into three key steps, *external fuel* determination, fire intensity analysis, and heat transfer calculations. To complete each of these steps, described in detail in *Chapter 3,* requires key assumptions to be made. Undoubtedly, these assumptions impact those calculations used to determine mitigation provisions. The scientific assumptions used in the *IBHS Wildfire Prepared Neighborhood Standard* provide a conservative and objective process for determining necessary mitigation actions to achieve the four core principles of this standard listed in *Chapter 1*.

B5.1 External fuel determination

Fuel is a critical component in determining fire behavior, influencing how fires ignite, spread, and intensify. Fuel data is crucial for the decision-making process in the *IBHS Wildfire Prepared Neighborhood Standard*. Due to the availability of detailed vegetation maps and integration within the United States operational fire management practice, *LANDFIRE* is used as the baseline data source for the *external fuel* determination. A *LANDFIRE* landscape file is a multi-banded raster, with five bands required: elevation, slope, aspect, fuel model, and tree canopy cover (*LANDFIRE*). For the external fuel determination, the processes described in this standard specifically consider the fuel model band. *LANDFIRE* creates their fuel model maps by creating a rule set based on the existing vegetation type, existing vegetation cover, existing vegetation height, and the environmental site potential and assigns a *fire behavior fuel model type* to each rule set. These rules are reviewed by local experts to maximize accuracy and calibrate the rules and resulting maps (*LANDFIRE*).

Two Fire Behavior Fuel Models are available in *LANDFIRE*, 40 Scott and Burgan (2005) Fire Behavior Fuel Model (FBFM40), and the original 13 Anderson Fire Behavior Fuel Model (FBFM13). These two fuel models represent the same fuel types, although Scott and Burgan's model, chosen for use in this standard, offers more fuel models in every fuel type providing higher resolution for the fuel characterization processes.

LANDFIRE products were created and are maintained to support national, regional, and sub-regional fire management and analysis, with a spatial resolution of 30 meters (*LANDFIRE*). At this scale, considering the fire interface at the edge of a community requires assumptions and analysis that account for this resolution. Two methods are used to consider variations in fuel that may occur within the 30-meter resolution of *LANDFIRE* products.

The first method conservatively considers all fuels within a 0.25-mile buffer (*flame fuel assessment zone*) of the *neighborhood*, allowing for an analysis of 10 times the minimum spatial resolution of *LANDFIRE* products when considering what surface fuels drive fire intensity and the resulting exposure a *neighborhood* may experience. Considering all fuels present within the *flame fuel assessment zone* of the *neighborhood*, the worst-case fuel —determined by the total heat release rate per unit area—with 10% or greater coverage is used for the exposure analysis. For assessing potential flame exposure all fuels, regardless of coverage, are used to ensure that all fuels capable of generating the spreading line fire assumed in the *fire behavior fuel model* are considered.

The second method allows local, regional, or expert knowledge and data to supplement *LANDFIRE* in the determination of the appropriate *fire behavior fuel model* for this analysis. Fuel management and planning are encouraged to reduce the potential fire exposure. Fuel management practices within the *flame fuel assessment zone* outside the defined *neighborhood* boundary will affect the surface fire behavior and the appropriate *fire behavior fuel model*.

B5.2 Vegetative fuel fire intensity analysis

To determine potential surface fire intensity of the vegetative fuels identified in the *flame fuel assessment zone*, BehavePlus is used to calculate Reaction Intensity (or HRRPUA). The BehavePlus fire modeling system is a Windows®-based computer program that can be used for any fire management application that needs to calculate fire behavior Andrews (2003). It uses specified fuel and moisture conditions to simulate surface and crown fire rate of fire spread and intensity, probability of ignition, fire size, spotting distance, and tree mortality. The resulting HRRPUA is determined for each one of the 40 fuel models is shown in *Table B5.1*.

Table B5.1 Fire behavior fuel models and the resulting heat release rate per unit area (HRRPUA) for use in this standard.

***Fire Behavior Fuel Model* Type Identifier**	**HRRPUA (kW/m²)**
GR1	88
GR2	233
GR3	301
GR4	454
GR5	852
GR6	1304
GR7	1598
GR8	1963
GR9	2993
GS1	309
GS2	503
GS3	819
GS4	3573
SB1	557
SB2	1127
SB3	1554
SB4	1637
SH1	313
SH2	1201
SH3	389
SH4	708
SH5	1163

Fire Behavior Fuel Model Type Identifier	HRRPUA (kW/m²)
SH6	1074
SH7	1547
SH8	1667
SH9	2678
TL1	106
TL2	156
TL3	178
TL4	222
TL5	354
TL6	509
TL7	357
TL8	727
TL9	1052
TU1	364
TU2	410
TU3	824
TU4	1397
TU5	1813

However, to consider potential *crown fire* intensity a different approach was followed since the crown Fire model in Behave requires canopy base height as input—information that is often unavailable—and does not provide the HRRPUA needed for FDS simulations. Therefore, a simplified yet conservative approach is used to assess the potential impact of crown fires. This approach utilizes the existing vegetation cover (EVC) from the LANDFIRE dataset or a supplemental dataset that meets the specifications outlined in this standard. If 10% or more of the sector's area is covered by trees, as identified from the EVC data, a 70-meter (230-foot) buffer is added to the *neighborhood flame zone* (*NFz*) distance derived from the fuel analysis. The buffer distance was determined based on exponent-based models for energy decay with distance in wildland fires. These models, derived from heat flux measurements of natural and prescribed wildland fires across Alaska to Florida between 2006 and 2010, identified four distinct regimes. Data from the most intense fires, typically associated with crown fires, yielded an incident heat flux equation, $q = 300/L^{0.75}$, where L is the distance from the fire (Butler et al. 2015). Using this equation, a radiative heat flux threshold of 13.1 kW/m^2—representing a realistic ignition potential for common structural fuels Cohen (2004)—corresponds to approximately 65 meters. To ensure a conservative margin, this distance was rounded up to 70 meters.

B5.2.1 Heat transfer calculations

Heat flux calculations were performed using FDS, considering a range of HRRPUA values (~80 kW/m^2 to 3600 kW/m^2) derived from BehavePlus for all fuel types. In all simulations, a fixed fire was positioned 5 meters from the boundary of the computational domain, with the fire's head assumed to be located at the *neighborhood's* edge or beyond any established *fuelbreaks* or *firebreaks*. A similar approach was previously employed by Parsons et al. (2014) to simulate potential burn injuries. In this case, the heat source is used to simulate potential structural ignition, with the fire size assumed to match the resolution of the LANDFIRE data (30 m x 30 m). However, it is acknowledged that the fire size significantly influences the simulation results, and this effect will be analyzed in the following section.

Total heat fluxes were calculated at distances of 10, 20, 30, 40, and 80 meters downwind from the fire at a height of 1 meter above ground level assuming neutral stability and a logarithmic wind profile defined by the following equation:

$$u(z) = \frac{u_*}{k} \, ln\left(\frac{z}{z_o}\right) \qquad \textit{Equation B5-1}$$

where *u* is wind speed, u_* is the friction velocity (m/s), *z* is height (m), *k* is the von Karman constant (0.4), and z_o is the surface roughness length (0.03 m for open terrain exposure). After the corresponding sensitivity analysis, all simulations were computed using a computational domain of 70 m x 130 m x 30 m and a grid resolution of 1 meter. An optical-thin approach is used for the radiation model, with a prescribed radiation fraction of 0.371. For all the simulations, the leading edge of the fire is positioned 5 meters from the boundary of the computational domain while the fire's head is assumed to be located at the edge of the *neighborhood* or outside any established *fuelbreaks* or *firebreaks*. No obstructions, such as *structures*, are considered in the model (*Figure B5.1*).

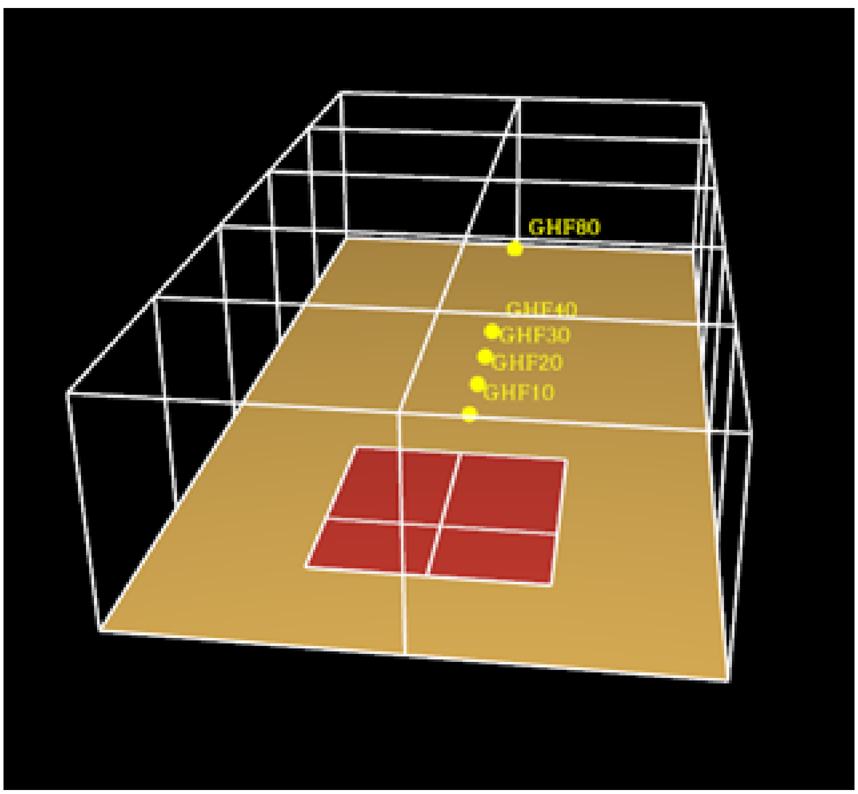


Figure B5.1. FDS simulation showing heat source and measurement locations

Mean heat fluxes, as a function of distance, are calculated during the quasi-steady state and used to determine a power-law or linear least-squares fit, depending on the HRRPUA range. An example for an HRRPUA of 1160 kW/m^2, corresponding to the FBFM SH5, is shown below in *Figure B5.2*.

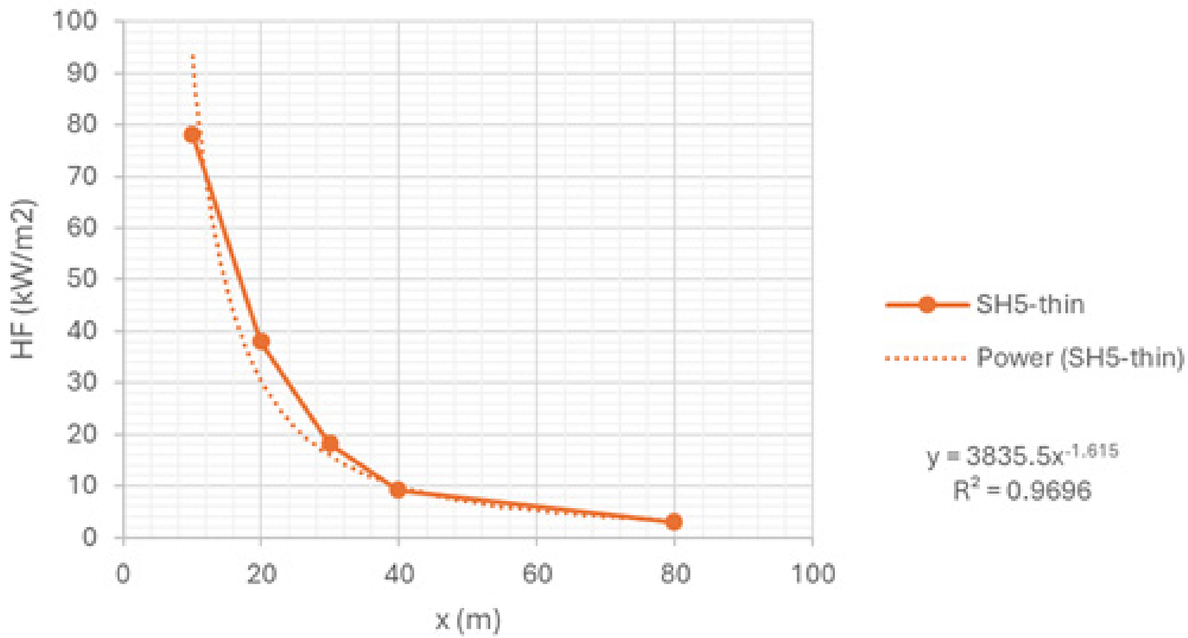


Figure B5.2. Power-law least squares fit for the mean heat flux (HF) as a function of the distance for a HRRPUA equivalent to the FBFM SH5.

These equations were derived for various HRRPUA values, ranging from 80 to 3600 kW/m^2, and solved with a radiative heat flux threshold of 13.1 kW/m^2, which is an appropriate threshold value to represent a realistic ignition potential for common structural fuels Cohen (2004). The solution identifies regions where this heat flux exposure threshold is met for different HRRPUA values, classifying them as part of the *neighborhood flame zone*. A second-degree polynomial fit with an R^2 value of 0.997 is then obtained to calculate the distances that meet this criterion as a function of HRRPUA, establishing the initial *neighborhood flame zone (NFz)* in meters, as given by *Equation 3-2*:

$$FZ\ (x)=1\times\ 10^{-6}\ x_2+0.0279x \qquad \textit{Equation B5-2}$$

where x is HRRUPUA determined by *Table 3.1* for the worst-case *fuel model type* in the *flame fuel assessment zone* in each sector. If the canopy fuel provision described above is met, then an additional 70-meter (230-foot) distance is added to obtain the value for FZ to use in *Equation 4-1* for vegetative fuels.

B5.2.1.1 Optically thin approach

An optically-thin limit is applied in the radiation model, a suitable approach for simulating outdoor fires (McGrattan et al. 2008). In this method, the fire radiates a user-specified radiative fraction of energy, which is transported to the domain boundaries without being reabsorbed by cooler gases. The radiative fraction (χ_R), is a common parameter in CFD models; however, it is not a universal constant and depends on factors such as fuel type and fire size

*Figure B5.*3 illustrates examples of radiative fraction measurements for various liquid fuels as a function of pool fire diameter. The data show that χ_R changes slightly with increasing size for smaller fires (less than 1 meter), but these variations become more pronounced for larger fires, generally resulting in lower χ_R values.

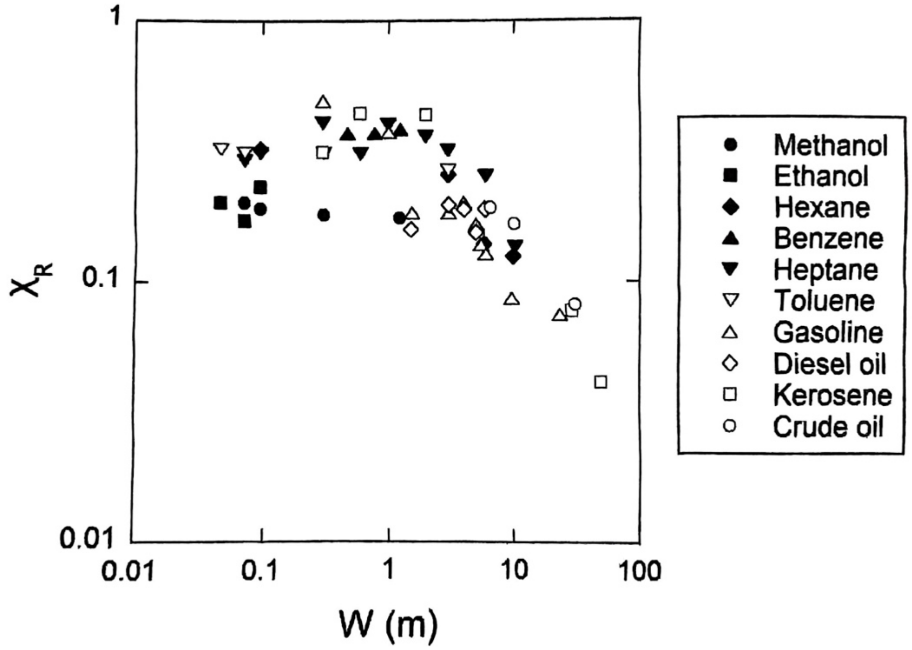


Figure B5.3 Radiative fraction as a function of pool fire diameter (Taken from Himoto, K. (2022). Large Outdoor Fire Dynamics. CRC Press.)

For biomass fires, several studies have measured the radiative fraction for different woody materials under various conditions. For example, Tihay et al. (2009) calculated the radiative fraction of laminar flames from vegetative fuels, finding values between 20% and 27%. Kremens et al. (2012) conducted experiments with preconditioned wildland fuels typical of mixed-oak forests, reporting an average radiative fraction of 17%. Morandini et al. (2013) studied the influence of fuel load on radiative fraction and other fire properties, using pine needle fuel beds (2 m x 1 meter) and found radiative fractions ranging from 17.4% to 22.4%. Further, Morandini et al. (2014) investigated the effect of slope on convective and radiative heat transfer. They observed slightly higher radiative fractions under sloped conditions, with values ranging from 25.1% to 38.9% for a slope of 20°, compared to flat surfaces.

In summary, χ_R that has not been measured or reliably predicted for all potential fuel types, and this parameter significantly influences the simulation results. For example, *Figure B5.4* illustrates mean heat fluxes at various distances for three different χ_R values, using a heat source of 20 meters x 20 meters. These data show higher heat flux values with increasing radiative fractions across all distances.

For this study, a conservative approach was adopted. Since most χ_R values reported in the literature for woody materials range from approximately 17% to 39%, we used a value of 0.37, which is the radiative fraction in FDS for "red oak." This value is close to the upper boundary of the reported range, ensuring higher heat flux predictions compared to smaller χ_R. Model results could be improved by inputting the appropriate χ_R values that better represent each specific type of vegetation.

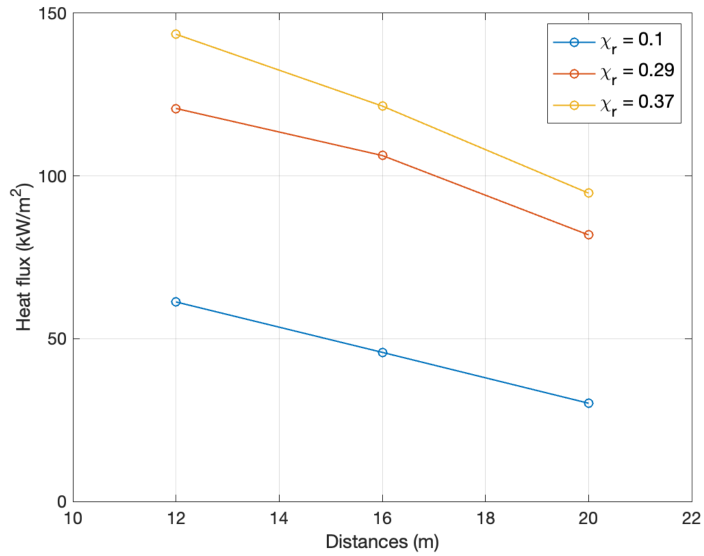


Figure B5.4. Simulation results for the mean heat flux values as a function of the distance for radiative fraction of 0.1, 0.29 and 0.37.

B5.2.1.2 Sensitivity analysis

Sensitivity analysis was done to evaluate the effect on the simulation results, specifically in the total heat fluxes as the grid size, the fire depth and fire width change. For this analysis, the larger fire provided by BehavePlus was used (HRRPUA = 3600 kW/m^2) to ensure there the domain is large enough to recreate the prescribed HRR.

To begin with the sensitivity analysis, the appropriate grid size was evaluated considering the smallest (5 x 5 meters) and largest (30 x 30 meters) heat source size evaluated in this work. For this, the criteria suggested by Mc Grattan et al. (2008) were followed as guidance, stating the ratio between length scales characterizing the diameter of the pool fire (z_c), and the grid cell size in the gas-phase (dx_g) has to range between 4 and 16. Considering,

$$z_c = \left(\frac{\dot{q}}{\rho_a c_p T_a \sqrt{g}}\right)^{2/5} \qquad \textit{Equation B5-2}$$

Where $\dot{q}$ is the HRR, ρ_a, c_p, T_a are respectively the density, specific heat and temperature of the ambient air and g is the standard gravity. *Table B5.5* presents the values of z_c, $z_c/4$, and $z_c/16$ for the smallest fire simulated (5m x 5m) and the largest one (30m x 30m). $\delta = 0.5$ meter, 1 meter and 1.5 meters were used to evaluate the effect of the grid resolution in the results. For these simulations a value of radiative fraction of 0.37 was used.

Table B5.2

	z_c (m)	$z_c/4$ (m)	$z_c/4$ (m)
5m x 5m heat source	5.8	1.4	0.4
30 m x 30 m heat source	24.3	6.1	1.5

To assess the impact of grid size on simulation results, fires measuring 5 x 5 meters and 30 x 30 meters were simulated using grid sizes of 0.5 meter, 1.0 meter, and 1.5 meter. The mean heat fluxes and their corresponding standard deviations from the simulations for each heat source size are presented in *Figure B5.5*. Due to significant fluctuations in heat fluxes near the heat source, no notable effect of grid resolution was observed at distances less than 30 m. However, at 40 meters and 80 meters, the effect became more apparent, particularly for the 1.5 meter grid size compared to the smaller grid sizes. Based on these findings, a grid cell size of 1.0 meter was selected for subsequent simulations.

Another important factor influencing the simulation results is the size of the fire. Since HRRPUA (Heat Release Rate Per Unit Area) is the primary input, larger fire sizes result in higher total HRR and consequently greater heat fluxes in front of the fire. To optimize computational resources, it is desirable to simulate the smallest possible fire size that still provides realistic results for the intended scenario.

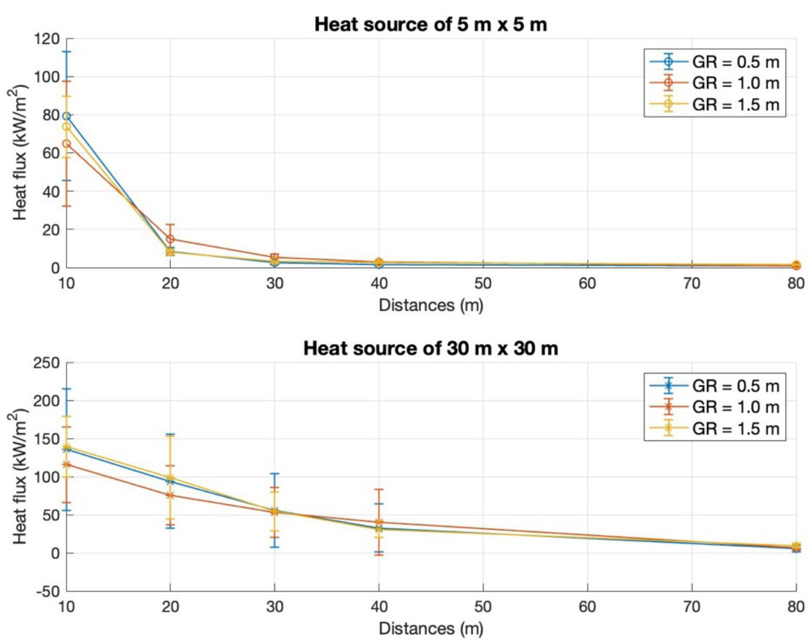


Figure B5.5. Mean heat flux results for varying grid cell sizes as a function of distance.

The effect of fire size was examined during the sensitivity analysis. *Figure B5.4a* shows the mean heat fluxes at various distances from the fire front as a function of FD with a fixed fire width (FW) of 10 meters. For locations closer to the fire front (less than 30 meters), no clear trend is observed, and the mean heat fluxes vary significantly as FD changes. However, this region is not the focus of this study, as structural ignition is assumed to occur in this zone due to proximity to the flame. The area of interest lies where heat flux values approach the ignition threshold of 13.1 kW/m^2. This region is highlighted in *Figure B5.6b*, where it can be observed that changes in HF have become less significant as FD increases. In fact, the difference in HF values calculated for FD = 30 meters and FD = 40 meters is less than 1%. A similar trend is observed when heat fluxes are evaluated as a function of fire width (FW) with a fixed FD. Based on these findings, a fire source measuring 30 x 30 meters is used in this study.

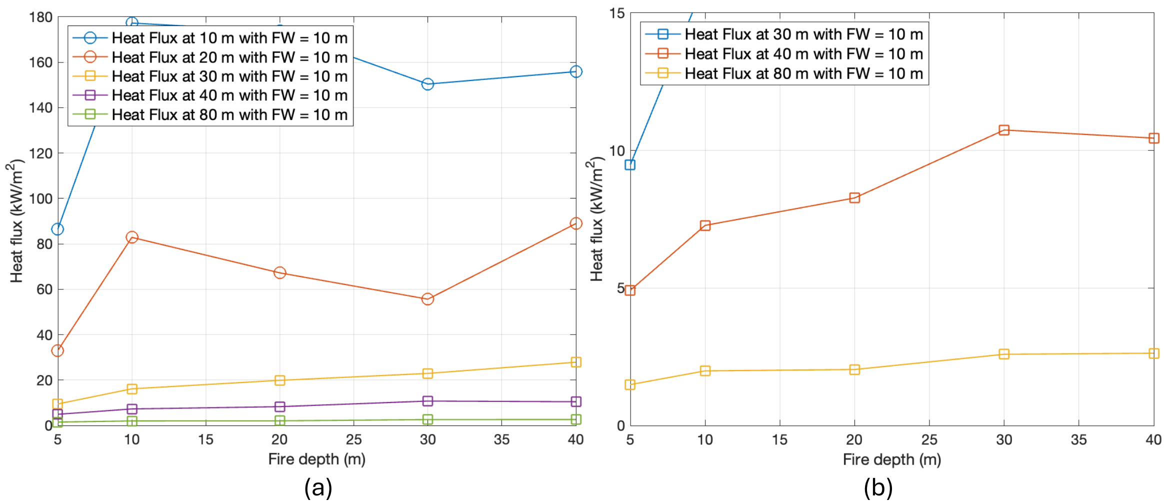


Figure B5.6. Mean heat fluxes at different distances from the fire front as a function of the fire depth (FD) considering a fire width of 10 m.

B5.3 Structural fuel fire intensity analysis

Structures are considered a non-burnable object in the *LANDFIRE* dataset, requiring an independent analysis from vegetative fuels. Burning structures can produce high radiant heat fluxes, large flames, and large embers capable of supporting extreme fire behavior and are an important exposure consideration for the defined *neighborhood*. However, there is a significant research gap in understanding the bounds of the potential exposures from burning structures in wind-driven fires, especially in extreme fire weather conditions. The variability of structure geometry and composition, complex fire dynamics, and scale of wind-driven structure fires are key challenges in the analysis of these potential exposures.

Research on building-to-building fire spread has predominantly relied on reduced-scale experiments (Narayanan et al. 2022) or on numerical, stochastic, and physics-based modeling approaches (Huang 2020; Masoudvaziri et al. 2021; Himoto and Tanaka 2008; Cheng 2011; Purnomo Dwi et al. 2024). Experimental investigations addressing fire spread between buildings, specifically considering flame radiation through openings during internal fires, are relatively scarce (Yuen et al. 2021; Lee et al. 2009; Maranghides and Johnsson 2008). In contrast, during wildfires, entire *structures* can become fully engulfed in flames and subjected to elevated wind speeds, resulting in significantly different fire dynamics and exposure risks to adjacent buildings. Research focusing on fire spread from fully engulfed *structures* to nearby buildings, particularly under high wind conditions, remains limited.

To address this research gap and improve our understanding of wind-driven building-to-building fire spread and verify if small-scale experiments still hold up in a more realistic scenario, a series of fire exposure experiments were conducted between sheds and *structures* at *IBHS*. In the shed experiments, 15 UL 711 Class 1-A – 6-A wood cribs were placed inside a 12 x 24 foot shed, and the spread of the fire, heating rate, and damage modes to a 30 x 40 x 16 foot building were monitored. Currently, *IBHS* is working on another series of experiments between *ADU's* and structures. The *ADU's* contain household fuels and are internally finished to include the impact of fire development in a multicompartment *structure* from internal and external ignitions.

In the initial structural fuel fire intensity analysis, the potential impact of structural fuels are considered through a point source radiant heat calculation as indicated in *Equation B5-3* (Himoto 2023) utilizing heat release rates from literature and experiments at *IBHS*, and cross referenced with experimental heat flux and flame length measurements at *IBHS*.

$$\dot{q}_r'' = \frac{\chi_R \, HRR}{4\pi R^2} \qquad \textit{Equation B5-3}$$

Where X_R is the radiative fraction, *HRR* is the heat release rate of the fire, and *R* is the distance from the source to the target. The radiative fraction X_R is assumed to be 0.3 for these calculations (Himoto 2023). An analysis of the potential of direct flame contact and convective heating due to plume dynamics is not yet considered in this analysis. Flame shape and plume dynamics of multicompartment fires under wind driven conditions are not well understood and were considered beyond the scope of the capabilities of this document until a better understanding of the problem is established. However, to provide a conservative analysis that does not dismiss the contributions of these heat transfer mechanisms, the measured total heat fluxes at *IBHS* for wind-driven experiments are incorporated in this analysis, shown in *Figure B5.5* and discussed in more detail later in this section.

Heat release rates for *structure* fires are limited in the literature. Values from studies with a variety of compartment sizes and fuel conditions are considered as well as computational fluid dynamic method utilized by Purnomo DM et al. (2024) shown in *Table B5.6*. These HRR and the resulting heat flux exposures determined using *Equation B5-3* are shown in *Figure B5.5*.

Table B5.6 Heat release rates from available literature.

Type	**Building Type/ Size (m^2)**	**Size (m^2)**	**Peak HRRPUA (kW/m^2)**	**Peak HRR (MW)**
Experimental Measurement IBHS	Shed w/ Wooden Cribs	26.8	2238	60
*Experimental Measurement**	Residence	8.64	255	2.2
*FDS Simulation 1**	Residence	174	575	100
*FDS Simulation 2**	Residence	109.2	687	75
*FDS Simulation 3**	Residence	14.4	1014	14.6

Type	Building Type/ Size (m²)	Size (m²)	Peak HRRPUA (kW/m²)	Peak HRR (MW)
Experimental Measurement NIST	Unfinished Residence (OSB & 2x4)	12	1816	21.8
Experimental Measurement FM Global	Residence	28.06	470.4	13.2

*Adapted from Jiang et al. (2021).

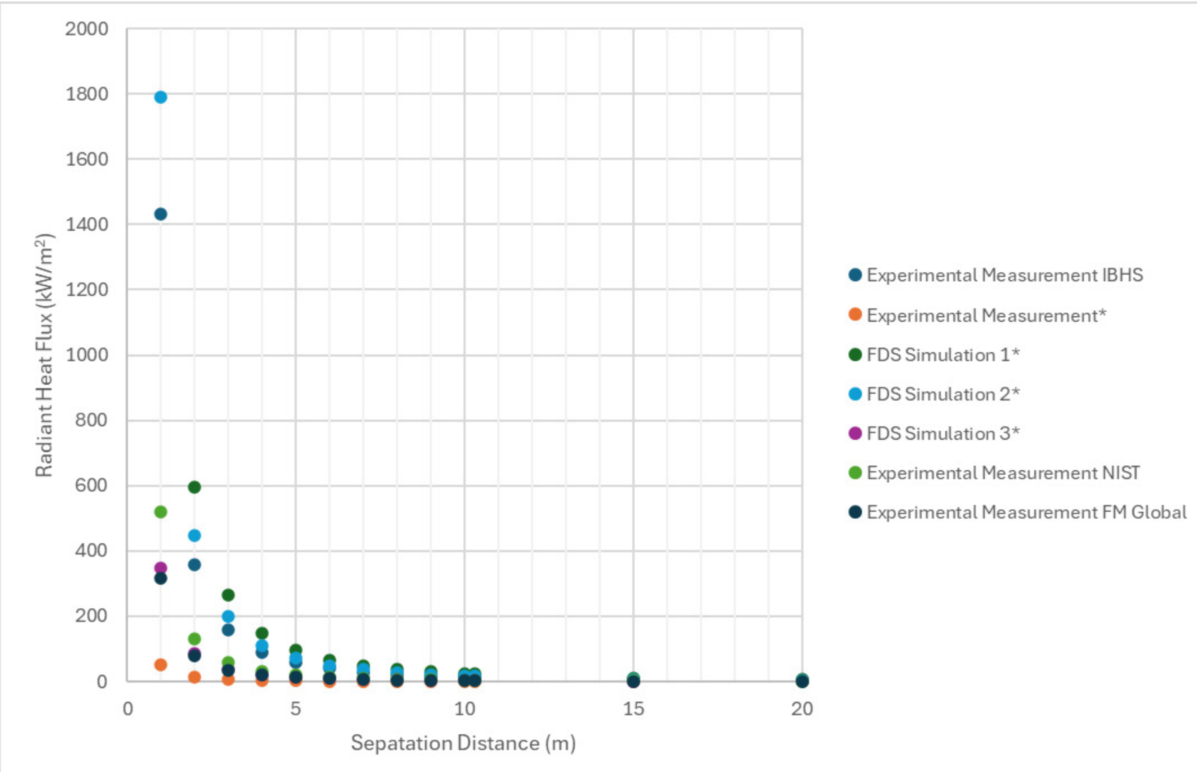


Figure B5.5. Plot of calculated radiant heat fluxes at varying distances using Equation B5-3 and Heat Release Rates for structures from literature and measurements at IBHS.

These calculated radiative heat flux values were compared to total heat flux measurements taken at *IBHS* during wind driven shed experiments at 20, 30, and 60 mile per hour wind speeds. It is known the wind component of the experiments at *IBHS* will have a significant impact of the resulting total heat flux measured downstream due to changes in the burning rate, flame stretch, flame tilt, and plume dynamics depending on the magnitude of the wind speed. The complexity of incorporating theses impacts characteristic of wind-driven fire is beyond the current capabilities of this standard and instead, measurements from experiments at *IBHS* are used to ensure that the methods applied in this standard are sufficient for the potential exposure. In *Figure B5.6* the maximum and minimum fire sources are shown with a power fit, bounding the radiant heat fluxes calculated using the estimated fire sizes in *Table B5.6* and *Equation B5-3*. *IBHS* experiments with wind speeds between 20 and 30 mph are labeled as "*IBHS* Wind Driven Fire Shed Tests" while the 60 mph tests are labeled as "*IBHS* Extreme Wind Driven Fire Tests" in *Figure B5.7*.

IBHS wind driven fire shed tests fall generally within the two HRRs considered aside from measurements at lower *structure separation* distances that are more impacted by the wind component of the test and likely convective heat flux not considered in *Equation B5-3,* however, none of the *IBHS* extreme wind driven fire tests fall within the estimate by *Equation B5-3.* The result suggests the 70-mph gust wind speed, set as the design wind speed for this standard, would have led to an underestimation of the exposure heat flux. The high wind speed impacts the fire by stretching the flame closer to the target, increasing the fire intensity significantly, and introducing a convective heating component not considered in *Equation B5-3,* or a combination of these.

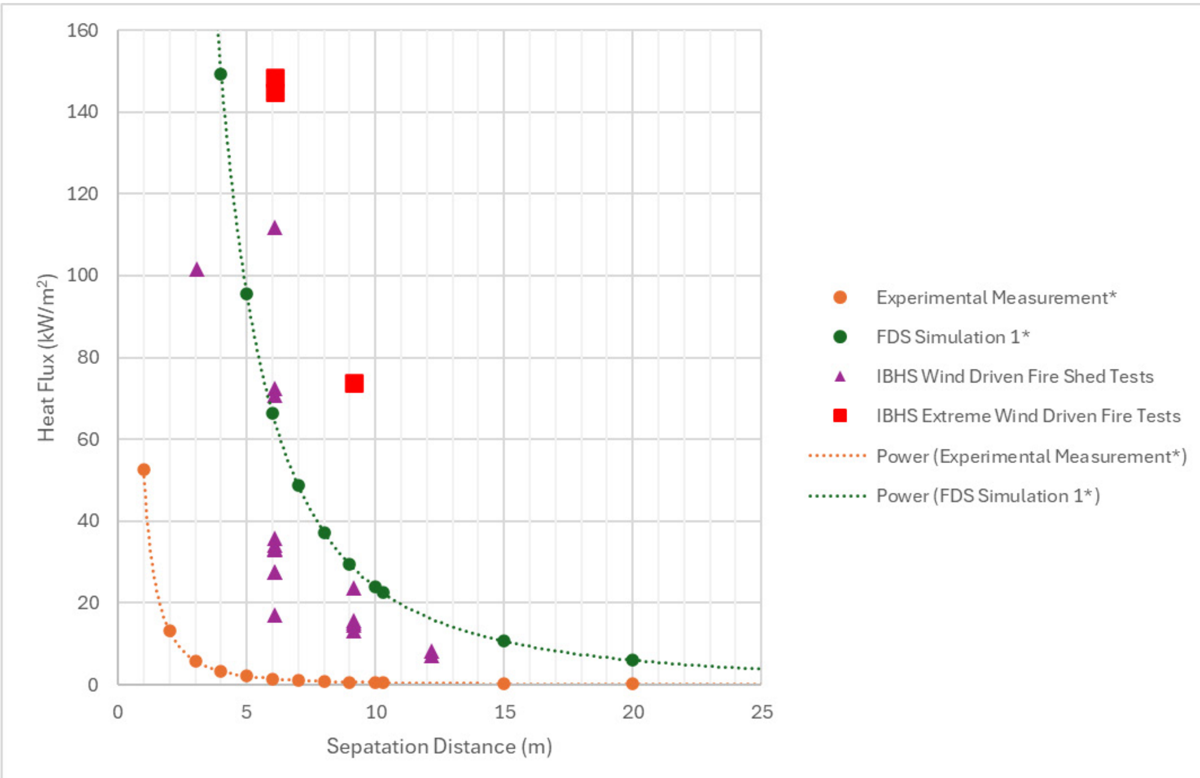


Figure B5.6. Maximum and minimum calculated radiant heat fluxes from Figure B5.5 and measured total heat fluxes from wind driven structure-to-structure fire spread experiments at IBHS.

To account for this underestimation, and to provide a conservative estimate for heating in the extreme wind-driven fire scenario, an effective HRR is determined. The effective HRR is calculated utilizing the measured heat fluxes in the extreme wind-driven fire tests and *Equation B5-3.* A heat release rate of 258 MW is determined using the maximum heat flux measurement from the extreme wind driven fire tests using *Equation B5-3.* Calculated heat fluxes using *Equation B5-3* considering a heat release rate of 258 MW are plotted in *Figure B5.7.*

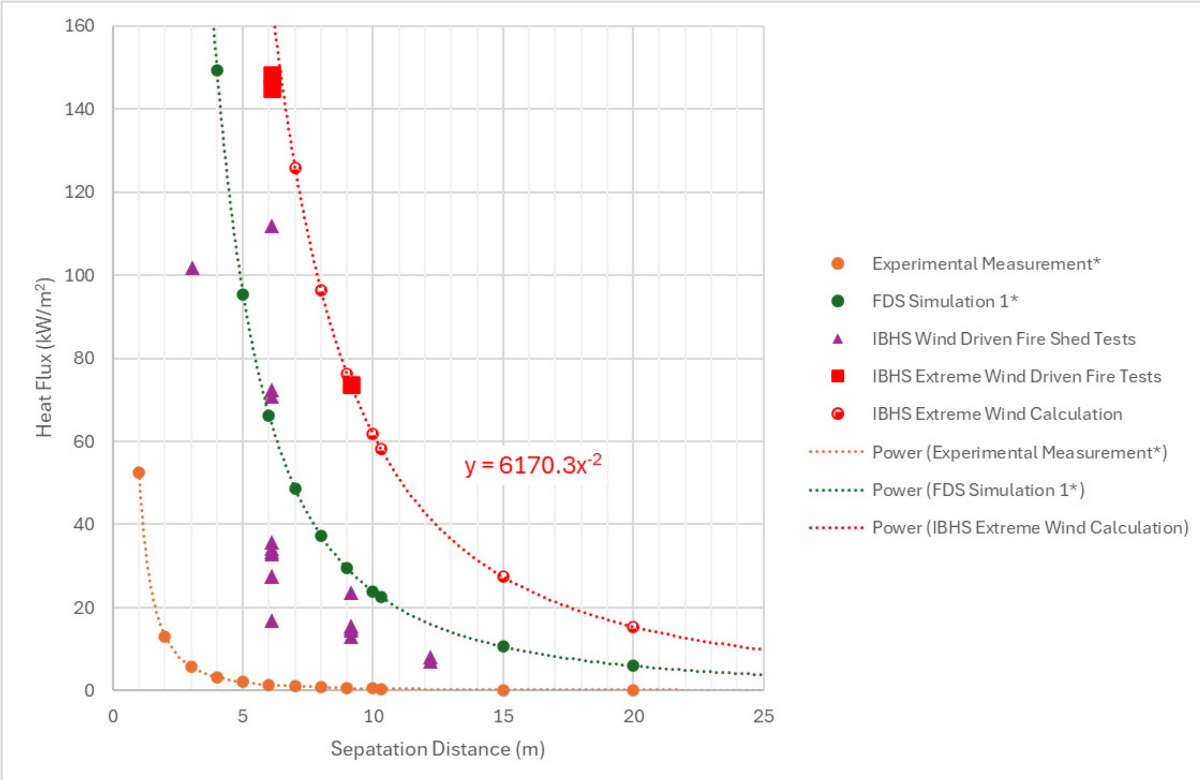


Figure B5.7. IBHS Extreme Wind-Driven Fire Shed Tests experimental measurements of total heat flux and associated curve fit using Equation B.5-3 to estimate the point exposure radiant heat flux, shown as a function of separation distance.

The curve fits for these heat fluxes provides a conservative estimate of distance in which *structures* require mitigation measures due to structural fuels outside the defined *neighborhood*. Solving for the threshold/design level heat flux of 13.1 kW/m^2, a *neighborhood flame zone* distance of 21.7 meters (71 feet) is used for structural fuels.

B5.4 Mitigation provisions for flames and radiant heat

While embers can ignite sporadic spot fires within communities, rapid fire spread from building to building occurs when spot fires grow and engulf *structures*. During such events, towering walls of flame can be driven by the wind, extending beyond the *structure separation* distance between homes and potentially causing direct flame contact. Furthermore, urban ladder/connective fuels—such as vehicles, sheds, fences, and vegetation—can ignite and contribute to the intensity and reach of the flames. As a result, *structures* at risk of direct flame contact must be hardened to withstand low to moderate heat exposure, which is the primary objective of the *IBHS WFPH Plus* requirements.

To achieve this, all primary vertical surfaces of the *structure*, including siding, windows, and exterior doors, should meet the highest fire resistance standards. It is also crucial to remove back-to-back fence rows, as they can facilitate fire spread between *parcels*. Additionally, the eaves and areas beneath bay windows should be enclosed to minimize heat accumulation in these zones. Deck assemblies should either be constructed from noncombustible materials or designed with solid walking surfaces that contain no gaps, further enhancing the home's fire resilience.

B6 *Neighborhood ember zone*

During wildland and WUI fires, numerous *firebrands* (the term embers is used interchangeably with the term *firebrands*)—flaming, glowing, or smoldering—are generated and transported by the fire's convective column and/or wind. Spotting consists of three key processes: generation, transport, and deposition. The likelihood of spot fires depends on fire intensity, ember properties, environmental conditions, and the characteristics of the fuel in which they land on (Filkov et al. 2023).

Fire intensity, driven by the interaction of fuel and local weather, is influenced by factors such as fuel load, wind speed, topography, and humidity. These elements determine the upward velocity of embers, with spotting distance largely dependent on fire intensity, wind conditions, and ember shape. A strong convective column lifts embers to a height where it descends as free-falling particles under wind influence. Disruption of the convective column by wind shear or premature ejection of embers can result in shorter-range spotting (Wadhwani et al. 2022).

Short-range embers, traveling less than 0.5 miles, are typically carried and/or tumbled by the wind rather than the fire plume, moving both vertically at times and/or horizontally over the ground. The travel distance is influenced by wind conditions, topography, and the type of burning material from which it originates. These embers often retain significant unburned material. Long-range ember transport, in contrast, are embers traveling substantial vertical and horizontal distances. These are lofted by the strong rising air associated with the fire's plume and tend to be less uniform in their dispersion. Several studies have attempted to model this phenomenon; however, the predicted long-range spotting distances in these models are often conservative. This is largely due to simplifying assumptions as there remains substantial gaps in the knowledge about the overall ember size distributions, their mass–diameter relationships, shape distributions, and overall aerodynamic properties.

B6.1 Ember characterization and transport

Several ember transport models have been developed to capture the complex behavior of embers and the environmental factors influencing their spread. Some models, particularly computational fluid dynamics (CFD)-based models, simulate the detailed physical processes of ember generation, lofting, and transport, accounting for convective currents, wind, and ember mass loss over time. While these models offer valuable insights into the interactions between embers, airflow, structures, and topography, it is computationally intensive.

These ember transport models share similar limitations, largely due to simplifying assumptions that affect predicted spotting distances. For instance, models often assume uniform wind profiles, disregarding natural fluctuations in wind speed and direction, which can significantly reduce ember travel. They also idealize ember properties, assuming fixed shapes (often spherical), constant mass with no mass loss during flight, and travel at terminal velocity. Additionally, steady heat conditions are commonly presumed, overlooking environmental cooling effects that can extinguish embers mid-flight. These models also assume unobstructed landscapes, omitting barriers such as vegetation, buildings, and varied topography that would hinder ember movement. Many models further exclude key factors like specific fuel types, detailed atmospheric conditions, and the true strength of the convection column, which influences terminal and initial vertical velocity. Together, these limitations often lead to conservatively large but comparable spotting distance outputs across models. For practical applications such as this standard, simpler, more efficient models are preferred. Applied ember transport models generally rely on statistical or empirical methods to represent ember generation, lofting, and spread over larger scales. Commonly used models include the McArthur (1967), Tarifa et al. (1965), Albini et al. (2012), and Himoto and Iwami (2021) models, each providing similar final transport distances.

McArthur (1967) developed a model for the maximum spotting distance in eucalypt forests, focusing on long-range *firebrand* transport, based on factors such as fire spread rate and fuel load. This model is derived by combining equations that describe the terminal velocity of *firebrands* during flight with models of lofting mechanisms and ambient wind conditions.

$$Average\ max\ spotting\ distance = rate\ of\ spread(4.17 - 0.033\ fuel\ load) - 0.36 \qquad \textit{Equation B6-1}$$

Tarifa et al. (1965) developed a model to estimate ember trajectory of burning wood particles of spherical and cylindrical shapes, representing embers. The particles were ignited and tested at their terminal velocity in horizontal and vertical wind tunnels. A differential equation was formulated using experimental data to predict the change in firebrand radius over time, which is essential for estimating both the flight duration and the time required for vertical ascent. The output of this model is depicted in *Figure B6.1.* One major challenge in this process was the particles typically break during flight and the validity range for the developed relation is not accurate at smaller sizes (Tarifa et al. 1965).

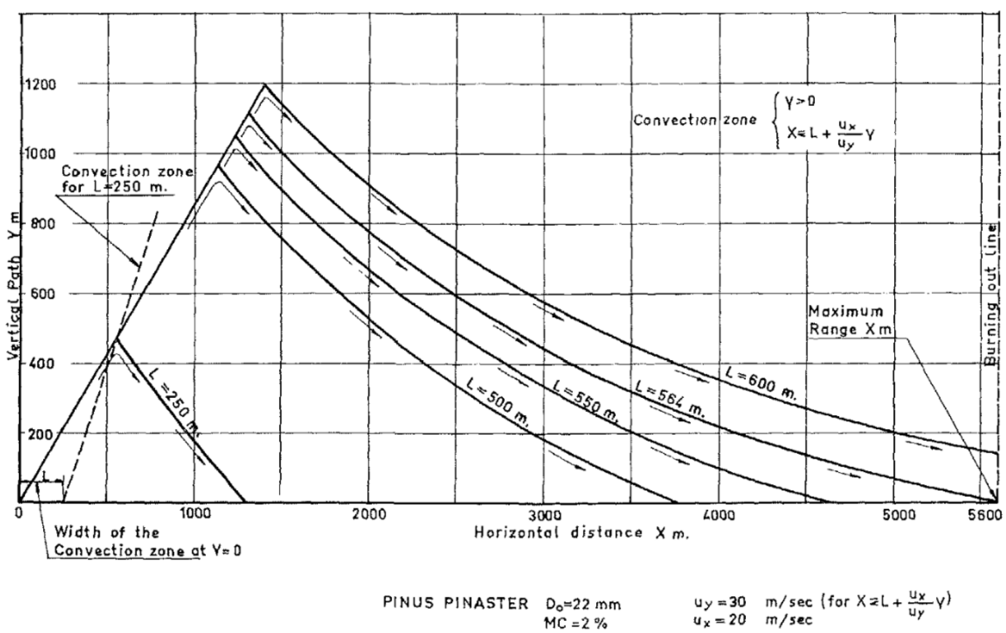


Figure B6.1. Flight paths of spheric firebrands (embers). Inclined convection column model. The initial position of the firebrands on the ground is fixed. From Tarifa et al. (1965).

Albini et al. (2012) developed a semi physical model to estimate the maximum spot fire distance from an active crown fire. This distance is based on flame height above the canopy, wind speed at canopy-top level, and the final size of the ember, represented by the diameter of a woody char cylinder. The model includes several components: a wind-blown flame front model, a two-dimensional buoyant plume model, a logarithmic wind speed profile with height, and an empirical model for the burning rate of a wooden cylinder (the *firebrand*). The ember's trajectory is calculated from its departure from the plume to its re-entry at the canopy, with the spotting distance depending on the ember's final diameter.

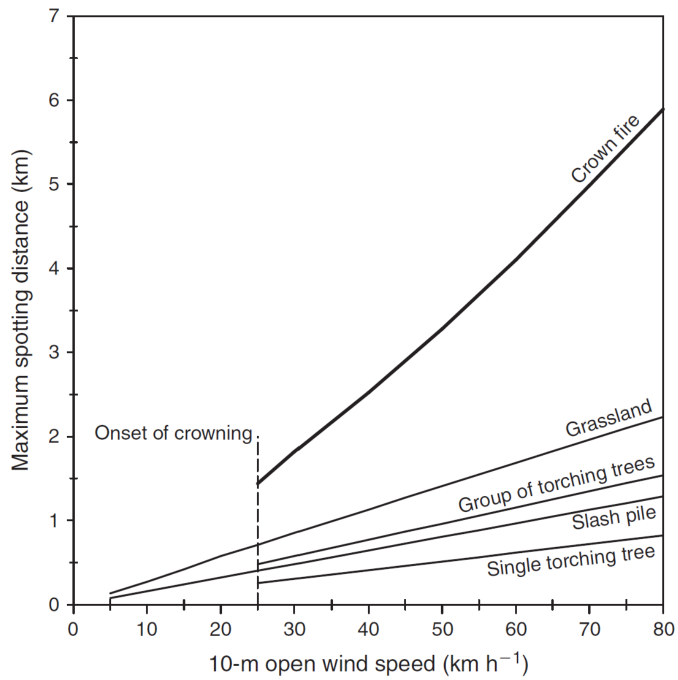


Figure B6.2. Comparison of model predictions for maximum potential spotting distance over level terrain as a function of wind speed for a specified set of burning conditions. From Albini et al. (2012).

Himoto and Iwami (2021) conducted a series of wind tunnel experiments to investigate the probabilistic variations in two of the three processes involved in spot ignition—*firebrand* generation and transport. The key variables studied were the ember ejection height (*H*), crosswind velocity (U_∞), and the thickness of the wood sticks used to construct the crib (*d*). Based on the experimental data, the projected area of embers and their downwind transport distances were modeled using simple physical principles. *Figure 3.7* illustrates the inputs for this model and the forces acting on embers. This includes: the ejection velocity, drag, gravitational forces, wind speed, and ejection height.

Himoto and Iwami's (2021) model was selected due to its simplicity in fuel characterization, allowing it to be used across different fuel assessment data sources and it offers a probabilistic approach. The probabilistic approach provides the opportunity to set a design level based on uncertainty in other elements of the standard through proper engineering judgement.

The following discussion outlines the ember transport calculation details used in this standard to ensure reproducibility. Relevant parameters in the Himoto and Iwami (2021) model are depicted in *Figure 3.7* in *Chapter 3*, *Section 3.4*. The constant values used in this standard are presented in *Table B6.1*. The ejection height was assumed to be equal to the fuel height, and all embers were considered to have a diameter of 1 cm. For the building fuel diameter, the equivalent hydraulic diameter of a rectangular (3.6 x 7.3 meters) was utilized. The values for heat release rate are the peak values reported for grass, for trees, and for buildings (sheds) (Overholt et al. 2014; Manzello et al. 2007; Maranghides et al. 2022). Accurately estimating the heat release rate of full-scale fires under windy conditions remains extremely challenging. Only a few studies have attempted to estimate the heat release rate of burning trees and grass. Since the heat release value for buildings is not available, a shed was used as a substitute.

Table B6.1. Constant values used in Himoto and Iwami (2021) model.

Parameter	**Grass**	**Tree**	**Buildings**
Ejection Height	1.5 m	3.45 m	3.45 m
Inflow Velocity		13,22,30 ms^{-1}	
Ember Diameter		1 cm	
Fuel Diameter	50 cm	225 cm	487 cm
Heat Release Rate	0.15 MW	7.5 MW	20 MW
Gravity		9.8 ms^{-2}	

The lognormal distribution has been widely applied to model *firebrand* dispersion in windy conditions.

$$P(x_p|\lambda,\vartheta) = \frac{1}{\sqrt{2\pi}\vartheta x_p} e^{\left(\frac{-1}{2}\left(\frac{\ln x_p - \lambda}{\vartheta}\right)^2\right)}$$ *Equation B6-2*

$$\mu = \ln\left(\frac{\mu_x}{\sqrt{1+\frac{{\sigma_x}^2}{{\mu_x}^2}}}\right)$$ *Equation B6-3*

$$\vartheta = \sqrt{\ln\left(1+\frac{{\sigma_x}^2}{{\mu_x}^2}\right)}$$ *Equation B6-4*

Where μ and ϑ are mean and standard deviation respectively. By analyzing the deposition distribution of *firebrands* from a full-scale burn experiment of a three-story wooden building, Hayashi et al. (2014) derived the following relationships for the mean and standard deviation.

$$\frac{\mu_x}{d} = 41.0\hat{B}^{1.06}$$ *Equation B6-5*

$$\frac{\sigma_x}{d} = 4.52$$ *Equation B6-6*

$$\hat{B} = \left(\frac{U_\infty U_0}{g\sqrt{dd_p}}\right)^2 \left(\frac{\rho_\infty}{\rho_p}\right)\left(1+\sqrt{1+\frac{2gH}{{w_0}^2}}\right)^2$$ *Equation B6-7*

Here, $\hat{B}$ governs the deposition behavior and is derived from embers with a diameter d_p, ejected from a fire with a height H and a vertical velocity w_0, subjected to drag forces caused by a crosswind with speed U_∞ , $\hat{B}$ can be viewed as the Froude number modified by the density ratio and initial effects of ejection velocity. The theoretical model for turbulent diffusion flames developed by Baum and McCaffrey (1989) was used to calculate the ejection velocity for intermittent flames.

$$w_0 = 1.85\dot{Q}^{1.5}$$ *Equation B6-8*

Where $\dot{Q}$is the heat release rate of the fire, listed in *Table B6.1*. By applying *equation B6-8* along with the values provided in *Table B6.1*, the ejection velocities obtained would be 5.04 m/s for grass embers, 11.02 m/s for tree embers, and 13.41 m/s for building embers. Applying these ejection velocities in *equations B6.2-7* and using the constants listed in *table B6.1*, the reported traveling distance for different embers could be obtained. It is important to note that this approach generates a probability distribution, allowing the integral of the probability density function to be used for calculating the cumulative density function. For the *IBHS Wildfire Prepared Neighborhood Standard*, the 80th percentile threshold was selected for use in this standard. *Figure B6.4* illustrates the cumulative density function for grass embers at three different wind speeds and serves as an example of this approach.

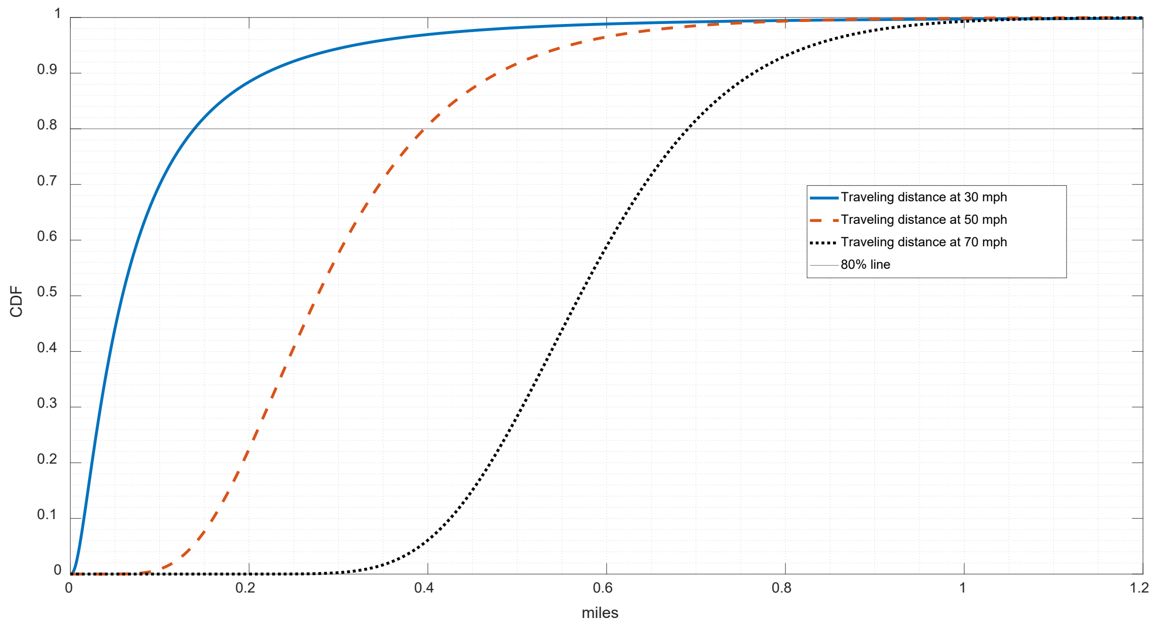


Figure B6.3 Estimated cumulative distribution function (CDF) of transport distance of firebrands from grass, based on parameters listed in Table B6.1

B6.2 Ember mitigation provisions

During wildfires, flying embers, along with wind-blown, ground-traveling burning debris, are the most common mechanisms that ignite *structures*, either directly or indirectly. Direct ignition occurs when embers land and accumulate on combustible building materials or enter through openings to ignite interior components. Indirect ignition happens when embers accumulate on nearby combustibles, igniting them and subsequently causing flames to reach the building through radiant heat or direct contact. While these spot fires typically burn with lower intensity than the main fire front, they can still spread to nearby *structures* under favorable conditions. Notably, only tall, thick flames can radiate enough heat to ignite *structures*; smaller flames must be in proximity or in contact to cause ignition.

Although experimental and numerical studies on ember storms in the *wildland-urban interface* (WUI) exist, predicting ember paths and accumulation locations remain challenging. During flight, embers follow unpredictable trajectories influenced by building features and environmental factors. The geometric characteristics of buildings, community density, and the nature of receptive fuel beds, along with the shape of the embers, their source fuel, and local wind patterns—especially coherent features at both meso- and microscales —affect ember accumulation. This complex thermal exposure necessitates systematic fuel management and home hardening strategies to mitigate the ignition probabilities of *structures*. In the *WUI*, ember-caused spot fires can use vulnerable *structures* as fuel, potentially escalating into tall flames and producing localized extreme fire behavior that threatens neighboring *structures*. While it may be possible to identify likely ignition pathways for an isolated *structure* during an ember storm, the chaotic accumulation patterns in communities complicate the identification of specific vulnerable components in any given *structure*. Recognizing these complexities, a systematic and comprehensive hardening approach is essential to protect homes and their immediate surroundings against known vulnerabilities, which is the design performance criteria for the *IBHS WFPH Base* level of protection. This includes the requirement for a well-maintained Class A roof and the necessity for all vents to have mechanisms that minimize ember entry into the building. The *structure*'s footprint should provide a 6-inch noncombustible vertical clearance to reduce direct contact between rolling, burning debris and any combustible exterior wall components. To mitigate the risk of indirect ember ignition, it is essential to maintain *defensible space*, with particular focus on the development and upkeep of a *0–5 Foot Noncombustible Zone*.

B7 Appendix specific references

Albert, C.M. and K.C. Liew. (2023). Recent development and challenges in enhancing fire performance on wood and wood-based composites: A 10-year review from 2012 to 2021. *J. Bioresources Bioproducts,* **9**, 27-42. https://doi.org/10.1016/j.jobab.2023.10.004.

Albini, F. A., M. E. Alexander, and M. G. Cruz. (2012). A mathematical model for predicting the maximum potential spotting distance from a crown fire. *Int. J. Wildland Fire,* **21.5**, 609-627.

American Society of Civil Engineers. (2022). Minimum design loads and associated criteria for building and other structures. ASCE/SEI 7-22, 1046 pp.

American Society for Testing and Materials. (2020). Standard Test Methods for Fire Tests of Roof Coverings.

Baum, Howard R. and B. J. McCaffrey. (1989). Fire induced flow field-theory and experiment. *Fire Safety Science,* **2**, 129-148.

Bryner, S. L. (2000). Fifteenth Joint Panel Meeting of the UJNR on Fire Research and Safety. N. 6588.

Bu, R., Y. Zhou, L. Shi, and C. Fan. (2021). Experimental study on combustion and flame spread characteristics in horizontal arrays of discrete fuels. *Combustion and Flame*, **225**, 136-146

Butler, B., R. Parsons, R., and W. Mell. (2015). Recent findings relating to firefighter safety zones. In *In: Keane, Robert E.; Jolly, Matt; Parsons, Russell; Riley, Karin. Proceedings of the large wildland fires conference;* May 19-23, 2014; Missoula, MT. Proc. RMRS-P-73. Fort Collins, CO*: US Department of Agriculture, Forest Service, Rocky Mountain Research Station,**73**, 30-34.*

Cheney N.P., J.S. Gould, and W.R. Catchpole. (1998) Prediction of fire spread in grasslands. *International Journal of Wildland Fire,* **8**, 1–13. doi:10.1071/WF9980001.

Cheng, C. (2011). Study on forest fire induced breakdown of 500 kV transmission line in terms of characteristics and mechanism. E*nviron. Sci. Eng*.

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

Cohen, J. D. (2004). The International Crown Fire Modelling Experiment (ICFME) in Canada's Northwest Territories: Advancing the Science of Fire Behaviour. *Canadian Journal of Forest Research*, **34**, 161–173. https://doi.org/10.1139/x03-193.

Cohen, J. D. (2004). Relating flame radiation to home ignition using modeling and experimental crown fires. *Canadian Journal of Forest Research,* **34**, no. 8, p.1616-1626.

Davis, J. B. (1990). The wildland-urban interface: paradise or battleground*? J. Forestry*, **88**(1), 26- 31.

Despain, D. G., D. L. Clark, and J. Reardon. 1996. Simulation of crown fire effects on canopy seed bank in lodgepole pine. *International Journal of Wildland Fire,* **6**, 45–49.

Di Cristina, G., S. Kozhumal, A. Simeoni, N. Skowronski, A. Rangwala, and S.K. Im. (2021). Forced convection fire spread along wooden dowel array. *Fire Safety Journal*, **120**, 103090.

FEMA. (2023). Mitigation Assessment Tean Report Marshall Fire Building Performance, Observations, Recommendation and Technical Guidance. *FEMA P-320*, Technical Report, 160 pp.

Filkov, A. I., et al. (2023). A review of thermal exposure and fire spread mechanisms in large outdoor fires and the built environment. *Fire safety journal, 103871*.

Foote, E., Liu, J., and S.L. Manzello. (2011). Characterizing firebrand exposure during wildland urban interface fires. *Proceedings of Fire and Materials Conference*, Interscience Communications, London.

Garner, J.M. and C.E. Kovacik. (2022). Extreme wildfire environments and their impacts occurring with offshore-directed winds across the Pacific Coast States. *Wea. Climate. Soc.*, **15**, 75-93.

Giammanco, I.M., F. Hedayati, S.R. Hawks, X. Sanchez Monroy, and E. Sluder. (2023). The return of conflagration in our built environment. *Insurance Institute for Business & Home Safety*, Technical Report, 40 pp.

Hayashi, Y., et al. (2014). Firebrand deposition and measurements of collected firebrands generated and transported from a full-scale burn test using a large wooden building. *AIJ Journal of Technology and Design* **20** (45), 605-610.

Hedayati, F., X. Sanchez Monroy, E. Sluder, H. Fallahian, and M. Shabanian. (2024). The 2023 Lahaina conflagration. *Insurance Institute for Business & Home Safety*, Technical Report, 69 pp.

Himoto K. and T. Tanaka. (2008) Development and validation of a physics based urban fire spread model. *Fire Safety Journal*. **43**, 477-494. https://doi.org/10.1016/j.firesaf.2007.12.008.

Himoto, K., and T. Iwami. (2021). Generalization framework for varying characteristics of the firebrand generation and transport from structural fire source. *Fire safety journal* **125,** 103418.

Himoto, K. (2023). Large outdoor fire dynamics. *CRC Press*, 1st ed. Boca Raton, FL, 393 pp.

Huang, Q., A. Razi, F. Afghah, and P. Fule. (2020) Wildfire spread modeling with aerial image processing. *2020 IEEE 21st International Symposium on "A World of Wireless, Mobile and Multimedia Networks"* (WoWMoM), Cork, Ireland, 2020, pp. 335-340. doi: 10.1109/WoWMoM49955.2020.00063.

Hurley, M. J., D. T. Gottuk, J. R. Hall Jr, K. Harada, E. D. Kuligowski, M. Puchovsky, J. M. Watts Jr and C. J. Wieczorak. (2015). SFPE handbook of fire protection engineering, Springer Inc. 3546 pp.

Insurance Institute for Business & Home Safety. (2020). California Wildfires of 2017 and 2018. Technical Report, 17 pp. https://ibhs.org/wp-content/uploads/member_docs/camp-fire-report_ibhs-1.pdf.

Insurance Institute for Business & Home Safety. (2021). Suburban Wildfire Adaptation Roadmaps. Technical Report, 52 pp. https://ibhs.org/wp-content/uploads/member_docs/ibhs-suburban-wildfire-adaptation-roadmaps.pdf.

Jiang, W., Wang, F., Fang, L., Zheng, X., Qiao, X., Li, Z., Meng, Q. (2021). Modelling of wildland-urban interface fire spread with the heterogeneous cellular automata model. *Environmental Modelling & Software*, Volume 135, 2021, 104895, ISSN 1364-8152, https://doi.org/10.1016/j.envsoft.2020.104895.

Koo, J.H., W. Wootan, W.K. Chow, H.W.A, Yeung, and S. Venumbaka.(2001). Flammability studies of fire-retardant coatings on wood. *Fire and Polymers,* ACS Symposium Series, American Chemical Society, Washington, DC, 2001, **797**, 361–374.

Kremens, R.L., M.B. Dickinson, and A.S. Bova. (2012). Radiant flux density, energy density, and fuel consumption in mixed-oak forest surface fires . Int. J. Wildland Fire, **21,** 722– 730.

LANDFIRE. (n.d.). *Fuel*. U.S. Department of the Interior & U.S. Forest Service. Retrieved November 26, 2024, from https://landfire.gov/fuel.

Lareau, N.P., N.J. Nauslar, and J.T. Abatzoglou. (2018) The Carr Fire vortex: A case of pyrotornado genesis. *Geo. Phys. Res. Lett.*, **45**, 107-113. https://doi.org/10.1029/2018gl080667.

Lee, S.W., M.B. Lee, Y.G. Lee, M.S. Won, J.J. Kim, and S.K. Hong. (2009) Relationship between landscape structure and burn severity at the landscape and class levels in Samchuck South Korea. F*orest Ecol. Manage.*, **258**, 1594-1604. https://doi.org/10.1016/j.foreco.2009.07.017.

Manzello, S. L., et al. (2007). Measurement of firebrand production and heat release rate (HRR) from burning Korean pine trees. *Fire Safety Science,* **7**, 108.

Maranghides, A. and E.L. Johnson. (2008) Residential structure separation fire experiments. *National Institute of Standards and Technology*, NIST Technical Note 1600, US Department of Commerce, 42 pp. https://doi.org/10.6028/NIST.TN.1600.

Maranghides, A. (2022). Structure Separation Experiments: Shed Burns without Wind. *National Institute of Standards and Technology*, US Department of Commerce.

Maranghides, A., E.D. Link, S. Hawks, J. McDougald, S.L. Quarles, D.J. Gorham and S. Nazare. (2022). WUI Structure/Parcel/Community Fire Hazard Mitigation Methodology, *National Institute of Standards and Technology*, NIST Technical Note 2205, 77 pp. https://doi.org/10.6028/NIST.TN.2205.

Maranghides, A., D. McNamara, W. Mell, J. Trook, and B. Toman. (2013). A case study of a community affected by the Witch and Guejito Fires: Report# 2: Evaluating the effects of hazard mitigation actions on structure ignitions (NIST Technical Note 1796). National Institute of Standards and Technology

Masoudvaziri, N., F.J. Szasdi Bardales, O.K. Keskin, A. Sarreshtehdari, K. Sun, and N. Elhami Khorasani. (2021). Streamlined wildland-urban interface fire tracing (SWUIFT): modeling wildfire spread in communities, Environmental *Modelling and Software*, 143.

McArthur, A. G. (1965). Fire behaviour in Eucalypt forests. *9th Commonwealth Forestry Conference*, Australia Forestry and Timber Bureau, 35 pp.

McGrattan, K., B. Klein, S. Hostikka, and J. Floyd. (2008). Fire dynamics simulator (version 5), user's guide. *NIST special publication*, *1019*(6).

Menning, K. M., and S. L. Stephens. (2007). Fire climbing in the forest: a semiqualitative, semiquantitative approach to assessing ladder fuel hazards. *Western Journal of Applied Forestry*, **22.2**, 88-93.

Moore, H. (1981). Protecting residences from wildfires: a guide for homeowners, lawmakers, and planners. Gen. Tech. Rep. PSW-GTR-50. *U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station.*, 44. https://doi.org/10.2737/PSW-GTR-50.

Morandini, F., Y. Perez-Ramirez, V. Tihay, P.-A. Santoni, and T. Barboni. (2013). Radiant, convective and heat release characterization of vegetation fire. *Int. J. Therm. Sci.,* **70**, 83–91.

Narayanan, V., A. Cicione, A.D. Botha, and R.S. Walls. (2022) Reduced-scale experiments and numerical simulations of informal settlement dwelling fires. *Progress in Scale Modeling an International Journal*, **3** (1), https://doi.org/10.13023/psmij.2022.03-01-01.

Nguyen, D., and N.B. Kaye. (2021). Experimental investigation of rooftop hotspots during wildfire ember storms. *Fire Safety Journal*, **125**, 103445.

Parsons, R., B. Butler, and W. Mell, (2014). "Ruddy" Safety Zones and Convective Heat: Numerical Simulation of Potential Burn Injury from Heat Sources Influenced by Slopes and Winds; Imprensa da Universidade de Coimbra: Coimbra, Portugal; ISBN 978-989-26-0884-6.

Purnomo Dwi, M. J., Y. Qin, M. Theodori, M. Zamanialaei, C. Lautenberger, A. Trouvé, and M.J. Gollner. (2024) Integrating an urban fire model into an operational wildland fire model to simulate one dimensional wildland–urban interface fires: a parametric study. *International Journal of Wildland Fire,* **33***,* WF24102. https://doi.org/10.1071/WF24102.

Östman B. and L.D. Tsantaridis. (2016). Durability of the reaction to fire performance for fire retardant treated (FRT) wood products in exterior applications – a ten years report. MATEC Web of Conferences. **46**. 05005. 10.1051/matecconf/20164605005.

Overholt, K. J., J. Cabrera, A. Kurzawski, M. Koopersmith, and O.A. Ezekoye (2014). Characterization of fuel properties and fire spread rates for little bluestem grass. *Fire Technology,* **50**, 9-38. https://doi.org/10.1007/s10694-012-0266-9.

Quarles, S.L. and C. Standohar-Alfano. (2017). Performance of fire-retardant coatings used in exterior applications. *Insurance Institute for Business & Home Safety*, Technical Report, 46 pp.

Ramsay, G. C., N. McArthur, and V. Dowling. (1987). Preliminary results from an examination of house survival in the 16 February 1983 bushfires in Australia. *Fire and Materials*, **11**, 49-51.

Rothermel, R.C., (1972). A mathematical model for predicting fire spread in wildland fuels. Rocky Mountain Research Station. *United States Department of Agriculture*. Res. Pap. INT-115, 40 pp.

Scott, J. H., and R. E. Burgan. (2005). Standard fire behavior fuel models: A comprehensive set for use with Rothermel's surface fire spread model. *USDA Forest Service*, General Tech. Rep. RMRS-GTR-153, 72 pp., https://doi.org/10.2737/RMRSGTR-153.

Shields, W.M. (2008). Urban conflagrations in the United States, Society of Fire Protection Engineers, Technical Report, 28 pp.

Syphard, A. D., T.J. Brennan, J.E. and Keeley. (2014). The role of defensible space for residential structure protection during wildfires. *International Journal of Wildland Fire*, **23**, 1165-1175.

Tarifa, C. Sánchez, P. Perez Del Notario, and F. García Moreno. (1965). On the flight paths and lifetimes of burning particles of wood. *Symposium on combustion*. **10** (1). Elsevier.

Tihay, V., P.-A. Santoni, A. Simeoni, J.-P. Garo, and J.-P. Vantelon (2009). Skeletal and global mechanisms for the combustion of gases released by crushed forest fuels. *Combust. Flame* **156** 1565–1575.

Tihay, V., F. Morandini, P.-A. Santoni, Y. Perez-Ramirez, and T. Barboni (2014). Combustion of forest litters under slope conditions: burning rate, heat release rate, convective and radiant fractions for different loads. *Combust. Flame,* **161**, 3237–3248.

Van Wagner, C.E. (1977). Conditions for the start and spread of crown fire. *Canadian Journal of Forest Research,* **7**, 23–34. doi:10.1139/X77-004.

Vogel M., and F.R. Williams. (1970). Flame propagation along matchstick arrays. *Combustion Science and Technology,* **1**, 429–436. doi:10.1080/ 00102206908952223.

Wadhwani, R., C. Sullivan, A. Wickramasinghe, M. Kyng, and K. Mounuddin (2022). A review of firebrand studies on generation and transport. *Fire Safety Journal*, **124**, 103674.

Weber R.O. (1990) A model for fire propagation in arrays. *Mathematical and Computer Modelling,* **13**, 95–102. doi:10.1016/0895-7177(90) 90103-T.

Weise D.R., X. Zhou, L. Sun and S. Mahalingam. (2005) Fire spread in chaparral – 'go or no-go'. *International Journal of Wildland Fire,* **14**, 99–106. doi:10.1071/WF04049.

Yuen A.C.Y, et al. (2021) Evaluating the fire risk associated with cladding panels: An overview of fire incidents, policies, and future perspective in fire standards. *Fire and Materials*. **45,** 663–689. https://doi.org/10.1002/fam.2973**.**

Zhou, B., H. Yoshioka, T. Noguchi, X. Wang, and C.C. Lam. (2018). Experimental study on fire performance of weathered cedar. Int. J. Architectural Heritage, **13**, 1195-1208. https://doi.org/10.1080/15583058.2018.1501115.

APPENDIX C
Practitioner guide

C1 Standard summary

C1.1 Applicability

Construction Types: This standard applies to typical single-family, duplex, and townhome construction types.

Structure spacing: This standard can be applied to a defined neighborhood when 90% or more *structures* are separated by greater than 10 feet and less than 100 feet.

C1.2 Requirements summary

Roof: All structures within the defined neighborhood must have a Class A roof covering. In addition, no wood roofing products of any kind are allowed.

C1.2.1 Neighborhood flame zone

The *neighborhood flame zone* is an area typically located from the boundary of the *neighborhood* inward for up to approximately 450 feet (distances are dependent on fuel characteristics) which has the highest likelihood of experiencing the most severe fire exposure resulting from external fuels.

The *neighborhood flame zone* is determined using the processes described in *Chapter 3*. It accounts for external fuels within 0.25 miles of the neighborhood boundary and how it may produce flames/radiant heat sufficient to ignite common building materials. Any *parcels* which fall on the *neighborhood flame zone* boundary are considered in the *neighborhood flame zone* and must meet its requirements.

Those structures located in the *neighborhood flame zone* must meet the requirements of an *IBHS Wildfire Prepared Home – Plus* as specified in the *IBHS Wildfire Prepared Home Technical Standard* (https://wildfireprepared.org/wp-content/uploads/WFPH-Standard.pdf). This includes a fully 0-5 Foot Noncombustible Zone, ember or ember- and flame-resistant vents, fully noncombustible wall cover materials, noncombustible decks, double paned tempered glass windows, and no *auxiliary structures* within 30 feet, etc.

It is possible that external fuels and/or *fuelbreak/firebreak* features can result in the *neighborhood flame zone* not being needed and required.

Connective fuels: For *structures* located inside the *neighborhood flame zone*, there can be no *connective fuel pathway* to any neighboring *structures*. For *structures* that meet the *IBHS Wildfire Prepared Home – Plus* level there will typically be no connective fuel pathways to any side/elevation of a *structure*. However, care must be taken with regards to the impact of *ADUs* and *accessory structures* and their location relative to neighboring *structures*.

C1.2.2 *Neighborhood ember zone*

The *neighborhood ember zone* is the area, typically the remainder of the neighborhood not within the *neighborhood flame zone* which has a high likelihood of experiencing ember attack from *external fuels* and/or *structures* within the *neighborhood* should fire enter. It is determined by the processes described in *Chapter 3* and considers *external fuels* within 4.25 miles of the defined neighborhood.

Those structures located in the neighborhood ember zone must meet the requirements of an *IBHS Wildfire Prepared Home – Base* as specified in the *IBHS Wildfire Prepared Home Technical Standard* (https://wildfireprepared.org/wp-content/uploads/WFPH-Standard.pdf). This includes a fully 0–5 Foot Noncombustible Zone, Class A rated roof covering, noncombustible gutters and downspouts, 6-inch noncombustible vertical wall clearance, ember or ember- and flame-resistant vents, etc.

It is possible the *neighborhood ember zone* will not cover the entire *neighborhood;* this is contingent on neighborhood size and fuel characteristics.

C1.2.3 *Connective fuels* in the *neighborhood ember zone* and remainder of the neighborhood
Connective fuels are evaluated across clusters of homes as described in *Chapter 3*. In general, within the *neighborhood ember zone* and the remainder of the neighborhood, 90% or more homes must have 1 or less *connective fuel pathways* to any neighboring *structure*. It is possible that a home does not have any connective fuel pathways but does not meet the *IBHS Wildfire Prepared Home Base* or *Plus* levels, however all dwelling units which meet the *IBHS Wildfire Prepared Home Standard* (Base or Plus mitigation levels) will generally meet these criteria except for select circumstances likely involving connective *fuel elements*, *ADUs* and *auxiliary structures* and their relative location compared to dwelling units on neighboring *parcels*.

C1.3 New neighborhoods, builders, developers, and planners

The 100% application of *IBHS Wildfire Prepared Home Plus* construction across a new *neighborhood* development, provided the *structure spacing* applicability criteria is met, will generally meet the requirements of this standard except in special cases related to *ADUs*, *auxiliary structures*, and *connective fuels*.

C2 Critical variables

A sample table of critical variables that are required within the processes described in Chapter 3. Those fields which ensure applicability and compliance with the IBHS Wildfire Prepared Neighborhood Standard are shaded green.

Row number	Variable	Description	Value Options	Assigned value
Applicability				
1.	Construction type	Are all primary and accessory dwelling units in the defined neighborhood one of the three types listed in Chapter 1?	**Yes or No?** If yes, standard is applicable	
2.	Structure separation minimum	Are 90% or more structures within the defined neighborhood separated by a minimum distance of greater than 10 feet	**Yes or No?** If yes, standard is applicable	
3.	Structure separation maximum	Are less than 10% of structures within the neighborhood separated by a minimum distance of 100 feet or more	**Yes or No?** If yes, standard is applicable	
If the answers to rows 1,2, and 3 are yes, continue to roof requirements. If no, the standard is not applicable				
Roof				
4.	Class A roof cover compliance	Do all primary or accessory dwelling units in the defined neighborhood have a Class A roof covering? (*note: wood shake, wood shingles of any kind are prohibited*)	**Yes or No?** If Yes, neighborhood is compliant	
If the answer to row 4 is Yes continue to external fuel assessments				
Flame fuel assessment zone	**Variable**	**Description**	**Value Options**	**Assigned value**

Row number	Variable	Description	Value Options	Assigned value
FZ1a.	Sector 1 identified worst case fuel type flame intensity distance	Fuel model type in sector 1 with the longest distance from Table 3.2	Distance from column 2 *Table 3.2* (feet)	
FZ1b.	Sector 1 final FZ value for use in *Equation 4-1*. Canopy Provision	Is the vegetation canopy provision met in sector 1	**If Yes**, distance assigned from column 4 of *Table 3.2* **if No**, value from **FZ1a**. is used	
FZ2a.	Sector 2 identified worst case fuel type flame intensity distance	Fuel model type in sector 2 with the longest distance from *Table 3.2* sector 2	Distance from column 2 *Table 3.2* (feet)	
FZ2b.	Sector 2 final FZ value for use in *Equation 4-1*. Canopy Provision	Is the vegetation canopy provision met in sector 2	**If Yes**, distance assigned from column 4 of *Table 3.2* **if No**, value from **FZ2a**. is used	
FZ3a.	Sector 3 identified worst case fuel type flame intensity distance	Fuel model type in sector 3 with the longest distance from *Table 3.2* in sector 3	Distance from column 2 *Table 3.2* (feet)	
FZ3b.	Sector 3 final FZ value for use in *Equation 4-1*. Canopy Provision	Is the vegetation canopy provision met in sector 3	**If Yes**, distance assigned from column 4 of *Table 3.2* **if No**, value from **FZ3a**. is used	
FZ4a.	Sector 4 identified worst case fuel type flame intensity distance	Fuel model type in sector 4 with the longest distance from *Table 3.2* sector 3	Distance from column 2 *Table 3.2* (feet)	
FZ4b.	Sector 4 final FZ value for use in *Equation 4-1*. Canopy Provision	Is the vegetation canopy provision met in sector 4	**If Yes**, distance assigned from column 4 of *Table 3.2* **if No**, value from **FZ4a**. is used	
FZ5a.	Sector 5 identified worst case fuel type flame intensity distance	Fuel model type in sector 5 with the longest distance from *Table 3.2* in sector 5	Distance from column 2 *Table 3.2* (feet)	
FZ5b.	Sector 5 final FZ value for use in *Equation 4-1*. Canopy Provision	Is the vegetation canopy provision met in sector 5	**If Yes**, distance assigned from column 4 of *Table 3.2* **if No**,	

Row number	Variable	Description	Value Options	Assigned value
			value from **FZ5a**. is used	
FZ6a.	Sector 6 identified worst case fuel type flame intensity distance	Fuel model type in sector 6 with the longest distance from *Table 3.2* in sector 6	Distance from column 2 *Table 3.2* (feet)	
FZ6b.	Sector 6 final FZ value for use in *Equation 4-1*. Canopy Provision	Is the vegetation canopy provision met in sector 6	**If Yes**, distance assigned from column 4 of *Table 3.2* **if No**, value from **FZ6a**. is used	
FZ7a.	Sector 7 identified worst case fuel type flame intensity distance	Fuel model type in sector 7 with the longest distance from *Table 3.2* in sector 7	Distance from column 2 *Table 3.2* (feet)	
FZ7b.	Sector 7 final FZ value for use in *Equation 4-1*. Canopy Provision	Is the vegetation canopy provision met in sector 7	**If Yes**, distance assigned from column 4 of *Table 3.2* **if No**, value from **FZ7a**. is used	
FZ8a.	Sector 8 identified worst case fuel type flame intensity distance	Fuel model type in sector 8 with the longest distance from *Table 3.2* in sector 8	Distance from column 2 *Table 3.2* (feet)	
FZ8b.	Sector 8 final FZ value for use in *Equation 4-1*. Canopy Provision	Is the vegetation canopy provision met in sector 8	**If Yes**, distance assigned from column 4 of *Table 3.2* **if No**, value from **FZ8a**. is used	

The values determined in rows FZ1b, FZ2b…FZ8b are used to create a polygon inside the defined neighborhood boundary which determines the *neighborhood flame zone*.

Once the *neighborhood flame zone* boundary is determined:

Row number	Variable	Description	Value Options	Assigned value
Neighborhood flame zone				
FRz1.	Structure separation	Are 10% or more *structures* within the *neighborhood flame zone* separated by a minimum distance of less than 30 feet	**Yes or No?** If yes, specific *connective fuel* provisions are required in this zone &	

Row number	Variable	Description	Value Options	Assigned value
			additional ember transport distances are also required (see *Table 3.3*)	
FRz2a.	*Neighborhood flame zone* mitigation requirements – connective fuels	**If FRz1 is Yes**: Does any primary or accessory dwelling unit in the neighborhood flame zone have one or more connective fuel pathways to any side/elevation?	**Yes or No?** If yes, the zone is non-compliant If no, the zone is compliant	
FRz2b.	*Neighborhood flame zone* mitigation requirements – connective fuels	**If FRz1 is No**: Does any primary or accessory dwelling unit in the neighborhood flame zone have more than one connective fuel pathways to any side/elevation?	**Yes or No?** If yes, the zone is non-compliant If no, the zone is compliant	
FRz3.	*Neighborhood flame zone* structure mitigation requirements	Do all primary and accessory dwelling units in the neighborhood flame zone meet the requirements of IBHS *WFPH Plus?*	**Yes or No?** If yes, the zone is compliant If no, the zone is non-compliant	

The *neighborhood ember zone* is determined by the processes stated in *Chapter 3, Section 3.4*. For each sector vector length calculations are required for each sector to determine the final *neighborhood ember zone* provisions.

Row number	Variable	Description	Value Options	Assigned value
Neighborhood ember zone				
Ez1.	Sector 1 longest ember transport vector length	Sector 1 longest ember transport vector length measured from the boundary of the *neighborhood* directed radially inward toward or through the	Calculated distance using *Table 3.3* and the defined *neighborhood* boundary	

Row number	Variable	Description	Value Options	Assigned value
		centroid of the *neighborhood*		
Ez2.	Sector 2 longest ember transport vector length	Sector 2 longest ember transport vector length measured from the boundary of the *neighborhood* directed radially inward toward or through the *centroid* of the *neighborhood*	Calculated distance using *Table 3.3* and the defined *neighborhood* boundary	
Ez3.	Sector 3 longest ember transport vector length	Sector 3 longest ember transport vector length measured from the boundary of the *neighborhood* directed radially inward toward or through the *centroid* of the *neighborhood*	Calculated distance using *Table 3.3* and the defined *neighborhood* boundary	
Ez4.	Sector 4 longest ember transport vector length	Sector 4 longest ember transport vector length measured from the boundary of the *neighborhood* directed radially inward toward or through the *centroid* of the *neighborhood*	Calculated distance using *Table 3.3* and the defined *neighborhood* boundary	
Ez5.	Sector 5 longest ember transport vector length	Sector 5 longest ember transport vector length measured from the boundary of the *neighborhood* directed radially inward toward or through the *centroid* of the *neighborhood*	Calculated distance using *Table 3.3* and the defined *neighborhood* boundary	
Ez6.	Sector 6 longest ember transport vector length	Sector 6 longest ember transport vector length measured from the boundary of the *neighborhood* directed radially inward toward	Calculated distance using *Table 3.3* and the defined *neighborhood* boundary	

Row number	Variable	Description	Value Options	Assigned value
		or through the *centroid* of the *neighborhood*		
Ez7.	Sector 7 longest ember transport vector length	Sector 7 longest ember transport vector length measured from the boundary of the *neighborhood* directed radially inward or through the *centroid* of the *neighborhood*	Calculated distance using *Table 3.3* and the defined *neighborhood* boundary	
Ez8.	Sector 8 longest ember transport vector length	Sector 8 longest ember transport vector length measured from the boundary of the *neighborhood* directed radially inward toward or through the *centroid* of the *neighborhood*	Calculated distance using *Table 3.3* and the defined *neighborhood* boundary	

Row number	Variable	Description	Value Options	Assigned value
Neighborhood ember zone				
Ez9.	*Neighborhood ember zone* coverage	Does the *neighborhood* ember zone cover the remainder of the *neighborhood* not included in the *neighborhood flame zone* or if no *neighborhood flame zone* is present, is the entire neighborhood included in the *neighborhood ember zone*?	**Yes or No?**	
Ez10.	*Neighborhood ember zone* mitigation requirements	Do all primary and secondary dwelling units located in the *neighborhood ember zone* meet the requirements of *IBHS WFPH Base*?	**Yes or No?** If yes, the *neighborhood ember zone* is compliant. If no, the *neighborhood ember zone* is non-compliant	

Connective fuels are evaluated by identified *clusters* of *structures*. Each *cluster* is assigned its own integer identifier. If the *neighborhood flame zone* is present and 10% or more of its *structures* have a minimum spacing of less than 30 feet the *neighborhood flame zone* is evaluated separately for *connective fuels*.

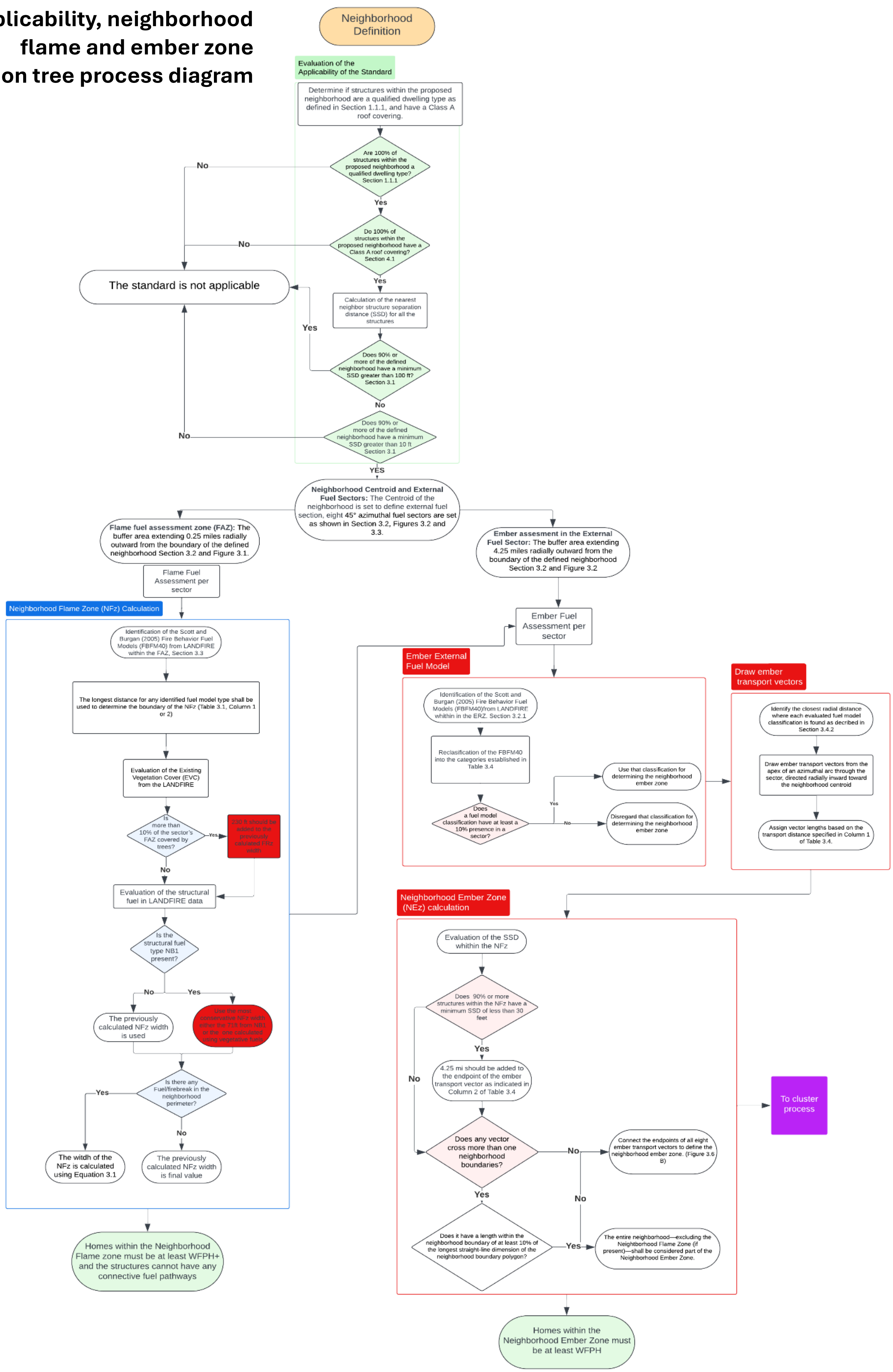
Row number	Variable	Description	Value Options	Assigned value
Connective Fuels				
CF1a.	Connective fuel flagged clusters	How many identified *structure clusters* were flagged for *connective fuels*?	Integer	
CF1b.	Total structures in connective fuel flagged clusters	How many *primary or accessory dwelling units* are located in a *connective fuel flagged clusters*?	Integer	
CF2a.	Connective fuel compliance	**If NFz1 is Yes**, Does the total number of	**Yes or No?**	

		primary and accessory dwelling units inside *connective fuel flagged clusters* AND not inside the *neighborhood flame zone* 10% or less than the total number of *dwelling units* in the *neighborhood*	If yes, the neighborhood not included in the *neighborhood flame zone* is compliant. If no, the area not included in the *neighborhood flame zone* is non-compliant	
CF2b.	Connective fuel compliance	**If NFz1 is No**, Does the total number of *primary and accessory dwelling units* inside connective fuel flagged clusters 10% or less than the total number of *dwelling units* in the *neighborhood*	**Yes or No?** If yes, the entire *neighborhood* is compliant. If no, the entire *neighborhood* is non-compliant	

C3 Process diagrams

The decision-tree process diagrams for the standard applicability, neighborhood flame zone, neighborhood ember zone, cluster, and connective fuels are provided on pages 105–106 and available to download at wildfireprepared.org along with this standard.

Applicability, neighborhood flame and ember zone decision tree process diagram



Cluster and connective fuels process