Photo credit: Nathan Waters, Assistant District Forester, Tennessee Division of Forestry

Black Bear Cub Fire: March 17, 2013
Sevier County, Tennessee

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February 3, 2016

Introduction

On March 17, 2013, a fire started at a cabin located at 920 Black Bear Cub Way in the Black Bear Ridge Resort (BBRR) development in Sevier County, Tennessee. The resort is approximately two miles west of the Pigeon Forge City Hall. A specific cause of the fire has not been determined; it is being called accidental. The fire spread rapidly to other cabins. Before being fully contained, 53 cabins were destroyed and 20 cabins were damaged.

On April 10, 2013, the Sevier County Board of Zoning Appeals requested assistance from the Tennessee Division of Forestry to create expert analysis of the fire and provide possible mitigation strategies. As a result, Dr. Steve Quarles of the Insurance Institute for Business & Home Safety (IBHS) was asked to make an assessment of the buildings in the development.

On April 26, 2013, the Pigeon Forge Fire Department (PFFD) hosted a meeting to give Steve Quarles an orientation to the fire. It was facilitated by Kevin Nunn and Donnie Shular. In addition to several Pigeon Forge firefighters, those in attendance included (in alphabetical order):

- Peter Bush, Board of Zoning Appeals; Bush Builders
- Ted Dailey, East Tennessee District Forester, Tennessee Division of Forestry (TDF)
- Leon Konz, Wildfire Mitigation Specialist, Tennessee Division of Forestry
- John Matthews, Sevier County Emergency Management Director
- Kevin Nunn, PFFD Lieutenant; Seymour VFD Chief; President, Sevier County Fire Chief's Association
- Jeff Ownby, Sevier County Planner
- Roger Price, Pigeon Forge Fire Marshal
- Steve Quarles, Insurance Institute for Business & Home Safety
- Donnie Shular, Assistant Fire Chief, Waldens Creek VFD; Captain, Sevierville FD
- Nathan Waters, Assistant District Forester, Tennessee Division of Forestry

The following information was gathered about the fire in the BBRR development:

- The fire danger was "moderate." Fire danger staffing levels range from 0 to 5, with 0 being no fire danger and 5 being extreme fire danger. On the day of the fire, the staffing level was 3 at the TDF Lenoir City fire-weather station.
- Overall forest conditions were wet. The Keetch-Byram Drought Index (KBDI) ranges from 0 to 800, with 0 being extremely wet and 800 being an extreme drought. On the day of the fire, the KBDI was 31 at the Lenoir City fire-weather station.
- Wind gusts up to 20–25 mph were reported by firefighters at the fire. The weather station at Gatlinburg–Pigeon Forge Airport in Sevierville reported wind speeds of about 21 mph between 4:00 and 5:00 p.m. on March 17, with winds generally out of the SW. Wind speeds diminished during the course of the evening.
- At 20 feet wide, the BBRR roads were relatively wide compared to roads in most communities within Sevier County.
- Hydrants were present in the development. Water shortage, however, was still an issue during fire suppression.

- No other fires were burning in the surrounding area when the fire started, and therefore extended attack resources from other departments were plentiful. However, during the early stages, firefighters had to just stand back and watch things burn due to shortage of suppression resources and water.
- Cabin owners own a 50-foot x 50-foot area.
- Propane tanks from grills exploded and some heating/air conditioning units rolled downhill when their wooden platforms burned.
- The fire moved from the cabins to the woods (rather than vice versa). A building-to-woods fire-spread scenario is a developing trend within the county.
- It was group consensus of those that witnessed the fire that heat from the fire would typically break the glass near the roofline, enter the home, and heat the interior. In the order of minutes, the windows on the opposing side would break and the entire upper portion of the cabin would be engulfed.
- Embers and debris from the burning cabins in the BBRR development caused numerous spot fires approximately 0.25 miles downwind on the slopes of Pine Mountain (across the valley from BBRR). Characteristics of the fire in that area included:
    - Extreme fire behavior in the form of individual tree torching and crowning (fire spreading from tree crown to tree crown) occurred. This occurred due to the presence of combustible brush and stands of pine trees on the hillside, coupled with the steep slopes, southerly exposure of the land, and the wind pushing the fire upslope.
    - Even though fire danger was calculated only as “moderate” and forest fuels were not particularly dry, the resulting fire caused many cabins to be threatened.
    - Roads were narrow, dead-ended, and there was no water supply.
    - A combination of road and fire behavior characteristics created hazardous working conditions for firefighters due to the absence of escape routes, safety zones, and defensible space around buildings. At times, firefighters found themselves in situations where buildings were simply too hazardous to protect and had to be abandoned for their own personal safety.

The objective of this report is to summarize the results of the site visit and review possible mitigation strategies and options that could minimize the loss of buildings from fire in the future.

Site Visit

After meeting at the Pigeon Forge Fire Department, many attendees drove to the Black Bear Ridge Resort development and spent a couple of hours looking around. Quarles and Konz then spent the balance of the day at the site, leaving at about 7:00 p.m. Most of the damaged and destroyed cabins were visited, data were collected and observations were made. Digital photographs taken during the fire were also evaluated.

Fire Spread

Wildfire spreads through a combination of fire burning through combustible materials (vegetation or buildings and other structures) and when new fires ignite as a result of spotting from wind-blown embers (also called firebrands). Embers are generated by burning vegetation and other combustible materials that include burning building materials. Building ignitions during wildfires result from a component of the building igniting from at least one of the three basic wildfire exposures, including (1) embers, (2) radiant heat, or (3) direct flame contact (Quarles, et al. 2010). As already stated, although the cause of the Black Bear Cub Fire is unknown, the fire originated in one cabin, and subsequently spread to other cabins and into the surrounding woods. Fire spread to the woods and to other cabins was caused by one or more of these three basic exposures. Fire spread is increased by wind, and therefore the reported wind gusts of 20 to 25 mph would have exacerbated fire spread throughout the development. Wind speeds measured at the automated weather observing station (AWOS) at the Gatlinburg–Pigeon Forge Airport during the late afternoon and evening are in agreement with the reported wind gusts.

Close building-to-building spacing can also result in an increased number of building ignitions resulting from building-to-building fire spread. In these situations, a wildfire building ignition scenario, with individual wildfire-to-building ignitions, becomes more of an urban fire growth scenario with an increased number of building-to-building ignitions. In wildfires that result in a large number of homes and buildings being destroyed, building-to-building spread is common (e.g., the 1991 Oakland/Berkeley Hills “Tunnel” Fire, the 2007 Witch Creek Fire [San Diego County, CA], and the 2012 Waldo Canyon Fire [Colorado Springs, CO]).

It was not possible to determine the number of cabins that ignited from each of the possible exposure scenarios. However, observations made during the site visit—and those made by reviewing the digital photographs taken by persons at the scene on the day of the fire—provided evidence that cabin-to-cabin radiant heat exposure was an important cause of building ignition, but that ember exposure also contributed.

Between-cabin distances measured during the site visit are shown in Figure 1. Between-cabin measurements that include estimates based on an April 11, 2012 Google Earth image are shown in Appendix A. The average side-to-side cabin spacing (of those measured on-site) was 32 feet. This distance is greater than the approximate 15-foot between-building separation reported in some post-fire assessments where home-to-home fire spread has been common. As shown in Figure 1, the fire in the BBRR development was thought to have started on the deck of a cabin on Black Bear Cub Way. Fire spread to the cabin to the south via a radiant heat exposure seems likely. Damaged and destroyed cabins to the east of these initial starts are approximately 80 feet away, making a radiant heat exposure, exclusively, less likely. The same can be said for two of the following three subsequent ignitions, where, continuing to the east, between-cabin separations were between 50 and 70 feet. Wind-blown ember and/or flames were also contributing.

The effect of radiant heat resulting in building ignition and fire growth is seen in a series of photographs shown in Figures 2 and 3. The effect of radiant heat resulting in damage is shown in Figure 4. The between-building separation shown in Figure 4 was approximately 70 feet (see Autumn Path Way in Figure 1). The damage observed on this building consisted of scorch on combustible siding, cracked and broken window (annealed) glass, and deformed interior vinyl window blinds. Testing has demonstrated that heat flux of about 10 kW/m^2 would be sufficient to break the outer pane of a dual pane (annealed glass) window (Cohen 1995; Babrauskas 2003). For comparison, this damage should be considered relative to the typical complete destruction of other cabin homes with much less between-building separation. The level and duration of the radiant heat exposure will determine whether ignition or other types of damage, such as broken glass in a window or door, occurs.

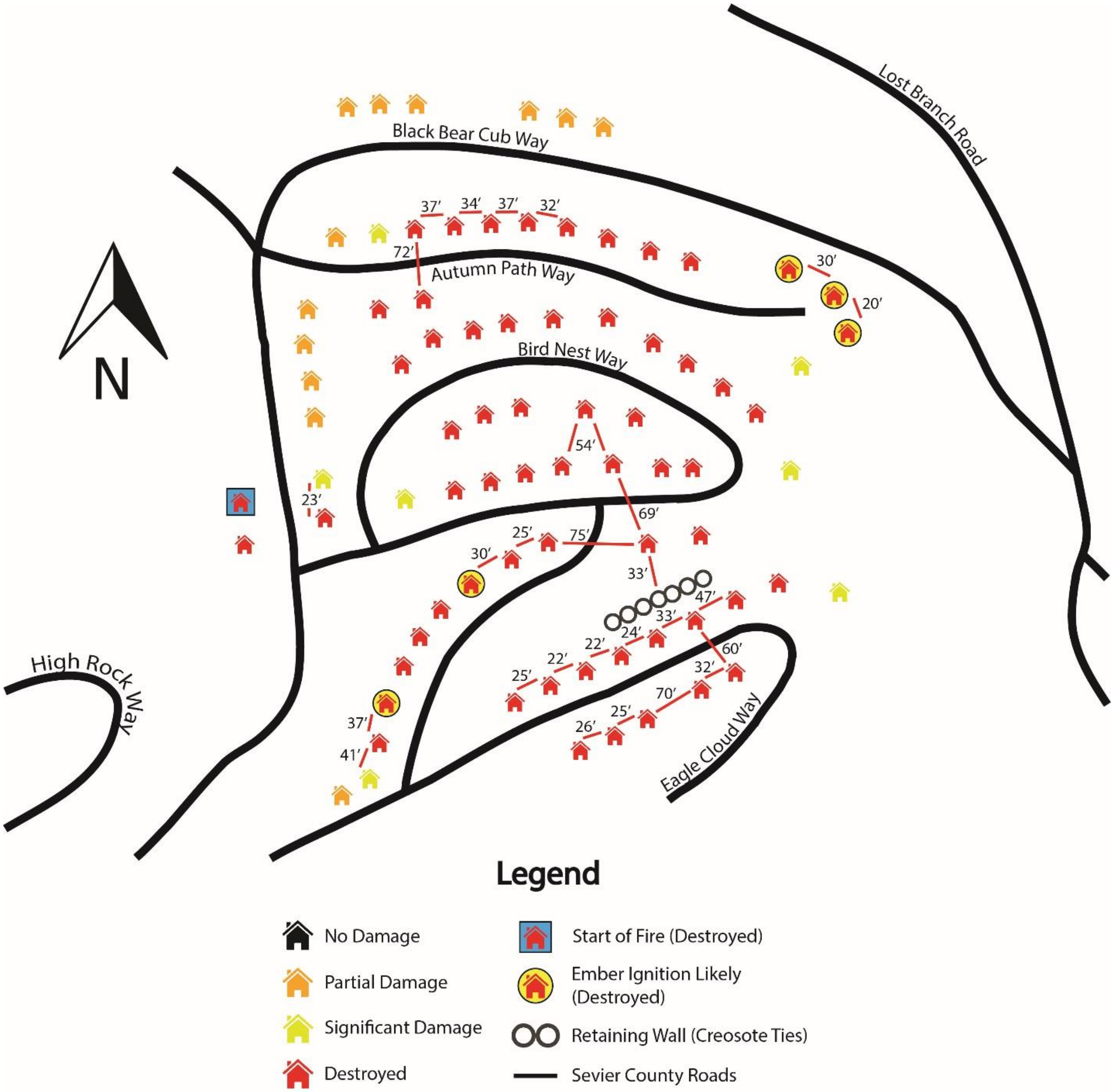

Figure 1. Between cabin distances measured during the April 26 site visit. Based on reports from the Gatlinburg–Pigeon Forge Airport automated weather observing station, winds were from the southwest.

Figure 2. The first of two sequence figures taken by firefighters showing the growth of the fire at the front of a cabin. Note that in this figure and Figure 3, the circled areas are showing the same relative area. Photo credit: Chris Knutsen, Training Captain, Pigeon Forge Fire Department

Figure 3. The second of two sequence figures taken by firefighters showing the growth of the fire at the front of a cabin. Note that in this figure and Figure 2, the circled areas show the same relative area. Photo credit: Chris Knutsen, Training Captain, Pigeon Forge Fire Department

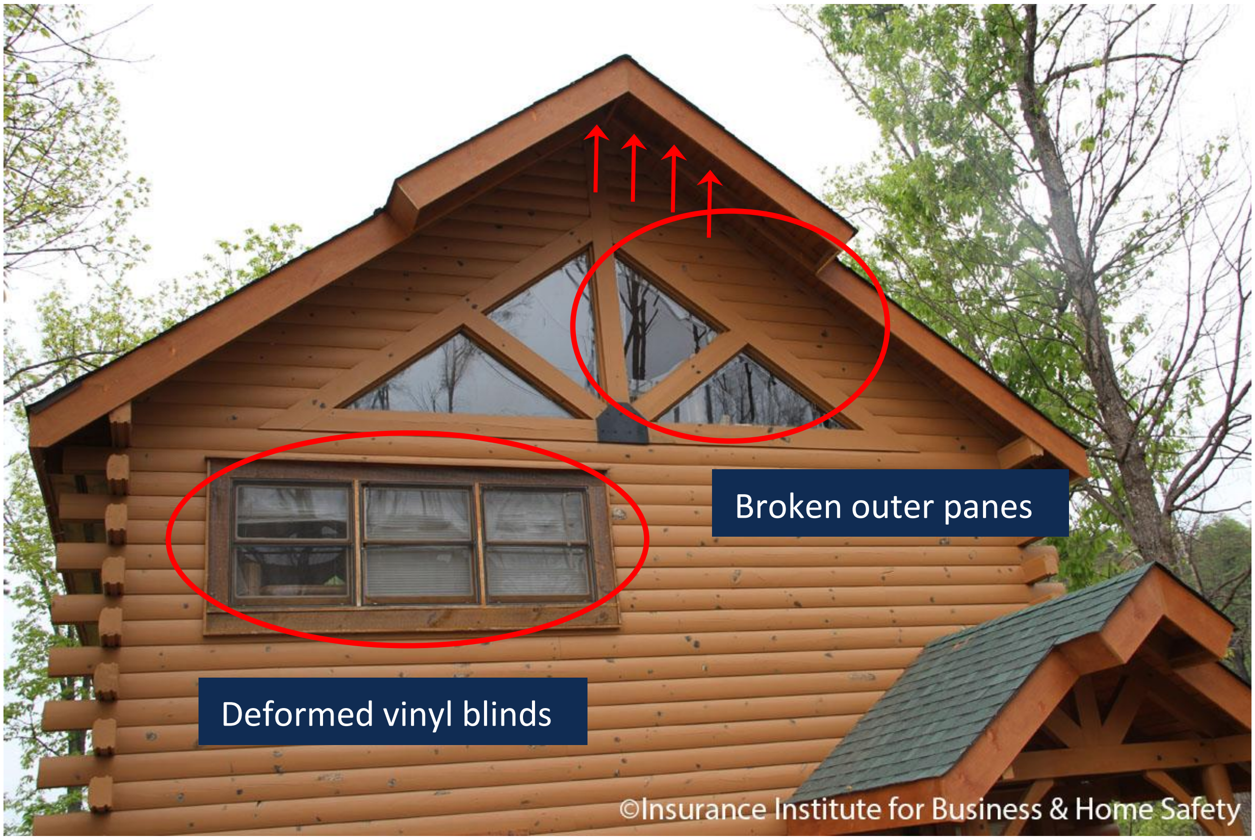

Figure 4. Radiant heat exposure resulting in damage to a cabin 72 feet from a burning cabin. In this case, damage consisted of broken glass in the outer pane of a dual pane window and deformed vinyl blinds.

An example of a probable ember ignition, in this case a deck, is shown in Figure 5. An accumulation of embers on a debris-free deck, or in the between-deck-board gaps, could have resulted in ignition (referred to as a direct ember ignition). Another possible scenario would be an indirect ember ignition whereby embers ignited debris (pine needles, twigs, leaves) that had accumulated in the gap between deck boards or other locations on the deck, such as against a wall. In these cases, whether or not fire growth occurred or self-extinguished (or was put out by a firefighter) will determine the extent of damage caused by the ignition. A photograph taken during the evening showing embers produced by a burning house is shown in Figure 6.

Figure 5. Evidence of likely ember ignition on an entry deck (circled area).

Figure 6. Embers produced by a burning cabin. Also shown is a flaming wood member that has detached from some component of the cabin. Photo credit: Chris Knutsen, Training Captain, Pigeon Forge Fire Department

Common Construction Features at Black Bear Ridge Resort

The construction in this development was referred to as log cabin. As seen in Figure 7, traditional log-wall construction in these log homes was limited to one level, typically the main walk-in level. The balance of the occupied floors was traditional wood-frame construction that were clad with a solid wood siding product having a rounded profile to resemble a log.

Many cabins in the development were built on a slope. These cabins consisted of several occupied levels, with most of the levels having an attached deck. Decks were typically wood framed for structural support and used solid-wood lumber for deck boards. On especially steep sloped sites attached decks used steel I-beams and columns for structural support.

Building material weight information for wood frame and log walls is given in Table 1. As seen in this table, the weight of log-wall construction is more than two times that of conventional 2x4 wood-frame construction. Since log-wall construction was limited to one floor in cabins built in the BBRR development, the weight difference would not be as large. Log-wall and heavy timber construction is commonly treated differently than conventional wood-frame construction—the resistance to fire penetration is typically better in larger-dimension wood members because the larger-dimension members are more difficult to ignite and have a higher fire resistance rating. However, they would provide more fuel and the potential for a longer exposure time to adjacent buildings once ignition occurs. Regardless of log-wall or wood-frame construction, the exterior and interior of cabins in the BBRR development consisted of a considerable amount of combustible materials, and once ignited, were able to burn for an extended period.

Figure 7. Common construction at Black Bear Ridge Resort consisted of log-wall construction on one level and wood-frame construction on other occupied levels, as shown in this photograph of a cabin being re-built after the Black Bear Cub fire. Note the concrete masonry unit (CMU-block) walls used for the foundation. Photo credit: Leon Konz, Wildfire Mitigation Specialist, Tennessee Division of Forestry

Table 1. Building Material Weights (Boise Cascade 2009)

Construction	Building Material Weights (pounds per ft^2)
2x4 studs at 16 inch on-center spacing, 5/8-inch gypsum board, insulation, 3/8-inch siding	11
Log wall, 10-inch-diameter logs	26

Mitigation Strategies

Mitigation strategies for improving the survivability of homes and buildings subjected to wildfire exposures have evolved to incorporate three approaches that includes:

- Developing and maintaining an effective defensible space on the property, where vegetation is carefully selected, located, and grouped, and other combustible materials (e.g., firewood piles) are carefully located a sufficient distance from buildings.
- Using appropriate construction materials and incorporating appropriate design features and construction components that help the home or building resist wildfire exposures.
- Promoting good maintenance practices that encourage removal of leaves, pine needles, etc. from roofs, gutters, decks, foundations, and other areas.

Many factors can be included in wildfire codes and standards, including those related to firefighter and fire apparatus access, fire protection systems (i.e., sprinkler and warning systems), water supply, building design and construction regulations, and vegetation management requirements on a parcel/landscape level. This report is primarily focused on regulations and standards related to building design and construction.

Available national or state-wide codes and standards that could be considered to reduce the ignitability of buildings within communities designed like BBRR include:

- International Code Council (ICC), International Wildland-Urban Interface Code (IWUIC) [Most current edition, 2015]
- National Fire Protection Association (NFPA), NFPA 1144: Standard for Reducing Structure Ignition Hazards from Wildland Fire [Most current edition, 2013]
- National Fire Protection Association (NFPA), NFPA 1141: Standard for Fire Protection Infrastructure for Land Development in Wildland, Rural, and Suburban Areas [Most current edition, 2012; the focus of NFPA 1141 is new development]
- California Building Code (CBC), Chapter 7A - Materials and Construction Methods for Exterior Wildfire Exposure

California has now adopted Chapter 7A as part of part of the California Building Code. The International Code Council reports that the IWUIC has been adopted in state-wide by three states (Nevada, Pennsylvania, and Utah). It has been locally adopted by jurisdictions in 14 other states (ICC 2016). NFPA 1144 has not been adopted on a statewide level.

Each of these documents is similar in some respects. All acknowledge the importance of vegetation and vegetation management and provide either mandatory or non-mandatory information regarding the wildfire hazard where the home or building is located. Each provides information that allow for “rating” the area in terms of “fire hazard severity zones.” The severity zones are classified based on type of vegetation, slope of the land, typical weather conditions, and history of wildfires in the area. The levels escalate from “moderate” to “very high” or “extreme.” Each code or standard provides information on how the zone can be determined (or, in the case of CBC Chapter 7A, how the zone was determined). NFPA 1144 and CBC Chapter 7A provide one level of construction requirements: a home is either “in” or “out” of a wildfire-prone area and therefore either needs to comply with construction requirements or not. The IWUIC provides different construction requirements for each of three defined fire hazard severity zones/classes. These requirements are separated in Ignition Resistant Construction Classes (1, 2 or 3), with Class 1 being the most restrictive and 3 being the least restrictive. The fire hazard severity zone in the BBRR development was not determined, but all discussion is based on use of an Ignition Resistant Construction Class #1.

All construction requirements divide the home or building into component parts and provide material or assembly options for the component (or assembly). The codes and standards provide material and assembly options for complying with the provisions for a given component. These options are separated by “or” statements, meaning that any one of the options can be used to comply with the provisions of the particular code or standard. A comparison of the requirements for these three codes and standards is given in Table 2. As previously indicated, only the IWUIC Ignition Resistant Construction Class 1 is included in this table. The California Office of the State Fire Marshal Standard Test Methods are published on line (California OSFM 2016).

Where appropriate, these options will be discussed in this report.

Table 2. A Component-by-Component Comparison of Requirements for IWUIC, NFPA 1144, and Chapter 7A of the California Building Code

Code or Standard	Component			
	Roof	Eave	Gutters/ Downspouts	Vents
2009 and 2012 IWUIC (Ignition-Resistant Construction Class 1)	Specifies class A fire-rated covering. Plug gaps at the end (i.e., bird stop).	Soffited or open-eave allowed. If open-eave, nominal 2 x material required as blocking.	Specifies gutter made of noncombustible materials (vinyl gutters not allowed). Use of gutter cover device is required.	Vents covered by 1/4-inch mesh screen. Vents not allowed in under-eave area.
2008 NFPA 1144	Fire-rated covering (fire-rating class not specified). Plug gaps at ends (i.e., “bird stop”). Specifies that a minimum 36-inch-wide cap sheet be installed under metal valley flashing.	Soffited or open-eave allowed. If open-eave, nominal 2 x material required as blocking.	Not addressed in Chapter 5. Documentation of material and condition requested in Chapter 4.	Vents covered by 1/4-inch mesh screen. Vents not allowed in under-eave area.
2010 Chapter 7A - California Building Code	Requires a fire-rated covering, actual rating (class A, B or C) dependent on fire hazard severity zone. Plug gaps at ends (i.e., bird-stopped, fire-stopped). Specifies that a minimum 36-inch-wide cap sheet be installed under metal valley flashing.	Soffited or open-eave allowed. If open-eave, nominal 2 x material required as blocking.	Metal and vinyl gutters allowed. Installation of a gutter cover device is required.	General requirement for vents to resist intrusion of burning embers and flame through ventilation openings. 1/16- to 1/8-inch mesh screening is specified. Vents not allowed in under-eave area unless vent has been accepted as ember and flame resistant.
Code or	Component			

Standard	Exterior Walls	Windows	Decks
2009 and 2012 IWUIC (Ignition-Resistant Construction Class 1)	Specifies compliance with one of five methods: (1) One-hour fire-resistance-rated construction, (2) Approved noncombustible materials, (3) Heavy timber or log wall construction, (4) Fire-retardant-treated wood on exterior side (rated for exterior use), or (5) Ignition-resistant materials on exterior side.	At a minimum, dual pane windows with tempered glass is required. These requirements also apply to skylights.	Requires noncombustible material, fire-retardant-treated wood or other ignition-resistant material, or be a 1-hour fire-resistance-rated assembly. Heavy timber is allowed. A deck extending over a slope greater than 10% must be enclosed to within 6 inches of the ground. Decks attached at different floors on the same side of a building are not explicitly considered.
2008 NFPA 1144	Specifies heavy timber, ignition-resistant material (including fire-retardant-treated wood) or an assembly with, at minimum, a 20-minute fire rating.	At a minimum, dual pane windows required. Noncombustible screening is also required.	Requires noncombustible material, fire-retardant-treated wood or other ignition-resistant material, or be a 1-hour fire-resistance-rated assembly.
2010 Chapter 7A - California Building Code	Four options for compliance: (1) noncombustible material, (2) ignition-resistant material, (3) heavy timber assembly, (4) log wall assembly, or (5) complying with SFM 12-7A-1 (10-minute direct flame exposure test). Some assemblies have been specified as complying prescriptively. designs (rafter tails and blocking).	Four options for compliance: (1) multi-pane glazing with a minimum of one tempered pane, (2) glass block units, (3) fire-resistance rating of not less than 20 minutes or (4) meeting performance requirements of SFM 12-7A-2.	Only applies to the walking surfaces of the deck. Four options for compliance: (1) be an ignition-resistant material that complies with an SFM Standard 12-7A-5 (similar to ASTM E2768), (2) be made from exterior fire-retardant treated wood, (3) be a noncombustible material, or (4) or comply with SFM Standard 12-7A-4A (an under-deck flaming exposure test).

Mitigation Strategies: Fire Suppression

Even though the cause of the ignition at 920 Black Bear Cub Way is officially listed as accidental, there was speculation by some in the firefighter community that the cause may have been related to a hot tub on a deck, with the fire subsequently moving into the occupied space of that cabin. Once the cabin was engaged, the fire spread to other cabins. There are a two fire suppression strategies that may be applicable to this fire-spread scenario, including:

- Use of a sprinkler system. NFPA offers a few sprinkler design systems (Klaus 2016). These include NFPA 13, Standard for the Installation of Sprinkler Systems, and 13R and 13D. NFPA 13R and 13D are life-safety systems rather than fire suppression systems and therefore the water flow requirements may not be sufficient to extinguish a fire, depending on the particular fire growth scenario. An NFPA 13 provides requirements for a fire suppression system and therefore requires water flow to the home that would not typical in domestic (residential) construction. Achieving adequate water supply in these areas may be a problem.
- NFPA 13D is for single family homes. It does not require sprinklers in locations such as an exterior deck since fires originating in these areas have not led to the loss of life (Klaus 2016). There is also the potential for freezing temperatures, as would be the case at BBRR. In this case a dry sprinkler option could be used. In this case, a short length of air-filled (pressurized) pipe, connected to an interior location water-filled pipe, would extend through the exterior wall to the deck area. Water enters the dry pipe when a pressure drop occurs after the sprinkler head is activated. A schematic of the dry pipe option is shown in Figure 8.
- Gel and/or foam systems are more readily available and sensor technology (usually UV- and/or IR-based) that have the potential to detect a fire and activate the gel or foam deployment system have been developed. These systems can be self-sufficient, and therefore not reliant on a municipal water system or power. Given these capabilities, the cost per unit could be relatively large.

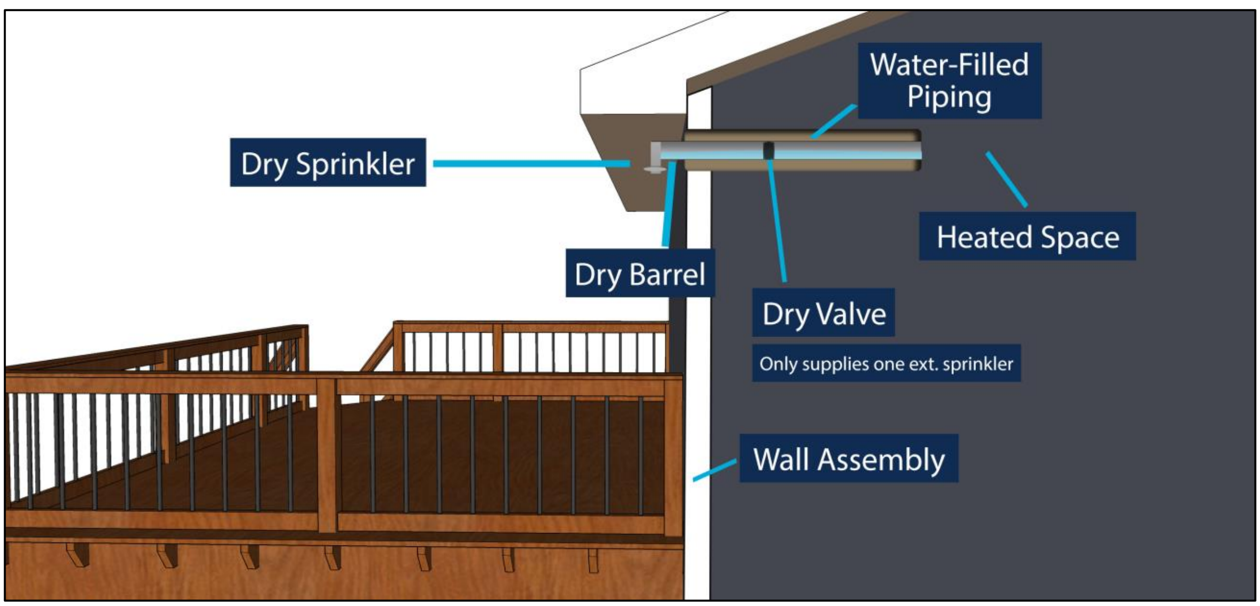

Figure 8. Diagram showing possible application of an exterior sprinkler arrangement for use on decks.

Mitigation Strategies: Radiant Exposure

Vertical surfaces, including siding and windows, were vulnerable to radiant heat exposures (Figure 9). Given that the BBRR development is an established community, adjusting building spacing would be difficult. Based on the measurements made during the site visit, the between-building spacing ranged between 20 and approximately 40 feet. These distances are less than the building separation requirements specified in Section 6.2 of NFPA 1141 (NFPA 2012). This section specifies that unless governed by other locally adopted regulations, between-building separation for buildings located on two different properties shall be a minimum of 60 feet. This 60-foot distance includes the required 30-foot setback from property lines. Given the typical 50-foot x 50-foot lot size in the BBRR development, and the typical footprint of a cabin, consistently achieving the 60-foot building-to-building separation specified in NFPA 1141 (2012) would not be possible. It should be noted that Section 6.2.1.1 in NFPA 1141 allows for building separation to be reduced to 15 feet if both homes are protected with automatic sprinkler systems meeting the requirements of NFPA 13 (Standard for the Installation of Sprinkler Systems).

Furthermore, the between-building separation shown in Figure 4 was approximately 70 feet, and it was downslope of the nearest cabin that burned, thus slope was not a contributing factor. The damage observed on this building consisted of scorch on combustible siding, cracked window glass, and deformation of vinyl window (interior) blinds. This evidence suggests that a minimum separation distance of 70 feet is prudent for this type of exterior and interior construction, if no other mitigating measures are employed, since an adjacent burning building produces so much heat.

Figure 9. Radiant heat exposure that resulted in glass breakage in windows and scorch to the siding, particularly near the under-eave area on the rake end of the cabin.

Heat damage to the side of a cabin is shown in Figure 9. The window in the upper most floor appeared to have been installed since the fire since the manufacturers label is still attached to the glass. (The condition of the old window is not known.) Observed damage included broken glass in the upper and lower lights of the hung windows and scorch to siding and other wood members (e.g., deck framing and rails, and window trim). The plastic-clad fiberglass screen also detached from the center window on the middle floor. It appeared that the screen covered the entire window. Based on the Google Earth estimated between-cabin distances (Appendix A), the adjacent destroyed cabin was approximately 32 feet from the damaged cabin shown in Figure 9.

Breakage of both panes of a dual-pane regular annealed (non-tempered) glass in the windows would indicate that a minimum exposure of approximately 35-40 kW/m^2 occurred for at least three to four minutes. Based on measurements and observations made on site, radiant heat exposure sufficient to break the outer pane of dual pane unit was possible at a cabin-to-cabin distance of approximately 70 feet. At similar radiant heat exposures, wood siding products ignited (flaming combustion) at exposure times between 5 and 15 minutes (Quarles and Sindelar 2011). It appears that flaming combustion occurred on siding near the roof line and on the dormer on the back side of the cabin, and on the corner trim at the dormer, but it did not sustain. It is not known whether firefighters were in the vicinity, but the damaged cabin was one of the two transition cabins between destroyed and undamaged cabins.

Mitigation Strategies: Wall and Windows

Round logs were only specified for use in wall construction on the entry level floor. The exterior siding on the balance of the floors was "log-like" D-shaped siding boards, typically attached to the wood-based sheathing and stud wall. Since cabin-to-cabin spacing is not likely to change, options to make the exterior more resistant to ignition include:

- Maintain entry level log-home specification but specify noncombustible siding material, such as fiber-cement product on other levels.
- Specify a noncombustible siding product on all new construction.
- Intumescent coatings (typically a film-forming paint) could be considered, but until there is a greater understanding of performance as a function of weathering (i.e., time), this approach should be taken with caution. CBC Chapter 7A does not allow for the use of coatings as a method of compliance.

Windows are a vulnerable component of an exterior wall, and must be included in mitigation strategies for the wall construction. For windows:

- Use tempered glass in dual pane units. Tempered glass is roughly four times more resistant to heat stress compared to annealed glass. Tempered glass is more expensive than annealed glass, but the cost of common-sized windows containing tempered glass has become more affordable in recent years. The IWUIC and CBC Chapter 7A require at least one pane of tempered glass in all windows. (Typically, building codes require tempered glass in windows for life and safety reasons. As such, windows in doors and those located near the floor, or in skylights, would need tempered glass, or some other glazing the meets code requirements.) Based on July 2016 cost estimates from two large building supply stores in the area, dual pane windows containing tempered glass can cost between 35% and 55% higher than the same window containing annealed (regular) glass. The cost difference will depend on window size and type.
- Window screens covering operable and non-operable windows. Window screens absorb radiant heat energy, thereby protecting the outer pane of glass. Screens are not effective against direct flame contact exposures; plastic-clad fiberglass screens will fail under a flame contact exposure.
- Metal shutters, similar to or the same as hurricane shutters, could be used to increase the protection of windows. Metal shutters would protect windows from radiant heat exposures. They would be particularly useful on the windows located near the roof line, but access to engage the shutters at this elevation and the expense to make a product to fit into this area may be prohibitive. An alternative approach would be to not allow windows in this area.

Mitigation Strategies: Under-Eave and Under-Deck Areas

Heat can become trapped in the overhang/under-eave area, particularly when open-eave framing is used (Quarles et al. 2011). In the experiments reported by Quarles et al. (2011), time to flaming ignition and rate of lateral flame spread in the under-eave area were both reduced with soffited eave construction. The same effect was observed when the fascia board was eliminated from the open-eave construction. The effect of an open-eave construction can also be observed in the attached decks (Figure 10), although the exposure could also be from a top-of-deck source, such as flame impingement from an interior fire that breaks the glass in a window and/or sliding glass door. Creating a horizontal enclosure under the deck would likely increase the chance of fungal decay (rot) developing in the in wood structural supports. Water from rain and/or snow melt would move into the enclosed area through between deck board gaps. The horizontal enclosure would limit the ability of water to move out of the enclosed space. To avoid this problem, a solid-surface deck, such as a lightweight concrete walking surface, could be used instead of deck boards. Such a deck surface, however, would likely be more expensive. A list of strategies includes:

- Box-in the eaves (i.e., create a soffited eave) using a noncombustible material (e.g., fiber cement panels).
- If a solid surface deck is used, create a horizontal under-deck enclosure using noncombustible panels (i.e., an enclosure that is attached to the bottom of the joists). This approach would increase the cost of the decks.
- An intumescent (paint) coating could be applied to the underside of the deck, however, at the present time, caution should be used since these products would have an unknown useful service life as a result of a degradation in performance as a result of weathering.
- The IWUIC requires decks extending over a slope greater than 10% to be enclosed (vertically) to within 6 inches of the ground. Although not explicitly stated in the IWUIC, this strategy would practically only apply to the bottom-most attached deck. This strategy could minimize the heat buildup in the underdeck area. The siding used for the enclosure would have to comply with siding provisions. Moisture-related degradation issues may also be a problem if venting is inadequate.

Mitigation Strategies: Deck Boards

Both the IWUIC and NFPA 1144 specify several options for decking, including noncombustible material (such as lightweight concrete previously mentioned), an ignition-resistant material (exterior-rated, fire-retardant-treated wood would qualify) or one-hour construction on the underside of the deck (this procedure would force the use of a solid surface covering, such as lightweight concrete). CBC Chapter 7A provides similar options, and provides a procedure to qualify other nominally combustible decking products (e.g., wood-plastic composite decking products and non-fire-retardant treated wood products). The California non-FRT complying combustible decking products would arguably be more vulnerable than the noncombustible and ignition-resistant material options, but would provide more affordable options and that have a defined known performance based on a standardized exposure and procedure.

- Exterior-rated, pressure-impregnated fire-retardant-treated lumber could be specified for the structural support members. Dual-treatments that provide both fire resistance and resistance to biological organisms are not available, but since it doesn't appear that lumber treated with a preservative is used for the structural support members, fire-retardant treated lumber and timbers could be considered.
- Decking could comply with the heat release rate (HRR) requirements of CBC Chapter 7A. Products that comply with the requirements of CBC Chapter 7A can be found on-line at: http://osfm.fire.ca.gov/strucfireengineer/strucfireengineer_bml.php. This universal resource locator (URL) is a link to the California Office of the State Fire Marshal Building Materials Listing Program. Once at this location, the user can view current State Fire Marshal Listings. Information on deck boards would be found in the "Decking for Wildland Urban Interface" category.

Figure 10. The under-deck structural support system in a deck will trap heat in the same way as under-eave open-frame construction.

Ember Exposure

Small deck platforms were commonly used to support air conditioning units (Figure 11). These platforms were often close to the ground. As reported by firefighters, these often burned. It is unclear what affect this had on the ignition of the cabin, but a likely ignition scenario would include ignition of under-deck combustibles such as leaves. Removal of vegetative and other combustible items is usually a maintenance item, but a noncombustible zone could be created under these platforms, and around the entire building through the use of rock mulch. This is a common recommendation by many education and outreach organizations, including the NFPA Firewise Program. It is acknowledged that this would be difficult to maintain given the steep terrain in the area. Instead of a wood framed deck, an alternative design using a concrete pedestal could be used to support the air conditioning units.

Figure 11. Small platform decks were used to support air conditioning units.

Concrete forms that incorporate foam insulation boards (insulating concrete forms/ICFs) were observed at different locations in the development (Figure 12). Ember accumulation at the base of these walls with exposed, unprotected rigid insulation board could result in ignition. In this example, flames from ignited foam could impinge on the underside of the stairs and deck. To protect this area from ember accumulation, a noncombustible surface, such as a piece of metal flashing, could be used at the ground-to-vertical surface interface.

Figure 12. Rigid foam insulation board used on the outside of this concrete form will be vulnerable to direct ember ignition.

Summary

Based on observations at the site and those by firefighting personnel on site during the March 17 fire, many of the cabin ignitions resulted from radiant heat exposures from cabins that were already burning. The windy conditions during the afternoon exacerbated the conditions for fire spread. This fire was thought to have started on the deck of a cabin, and then spread to other cabins as a result of radiant heat and other fire exposures, ultimately resulting in the ignitions of other cabins. On Pine Mountain, many homes, and some firefighters, were threatened by multiple new “spot” fires caused by embers blown downwind and landing in the forest.

Current national and statewide building codes and standards acknowledge the importance of a coupled approach to homes and buildings threatened by wildfire and provide mandatory or non-mandatory information to evaluate wildfire hazard level and guidance regarding creating and maintaining adequate defensible space at the parcel level. While the “near-building” noncombustible or low-combustible zone has been incorporated into educational materials developed and distributed by education and outreach organizations, this guidance is not explicitly specified in any of the codes or standards. This vulnerability has applicability when considering ember accumulation exposures either on or adjacent to exterior-use finishes and assemblies that are combustible.

All codes and standards address the vulnerability of buildings on a component basis (e.g., roof, siding, deck). The codes and standards specify required performance predominantly through the use of existing standard fire test methods that evaluate fire resistance of an assembly or combustibility of a material when subjected to a flaming or radiant heat exposure. Discrimination between the performance of materials and assemblies has largely been based on their response to these flame and radiant heat exposures. Since an ember exposure that causes damage or loss to buildings has ultimately occurred as a result of a flaming exposure to some component, selecting materials based on a response to these exposures can be useful. However, with some materials and components (e.g., vents), these measures do not necessarily provide all information regarding resistance to wildfire exposures, particularly related to embers.

When compared to existing wildfire building codes and standards (IWUIC, Chapter 7A, and NFPA 1144), the cabins at the BBRR development were deficient in the following areas:

- Siding (except for the log-wall level and CMU foundation walls)
- Windows (IWUIC and CBC Chapter 7A require tempered glass)
- Decking (in terms of decking material; IWUIC requires decks extending over a slope greater than 10% to be enclosed to within 6 inches of the ground)

Although it is hard to be certain about the exact mechanism/scenario for cabin-to-cabin fire spread, it seems clear that much of it was related to a radiant/convective heat exposure from a burning cabin to adjacent neighboring cabins. Given this scenario, actions that address wall construction would seem prudent. These actions could include more specific specifications for windows (tempered double-pane glass and shutters, limiting locations where windows could be located) and siding (log-wall or noncombustible). Specifying a soffited-eave assembly would reduce the potential for heat buildup in the under-eave area.

In this particular case, installation of an automatic sprinkler system meeting the specifications of NFPA 13, and installed using the dry section to avoid problems with freezing sprinkler pipes, may have been able to suppress the initial fire on the deck. It is possible that current water flow requirements for cabins in this development would not be adequate for an NFPA 13 system.

If increased building separation is not an option in the rebuilding of cabins within the BBRR development, it should still be followed for new developments of similar exterior and interior cabin construction, if other mitigating measures are not employed.

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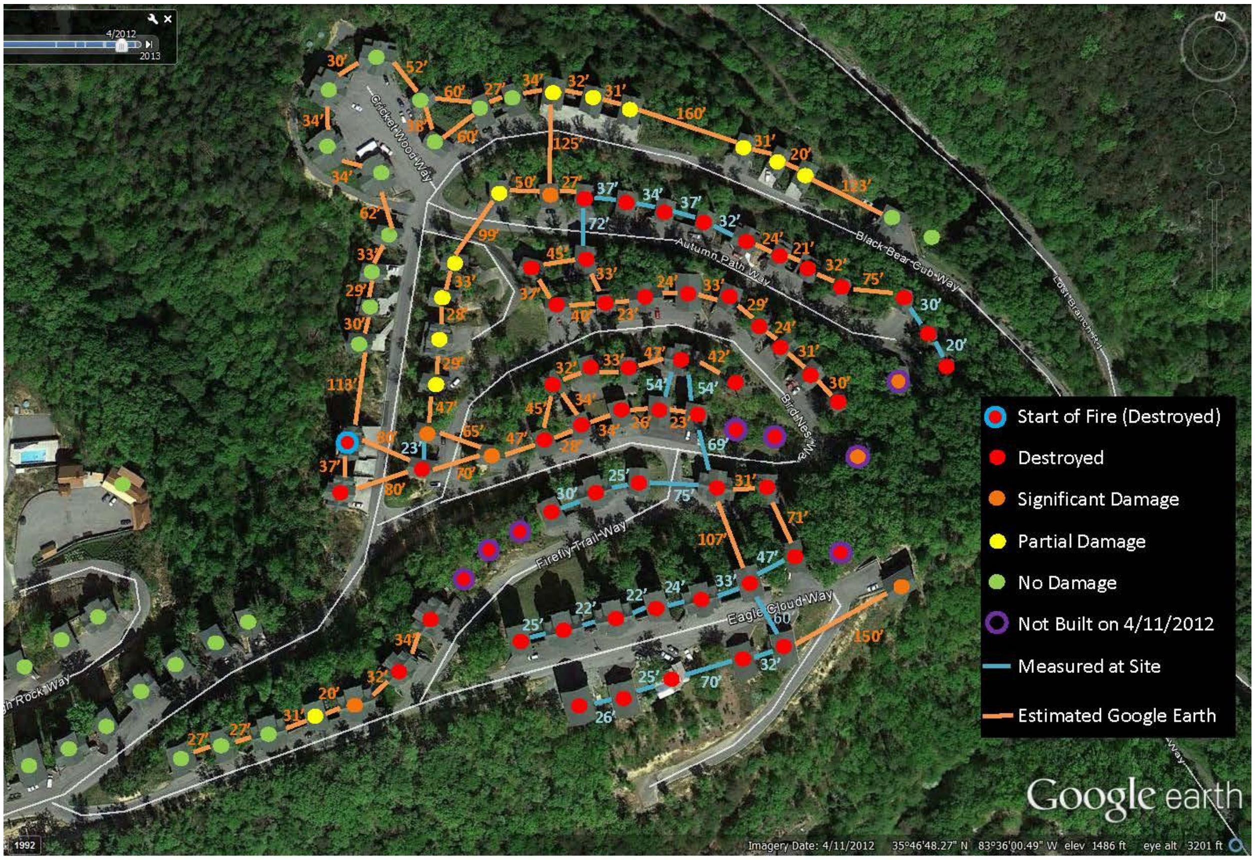
Appendix A

Between-cabin spacing, measured on site and estimated from an April 11, 2012 Google Earth image.



Black Bear Cub Fire: March 17, 2013 - Pigeon Forge, Tennessee (Executive Summary)

Wildfire risks are increasing for many property owners throughout the country. In fact, annual economic losses from wildfires have averaged $1.3 billion since 2000, almost five times the annual average of $286 million that occurred in the 1980s, according to Headwaters Economics.

On March 17, 2013, the so-called Black Bear Cub Fire started at a cabin located in the Black Bear Ridge Resort (BBRR) development in Sevier County, Tennessee, just outside of Pigeon Forge. After the "accidental ignition," fire spread rapidly from cabin to cabin within the resort; 53 cabins were destroyed and 20 cabins were damaged, highlighting the wildfire dilemma facing many high-risk communities.

The Insurance Institute for Business & Home Safety (IBHS) participated in a post-fire investigation to study the Black Bear Cub Fire with the goal of understanding how the fire was able to cause significant damage and how to reduce damage during future fires. IBHS' Dr. Steve Quarles, senior scientist, partnered with Leon Konz, a Wildfire Mitigation Specialist for the Tennessee Division of Forestry, to conduct this study. IBHS is an independent, nonprofit, scientific research and communications organization supported by property insurers and reinsurers.

This report documents the findings of that research and provides recommendations for improving construction, maintenance and preparedness practices that will reduce wildfire-related losses in the area. It is hoped that the research findings in this study and the resulting recommendations will add substantially to the scientific body of knowledge available regarding methods to prevent and mitigate wildfire losses.

Major Findings and Recommendations

Radiant heat resulting in building-to-building ignition of homes was the primary cause of fire spread and damage.

Based on observations at the site and those by firefighting personnel on site during the March 17 fire, many of the cabin ignitions resulted from radiant heat exposures from already ignited cabins. This fire was thought to have started on the deck of a cabin, and then spread to other cabins, likely from radiant heat exposure from the first home that ignited. Observations made during the site visit, and those made by reviewing digital photographs taken at the scene on the day of the fire, provide evidence that a building-to-building radiant heat exposure was the dominant cause of building ignition, while an ember exposure also contributed.

Tight building-to-building spacing was a major factor contributing to fire spread caused by radiant heat.

Based on the measurements made during the site visit, the building spacing ranged between approximately 20 feet and 40 feet. These distances are less than the building separation requirements specified in Section 6.2 of NFPA 1141 (NFPA 2012). If increased building separation is not an option in the rebuilding of cabins within the BBRR development, the report recommended increased building separation for new developments with similar cabin construction, especially if other mitigating measures are not employed.

Construction that relied heavily on combustible materials allowed the fire to burn for an extended period.
Regardless of log-wall or wood-frame wall construction used at the resort, the exterior and interior of homes in the BBRR development consisted of a considerable amount of combustible materials. Once ignited, these materials were able to burn for an extended period.

Mitigation Strategies

Walls Radiant Heat
Although it is hard to be certain about the exact mechanism of cabin-to-cabin fire spread, it seems clear that a major mechanism included radiant heat exposures from neighboring cabins. Since cabin-to-cabin spacing is not likely to change at the resort, the report suggests the following options to make the exterior more resistant to ignition:

- Maintain entry-level log-home specification, but specify noncombustible siding material, such as fiber-cement product on other levels.
- Specify noncombustible siding product on all new construction.

Windows
Windows are a vulnerable component of an exterior wall, and must be included in mitigation strategies for the wall construction. For windows, the report suggests the following:

- Install tempered glass in dual-pane units. Tempered glass is roughly four times more resistant to heat stress compared to annealed glass.
- Include window screens covering operable and non-operable part of windows. Window screens absorb radiant heat energy, thereby protecting the outer pane of the glass.
- Metal shutters, similar to or the same as hurricane shutters, could be used to increase the protection of windows.

Under-Eave and Under-Deck Areas
Heat can become trapped in the overhang/under-eave area of a home, particularly when open-eave framing is used. The report notes that creating a soffited eave will reduce this effect at the eave, reducing the potential for heat buildup in the under-eave area. Use of a noncombustible or ignition-resistant material in the soffit would improve the durability of this area.

Deck Boards
Both the IWUIC and NFPA 1144 specify several options for decking, including noncombustible material (such as lightweight concrete), an ignition-resistant material (exterior-rated, fire-retardant-treated wood typically qualifies) or one-hour construction on the underside of the deck (this procedure would force the use of a solid surface covering, such as lightweight concrete). California Building Code Chapter 7A provides similar options, and also provides a procedure to qualify other nominally combustible decking products (e.g., wood-plastic composite decking products and non-fire-retardant treated wood products).

Building Codes

Many factors can be included in wildfire codes and standards, including those related to firefighter and fire apparatus access, fire protection systems (i.e., sprinkler and warning systems), water supply, building design and construction regulations and vegetation management requirements on a parcel/landscape level. This report primarily focuses on regulations and standards related to building design and construction. Available national or statewide codes and standards that could be considered include:

- International Code Council (ICC), International Wildland-Urban Interface Code (IWUIC) [Most current edition, 2012]
- National Fire Protection Association (NFPA), NFPA 1144: Standard for Reducing Structure Ignition Hazards from Wildland Fire [Most current edition, 2013]
- National Fire Protection Association (NFPA), NFPA 1141: Standard for Fire Protection Infrastructure for Land Development in Wildland, Rural, and Suburban Areas [Most current edition, 2012; the focus of NFPA 1141 is new development]
- California Building Code (CBC), Chapter 7A - Materials and Construction Methods for Exterior Wildfire Exposure

When compared to existing wildfire building codes and standards (ICC's IWUIC, CBC's Chapter 7A, and NFPA 1144), the cabins at the BBRR development were deficient in the following areas:

- Siding (except for the log-wall level)
- Windows (IWUIC and Chapter 7A require tempered glass)
- Decking (in terms of decking material; IWUIC requires decks extending over a slope greater than 10% to be enclosed to within 6 inches of the ground)

In this particular case, installation of an automatic sprinkler system meeting the specifications of NFPA 13 could have suppressed the initial fire on the deck. This assumes an exterior sprinkler system that incorporates a dry, pressurized section, for example. It is possible that current water flow requirements for cabins in this development would not be adequate for an NFPA 13 system.