

# A SITE-SPECIFIC APPROACH FOR ASSESSING THE FIRE RISK TO STRUCTURES AT THE WILDLAND/URBAN INTERFACE

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**Abstract**—The essence of the wildland/urban interface fire problem is the loss of homes. The problem is not new, but is becoming increasingly important as more homes with inadequate adherence to safety codes are built at the wildland/urban interface. Current regulatory codes are inflexible. Specifications for building and site characteristics cannot be adjusted to accommodate homeowner values. USDA Forest Service Fire Research is developing a wildland/urban fire interface ignition assessment model as an alternative to current fire safety codes. This model is based on an analytical (rather than statistical) assessment of structural characteristics, site characteristics, and fire severity conditions. The model will be capable of assessing ignition risk for individual structures, and thus will be capable of accommodating homeowner preferences as they affect fire safety.

## INTRODUCTION

More than 1,400 homes were damaged or destroyed during wildland fires in Florida, North Carolina, California, and other States during 1985 (Laughlin and Page 1987). This created national interest in what has come to be called the wildland/urban interface fire problem. Interest in the problem continues to grow as the number of people who live in or adjacent to wildland areas increases (Davis 1990).

Although new emphasis has been placed on the problem of structure loss and damage associated with wildland fires, the problem is an old new. During the last 30 years, frequent conflagrations in California have resulted in losses of structures, primarily homes. After major California fires, reports that identified the fire problem and provided guidance for mitigation were generated (California Department of Conservation 1972; California Department of Forestry 1980; County Supervisors Association of California 1965; Howard and others 1973; Moore 1981; Radtke 1983). Generally, these reports were commissioned by State and local government agencies. With some exceptions (Dell [n.d.]; Radtke 1982), the target audiences were public officials and fire professionals. Many of these wildland/urban fire reports were comprehensive, providing recommendations, including technical specifications, for urban planning, fire suppression capabilities, vegetation management, and building construction. However, despite the production of these reports, the wildland/urban interface fire problem has continued with little abatement.

Little attention has been given to the social aspects of the wildland/urban interface fire problem, and this may be one reason why the problem persists. The technical aspects of this fire problem such as building codes and suppression improvements, have dominated discussions about the subject. However, the social aspects of the wildland/urban fire problem gained attention at wildland/urban interface

workshops conducted during 1986 and 1987 (Laughlin and Page 1987; USDA Forest Service 1987). The participants concluded that a solution to the fire problem must recognize and accommodate homeowner values and motivations.

The social aspects of the problem have not yet been addressed in the practical arena. Current fire standards are generally embodied in zoning and building codes (specification codes). These specification codes regulate minimum allowable building and site characteristics. Examples of specification codes include requirements for street width, the number of structures per area, vegetation clearance, roof material, and screening of vent openings. Standards such as these (California Department of Forestry 1980; County Supervisors Association of California 1965; Moore 1981) recommend minimum building and site characteristics for improving structure survival. Where these recommendations are implemented, structure survival is increased -- but they are generally not implemented at the wildland/urban interface.

Specification codes cannot make allowances for the diversity of social values. Generally, specification codes are not flexible in responding to homeowner values and motivations; trade-offs cannot be made to achieve a fire-safe condition. Specification codes are implemented or they are not. As a result, specification codes connote uncompromising compliance with government imposed regulations. Because many of the property owners who live in wildland/urban interface areas move there to escape urban regulation (Bradshaw 1988), there is great resistance to fire safety regulations that restrict building and site characteristics. This suggests the need for a regulatory approach that can make allowances for the diversity of social values while it identifies measures for reducing the fire risk.

This article examines the wildland/urban interface fire problem in terms of structure ignition and survival. It also describes a current USDA Forest Service effort to develop a flexible method for assessing the relative risk of structure ignition.

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## **TILE WILDLAND/URBAN INTERFACE FIRE PROBLEM--STRUCTURE SURVIVAL**

The essence of the wildland/urban interface fire problem is the damage to homes during wildland fires. Any attempt to analyze the problem should recognize the various factors that influence the survivability of homes during wildland fires.

Structure survivability is the probability that a building will not suffer major structural damage during a fire. A structure's survivability depends on the structure's resistance to ignition and on the ability to suppress any ignitions that might occur. Thus, theoretically, for a given likelihood of structure survival, a variety of ignition resistance levels can be balanced by compensating suppression capabilities. This introduces the idea of trade-offs--in this case, ignition resistance for suppression capabilities, and vice versa.

Structure survival can be examined in greater detail. The ignition aspect of structure survival can be further defined in terms of the structural fire performance, the fire exposure, and the fire severity conditions. Similarly, the suppression aspect can be defined in terms of suppression availability, safe access to the structure, and fire severity conditions. It is helpful to consider each of these factors in greater detail.

*Structural fire performance:* During a wildland/urban interface fire, ignition sources, i.e., firebrands, impinging flames, convective heating, and radiative heating, are initially external to the structure. Structural fire performance is the susceptibility to ignition and the degree of subsequent fire involvement. Structural fire performance depends on the physical characteristics of the structure. For example, a concrete structure with no window openings would resist an external ignition more than a structure with large window openings and an exterior covered with wooden shingles. Also, if an ignition occurs, the rate of fire involvement would very likely be greater for the wooden structure. The concrete structure has a higher fire performance than does the wooden structure. These simple examples represent the extremes of a broad spectrum of physical characteristics that determine structural fire performance.

*Fire exposure:* The fire exposure of a structure is defined here as the external sources (burning materials excluding flaming brands) of radiative and convective heating, and the site characteristics that influence the amount of heat transferred to the structure. For example, burning trees, shrubs, and wood piles at various distances from the structure determine how much the exterior is heated. When there is burning material downslope from the structure, the potential for convective heating is increased. In terms of fire exposure, only those burning materials close enough to the structure to influence an ignition are considered as heat sources. The area containing such materials can be termed the fire exposure zone. In this

way, the concept of fire exposure can be used to distinguish wildland vegetative fuels (outside the fire exposure zone) from vegetation adjacent to a structure. Because a fire exposure zone is defined by the characteristics of the fire and the fire performance of the structure, fire exposure is not limited by property lines. Thus, the delineation of a site-specific fire exposure zone aids in identifying all of the flammable materials relevant to structure survivability.

*Fire suppression availability:* Availability of protection during a fire is an important aspect of structure survival. Structure ignitions, if extinguished, can occur without the loss of the structure. The quantity of fire suppression staff and equipment, together with training, experience, and response times, determines fire suppression availability. This factor is generally considered the domain of fire suppression organizations, but community residents are also a part of the fire suppression availability factor. Residents are often the source of fire reports and augment organized suppression forces by working to protect individual properties.

*Access:* Assessability is critical for the utilization of available suppression resources, and thus to structure protection during a fire. Access is the ability of fire suppression forces, including residents, to locate, reach, and safely remain at a structure and continue suppression efforts.

*Fire severity conditions:* This refers to the conditions that affect the flammability of fuels, flame tilt, spread rates, and aerially transported burning brands. Fire severity conditions are determined primarily by on-site weather and topography. Fire severity conditions influence the degree of fire exposure and the effectiveness of structure protection.

Structure survivability is an expression of the interactions of the above-defined factors. Specification codes seldom take these factor interactions into account, and therefore present relatively rigid formulas for providing fire-safe environments. The failure to account for these factor interactions prevents the incorporation of social values into fire safety measures. The alternative to specifying minimum characteristics (specification codes) to produce a given level of structure survival is to make use of a model that incorporates factor interactions.

The essence of structure survival, and thus of the wildland/urban fire interface problem, is ignition. If ignitions do not occur, then structures survive. Although structure survival involves the interaction of all five factors discussed, just three of them--structural fire performance, fire exposure, and fire severity conditions--determine the potential for ignition. For a given level of fire severity, the ignition potential determines the level of fire suppression availability.

and accessibility necessary to produce a given level of structure survival. As structural fire performance decreases and fire exposure increases (increasing the ignition potential), the accessibility and suppression availability must increase if a structure is to survive. The wildland/urban fire interface problem would virtually disappear if structures did not ignite; therefore, the emphasis of a wildland/urban interface fire risk assessment should be on structure ignition.

### **IGNITION RISK ASSESSMENT MODEL**

A structure ignition risk assessment model is now being developed by the USDA Forest Service. This cooperative effort involves the Forest Products Laboratory, Madison, WI, the Riverside Fire Laboratory, Riverside, CA, and the Southern Forest Fire Laboratory, Macon, GA. The product will be a broadly applicable method for assessing the relative risk of individual homes to external ignitions from wildland fires. The prototype model is expected to be completed in 1991.

This model approaches interface home losses in a new way. Recent models by Abt and others (1987) in the United States and Wilson (1988) in Australia have used statistically derived relationships, based on specific fires, to describe characteristics related to potential fire incidence and structure survival. Our model uses analytical relationships to describe characteristics related to the potential for structure ignitions. This approach has the following advantages:

- An analytical approach is not limited by specific event data and its interpretation,
- An analytical approach, based on physical relationships can easily incorporate future gains in understanding to fill current gaps,
- An analytical approach can incorporate the interactions of the various factors affecting the wildland/urban interface fire problem,
- The modeling of interactions provides a means for analyzing mixes of factors, and thus a means for analyzing trade-offs in meeting fire safety requirements.

Our wildland/urban fire interface model assesses the risk of potential ignitions rather than potential structure survival. As noted previously, structure survival depends on both the ignition factors and the suppression factors. Thus, an assessment of potential structure survival would require an assessment of the suppression factors. However, many of these factors (access, suppression availability, and fire severity) are very hard to quantify. For example, the resident's presence at the home during the fire can be critical to the home's survival. But it may not be possible to reliably assess the likelihood that a homeowner will be at home at an unspecified time, especially in a situation complicated by emergency access

limitations and evacuation policies. (The statistical models previously cited also do not account for the suppression factors, although structure survival is ostensibly the product of the Australian method.)

### **The Ignition Risk Rating System**

The Ignition Risk Rating System borrows some of its underlying philosophy from the National Fire Danger Rating System (NFDRS) (Deeming and others 1978). The Risk Rating System is based on physical principles so that new understanding can be easily incorporated into it. Where gaps in knowledge exist, personal expertise estimates the effects of the physical processes. As with the NFDRS, the ratings are not incident-specific, but rate the potential fire situation. Therefore, a worst case approach is taken in acquiring data and making computations. Because it is not possible to make precise evaluations of ignition occurrences, the risk ratings are placed in ordinal categories.

Rating risks of potential structure ignitions requires that structure characteristics, site characteristics, and fire severity conditions be described and analyzed to produce assessments. The Ignition Risk Rating System does this in three stages. In their computational order, these stages are the fire source module, the heat transfer module, and the structure ignition module.

The fire source module describes the site and fuels around the structure and transforms that information into descriptions of the potential flaming sources affecting the structure. The fire severity conditions are locally identified using National Fire Danger Rating System (NFDRS) burning index cumulative frequency percentiles. The percentiles are computed from historical fire weather data. The flaming source descriptions are based on an on-site fuel inventory in conjunction with the potential fire behavior identified by the NFDRS calculations. The potential flaming sources are described by their flame length, flame zone depth, flaming width, flaming duration, and distance from the structure. A subjective assessment of the structure's relative firebrand exposure is made on the basis of the fuel sources adjacent to the structure and on nearby wildlands. For example, a structure is considered less exposed to ignition by firebrands from grass fuels than by a conifer stand with heavy understory fuels. These descriptions are then used by the other modules.

The heat transfer module uses flame source and homesite information from the flame source module to estimate the radiative and convective heating of the building exterior. Due to the impossibility of knowing the specific characteristics of a future incident, the worst case configurations for the heat transfer are used. For example, all fuels are considered to be burning at the same time, the radiative distance is considered to be the closest distance to the fuel, and the view angle between the structure and the flames is assumed to be the

angle that produces the greatest heat transfer. Convective heating occurs if the convection column intercepts the structure, but potential cooling from the wind is not considered.

The structure ignition module calculates the System's ignition risk rating. The module uses descriptions of the building's exterior structural characteristics along with the heat transfer information and the assessed firebrand exposure to compute the ignition risk. Exterior materials are generally described by type (wood, stucco, glass, etc.) and exposed surface area. The ignition risk assessment is largely based on data derived from laboratory fire tests conducted on exterior building materials (roof materials, siding, windows, etc.). The module produces the ignition risk rating based on the relative availability of energy for an ignition. Relative risk ratings fall into four classes: low, moderate, high, and extreme. To facilitate a consistent assessment of the ignition potential, the classes are defined in such a way that a structure in the next higher class has twice as much ignition potential as a structure in the one below.

### System Benefits

The System will provide property owners amid suppression organizations with a guide to assessing, and thereby reducing if necessary, the potential ignition risks to homes. The System will provide the following:

- A flexible means of integrating social values and fire performance requirements--one that will encourage greater acceptance of actions necessary to decrease the risk of structure ignition,
- A means for evaluating a mix of conditions of the components that contribute to structure ignition, thus allowing for site-specific and property-owner-specific actions that meet minimum requirements for ignition risk--making informed tradeoffs,
- A means for informing and educating property-owners about the relative risk to their homes,
- A means for informing suppression agencies of the relative fire risk to homes, leading to more informed suppression planning.

### SUMMARY

The wildland/urban interface fire problem, i.e., the loss of homes during wildland fires, is not new. The problem persists, not because there are no fire safety guidelines, but because guidelines are not fully implemented. Until recently, homeowner values and motives were not recognized as important in achieving fire safe home sites. The current guidelines used for the wildland/urban fire interface are fixed, discrete specifications that cannot incorporate variations in homeowner values while maintaining a given level of fire safety.

A USDA Forest Service cooperative research effort is currently developing a wildland/urban interface structure ignition risk assessment model. This physically based analytical model is being designed to account for the interactions of the factors that contribute to structure ignitions. Thus, the model may be used to identify a variety of fire safety measures that result in required risk reductions and also accommodate specific homeowner desires.

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