1983

Fire protection in the wildland/urban interface : a Montana viewpoint

Michael R. Dannenberg
The University of Montana

FIRE PROTECTION IN THE WILDLAND/URBAN INTERFACE: A MONTANA VIEWPOINT

by

Michael R. Dannenberg
B.S., University of Illinois, Champaign-Urbana, 1976

Presented in partial fulfillment of the requirements
for the degree of

Master of Forestry

University of Montana
1983

Approved by:

Dean, Graduate School

Chairman, Board of Examiners

Date Jan. 5, 1984

ACKNOWLEDGEMENTS

I would like to thank Dr. Ronald Wakimoto, my committee chairman, for his guidance, support and patience. I also would like to thank Prof. Fred Gerlach and Dr. James Habeck for their advice and critiques of this paper.

Thanks must also go to William Fischer, who provided much of the information and support for this project.

Special appreciation must be given to my wife, Joan, and a dear friend, Mick Hanson, both of whom provided the impetus required for this project to be completed.

I hope this document will provide local governing authorities, fire protection authorities, and land developers with some insight as to the fire problems plaguing wildland/urban development. It is hoped that through education and the application of appropriate regulations the overall fire hazard can be reduced to effectively protect life and property.

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	i
TABLE OF CONTENTS	ii
LIST OF TABLES	iii
LIST OF FIGURES	iv
CHAPTER	
1. Introduction	1
2. Wildland/Urban Fire History	4
3. Fire Dependent Environments	8
4. Creation of a Disaster	11
5. Existing Hazards and Risks	17
6. Predicting Wildfire Danger and Behavior	23
7. The Regulation of Subdivisions	32
8. Subdivision Design	40
9. Creating the Wildland/Urban Interface Conflagration	58
10. Conclusion	67
Literature Cited	76
Appendix A	80
Appendix B	82
Appendix C	85
Appendix D	95
Appendix E	98

LIST OF TABLES

TABLE NO.		Page
1	Possible Fire Regimes	8
2	Fire behavior, controllability, and fireline intensity	22
3	Fire behavior and vegetation characterizing fire hazard	26
4	Fire hazard rated on three weighted values of weather, fuels, and topography in California wildlands	17
5	Wildfire hazard severity scale	28
6	Vegetation and fire behavior characterizing proposed fire hazard classes for Montana wildlands	31
7	Acres subdivided in three western Montana counties	39

LIST OF FIGURES

FIGURE		Page
1	Landscaping to reduce radiant heat.............	54
2	Schematic representation of a hypothetical interface wildfire hazard situation immediately before a conflagration...........	59
3	Schematic representation of the hypothetical interface wildfire hazard situation immediately after a conflagration............	60

Fire Protection in the Wildland/Urban Interface

A Montana Viewpoint

Chapter 1

Introduction

During the last two decades America has undergone a major cultural change. By 1975, researchers had documented that the established trend of migration from rural communities to the cities had reversed itself and become a major exodus of city-dwellers to the urban fringe and isolated wildland areas (Lee, 1980). The roots of this "reverse migration" stem from advances in transportation, the western states' economy and the changing American lifestyles. More leisure time, early retirement and dreams of owning a few acres, planting a garden and communicating with nature are bringing city-dwellers in record numbers to rural areas. There is a strong desire to get away from the pressures of population centers. This has resulted in an increase of subdivisions and developments on and next to forested and wildland areas.

This migration is causing drastic changes in the traditional land use concepts. Besides the timber values, wildlands have been managed for their value as watersheds, game habitats and recreational playgrounds. Now the land has become more popular as building sites, for both permanent residence and second home developments. Permanent vacation dwellings have been built in many parts of the 2.2 billion acres that constitute rural America, and 42% of the nation's population now call these areas home (Bowman, 1979). The "reverse migration" adds a striking new dimension to an already complex and confusing fire problem. Residential development often takes place on lands with a view, seclusion and an abundance of aesthetically pleasing natural vegetation. Homes are located near dense vegetation so as to capture a sense of privacy and naturalness (Lee, 1980). However, the abundant, aesthetically pleasing natural vegetation often becomes an extreme accumulation of natural wildland fuels. This fuel accumulation is further aggravated by the presence of structures, as they reduce the possibilities of using controlled fire to alleviate the fuel buildup.

Fire hazards of unprecedented scale and severity result when naturally occurring fuels are supplemented with unnatural fuel buildup around structures located in wildland areas. Wildfire is a natural occurrence and is inevitable in western coniferous regions (Habeck and Mutch, 1973) and the chaparral ecosystem of California (Radtke, 1981). Catastrophic fires, with high risks to property and life, are becoming a more common event in this hazardous area where rural wildland fuels meet the urban settlements. This is the wildland/urban interface.

The wildland/urban fire interface has been defined as "Any point where the fuel feeding a wildfire changes from natural (wildland) fuel to man-made (urban) fuel" (Lee, 1980). This interface is simply a boundary between a structure in which fire is carefully restricted by culturally defined practices and wildland vegetation in which fire has always been a natural part of the ecology. Population growth in the wildland/urban interface is primarily in areas of non-commerical vegetation types but adjacent to valuable commercial forests. Uncontrolled wildfire originating in the interface can rapidly spread into productive coniferous forests resulting in the ultimate destruction of an important part of the local economic base (Curran, 1978). Conversely, wildfires that originate in forest zones threaten the lives and property of people living in the interface. This potential for disastrous conflagrations becomes more likely as further development occurs without implementing precautionary measures (Curran, 1978).

The objective of this paper is to bring to light the fire danger to homes being built in wildland fuels. Even the best equipped and most experienced fire fighting forces in the world are helpless against a hot, intense wildland fire. Homes are being built in wildland areas destined to burn with absolutely no regard to the dangers of wildfire. Thus, with the concepts contained within this paper, local governing authorities and land developers will be able to work with fire protection authorities to reduce the fire danger and provide a safer environment for people living in the wildland/urban interface.

Chapter 2

Wildland/Urban Fire History

Early explorers of the western states have documented the discovery of widespread forest fires and areas denuded by fire (Freedman, 1980). Numerous historical accounts exist regarding Indians using wildfire as a useful tool for hunting, brush removal from trails and to enhance the native vegetation. Wildfire has consumed native vegetation in the Americas for thousands of years. No physical control of fires was needed or attempted. Then, the early white settlers started moving westward, building permanent residences, towns and cities. The early towns were carved out of the forests and built entirely of wood from the clearing process. Naturally this made the towns vulnerable to major conflagrations. It was not unusual for wildfires to sweep through communities killing hundreds of people. Two such fires that will always stand out as reminders of wildland fire destruction are the Prestigo, Wisconsin Fire in 1871 that claimed 1,500 lives, and the Hinkley, Minnesota Fire killing 418 in 1894 (Lee, 1980).

A century has passed since the Prestigo fire, yet wildland fires continue to take an intolerably heavy toll of life and property despite the great advances in technology and firefighting techniques. The National Commission on Fire Prevention and Control states that over $11 billion worth of resources are wasted by destructive fires yearly. Additionally, 12,000 people will lose their lives to fire and tens of thousands are injured each year (Bowman, 1979).

The fire problem that plagues California is well known to fire researchers and firefighters. Much of California's destruction by wildfire occurs within a few critical fire weather days each year, when air temperature soars, the relative humidity drops to near zero and wind velocities increase to 50 miles per hour or more. Under these conditions wildland fires start easily and spread rapidly, control being next to impossible.

In 1961, the Bel Air Fire, pushed by the strong Santa Ana winds, swept down out of the Santa Monica Mountains and spread into the Bel Air-Brentwood area. The community lost 484 homes and 21 other structures in less than two days (Task Force on Calif. Wildland Fire Prob., 1971). In 1964, three fires raced through a total 71,601 acres of California brush and timber and into several cities consuming a total of 306 residences and other structures. In November of 1966 the Loop Fire started near the City of Los Angeles and spread over 2,028 acres in just 32 hours. The Loop Fire gained notoriety when in just one minute the fire flashed up a narrow canyon, trapped and killed 12 experienced firefighters. In 1970, fires raged through more than 500,000 acres of brush and timber covered wildlands within a 13-day period of extreme weather conditions. The 1970 fires rapidly moved into adjacent urban areas destroying 722 homes and killing 16 people. Despite California having the best financed and most effective wildland fire organization in the world, destructive fires will continue to occur in the wildland/urban interface (State of Calif., 1971).

The wildland/urban interface fire problem exists in many areas outside the California suburbs. Florida is experiencing a surge in growth with many retired couples settling into the rural areas. The Rocky Mountain states are finding more and more permanent and vacation homes being built where previously no roads existed. Hazards also exist where development has occurred in the Jack pine forests of the Lake States and the forests of Maine and New Jersey (Lee, 1980). Colorado has experienced a rise of up to six times as many fire starts in wildland/urban areas. Oregon residents have had several close calls with disasters in recent years (Curran, 1978).

In Montana, firefighters have watched with concern as homes are constructed in the wilds. Two decades ago, large fires like the Sleeping Child, Sundance, and Trapper Peak Fires posed little threat to homes. In recent years, the dangers associated with forest dwellings have been illustrated. On July 16, 1977, the Pattee Canyon Fire started a few hundred yards from the Missoula, Montana, city limits. Pushed by a strong wind, the fire consumed six homes and 1,200 acres of timber and watershed within a few hours. Fortunately no one was injured, although the dollar costs were high. Suppression costs of $300,000 were announced and the estimated value of the homes lost was $330,000 (Freedman and Fischer, 1980).

Two years after the Pattee Canyon disaster, Montana suffered another dry summer. As if to remind Montana home owners of the danger, several fires burned close to residences, but only one house was lost. The Deep Granite Fire, a 2,330 acre blaze near Libby consumed a house and barn before its control. Approximately 50 homes were threatened as the Anaconda-Barker Creek Fire burned to within two miles of Anaconda. Near Missoula, the Mill Creek Fire west of Lolo burned 600 acres of timber and came within one-quarter mile of residences. Later that same year, weary firefighters fought a 250 acre blaze two miles north of Missoula's

Grant Creek development. Several homes were evacuated as a safety precaution (Freedman and Fischer, 1980).

Despite the obvious reminders, homes are being constructed that will prove to be impossible to protect against wildfire. Some of the new constructions have views that look onto the scars of past conflagrations. The man who ignores history is destined to relive it.

Chapter 3

Fire Dependent Environments

Many areas in the western states have evolved through the ages with the aid of natural fire. An ecosystem is considered fire dependent if periodic changes in the system due to fire are essential to the succession of the natural system (U.S.D.A., 1980). In such systems, fire is an environmental trigger that starts and ends key vegetational seral stages, controls the age structure and species composition. Part of this ecosystem is the "natural fire regime". A natural fire regime is the total pattern of fires in vegetation, over time, that have like characteristics; i.e., fire type, intensity, fire size, and fire frequency or length of return intervals. (U.S.D.A., 1980). The fire rotation or fire cycle is an important factor in classifying the various fire regimes. Table 1 demonstrates a simple breakdown of seven possible fire regimes.

Table 1. Seven Possible Simple Fire Regimes

0 = No natural fire

1 = Infrequent light surface fires (more than 25-year intervals)

2 = Frequent light surface fires (1 to 25-year interval)

3 = Infrequent severe surface fires (more than 25-year intervals)

4 = Short return interval crown fires and severe surface fires in combination (25 to 100 year interval)

5 = Long return interval crown fires and severe surface fires in combination (100 to 300 year interval)

6 = Very long return interval crown fires and severe surface fires in combination

Source: U.S.D.A., 1980

The interval between fires depends primarily upon the time it takes for flammable vegetation to develop and dead, flammable fuels to accumulate (Fischer, 1977). Forest Service researchers have traced the fire history on several areas in the northern Rockies (Arno, 1976, 1980). Findings show that on areas of the Bitterroot National Forest, Montana, between the years 1735 and 1900, the mean fire interval in selected stands of timber ranged from 6 to 41 years. Studies done in the Lick Creek area near Hamilton, Montana, under old growth ponderosa pine (Pinus ponderosa) demonstrated that fire intervals between 3 and 30 years were not unusual (Gruell et al., 1982). These low-intensity fires consumed most of the grass, shrubs and tree regeneration without causing damage to overstory trees. In California, much the same was true before man's influence. Natural fire ignitions within the chaparral fuel complex would occur on an average of every 10 to 40 years (Muller et al., 1968). While some fires during extreme fire weather conditions would grow to large fire size, most fires occurred during less severe conditions and would clean the area of flammable fuels (Cowles, 1973).

Researchers noted a marked decrease in fire incidence after 1920, about the time that fire control activities were initiated (Arno, 1976). As fire control technology and organizations improved, a parallel increase in the average fire interval occurred. This lengthening of the fire interval, caused by control of the "cleansing fires" causes an abnormal increase of fuel accumulation in some wildland areas. In many northwest timber stands where ponderosa pine (Pinus ponderosa) and Douglas-fir (Pseudotsuga menziesii) are climax species, large accumulations of dense understories have developed, creating a "ladder of fuels" endangering the normally groundfire-tolerant species with a deadly crown fire (Arno, 1976).

Fire dependent regimes have other factors that control the severity of a fire. Such things as fuel flammability, fuel continuity and plant regeneration strategies are all items that encourage or discourage fire in an eco-system. But man, through his control practices has upset the balance of fire in the wilds. Today we extinguish the early season cleaning fires and create more fuel for the major conflagration bound to occur during the hotter, drier months when fire control is not as easy. As more homes are constructed in rural areas, less fire is allowed and the dangerous flammable fuels continue to accumulate.

Chapter 4

Creation of a Disaster

Each year the news media covers stories relating disastrous events that kill, injure or leave homeless portions of the world's population. Newscasts relate the horrors experienced by people facing floods, earthquakes, volcanoes or other major disruptions in lifestyles. The researchers of major disasters have not subjected the wildland/urban interface fire to as intensive a study as tornadoes, earthquakes and volcanoes. One possible reason for this is that researchers have adopted the thinking that wildfires are human-caused disasters rather than a natural hazard (Lee, 1980).

Man has little defense against the destructive powers of a volcano, earthquake or other major disruptive forces. Large levees are constructed to protect against floods, yet little is done to prevent homes from being built in "natural hazard" areas. A natural hazard is conventionally defined as "a source of danger or risk" (Webster, 1973). In wildfire terminology, hazard is a description of "a condition of fire potential defined by fuels and other environmental factors which form a threat or potential of ignition" (Gaylor, 1974). The notion of risk is fundamental to the concept of hazard, since risk involves the assignment of probability or chance that harm will occur. Gaylor (1974) defines risk as "the chance of a fire starting as determined by the presence and activity of a causative agent". Thus risk is directly proportional to hazard; as the hazard increases so does the risk.

These simple notions of hazard and risk require some elaboration when employed for the purpose of taking action. Risk assessment involves the identification of hazards, possible sources of ignition and probability of ignition. Hazard management or reduction involves the choice of options to be used in controlling and minimizing the hazardous conditions (Lee, 1980).

Thus both risk assessment and hazard reduction require a knowledge of cause and effect relationships which produce hazardous conditions. Such knowledge is usually limited because authorities believe the legal concept that natural hazards and the disasters to which they give rise are "Acts of God" or events beyond human control. The fact that people repeatedly build in brush fields, timber, floodplains and seashores or other hazardous locations proves that very little precautionary planning goes into preconstruction site location.

Precautionary planning makes it possible to address the vulnerability of construction sites. The alternative to precautionary planning is to repeatedly resolve hazardous problems through increasingly expensive public service and disaster relief organizations. Thus some disasters may display a systematic development. In order to study the sequence of steps leading toward a disaster, Lee (1980) defines disaster as:

> "An event which threatens a population with unwanted consequences as a result of the breakdown of precautions which had been accepted as adequate."

This definition emphasizes the breakdown of precautions as the central feature of a disaster. The inadequacy of fire prevention and suppression methods are demonstrated when an interface fire grows into a conflagration.

Turner, (1976), a sociologist has compiled a six-stage development sequence for disaster.

STAGE I

The first stage of the disaster sequence begins with a set of beliefs or precautions about the hazards of living in the rural/urban interface. These beliefs compose the normal stock of knowledge that residents have about wildfire. Such knowledge might include some conceptions on the causes of fires, the association of fire with heavy fuels and possible source of ignition. The state of knowledge that a community lives with is the foundation for precautionary rules, which may take the form of laws, practices, customs or fire prevention laws. Acceptance of these precautions is possible because people believe that failure to abide may cause a disaster.

STAGE II

A wildfire disaster occurs when the accepted beliefs and precautions prove to be inadequate or inaccurate. The major concern here is not the breakdown of accepted guidelines that occurs instanteously, but the slow accumulation of unnoticed events. Fire prevention measures are thought to be adequate to alleviate the known fire hazards. However, there are events that are inconsistent with the normal image of the wildfire hazard. These events "incubate" over a period of time until all factors come to a head and a conflagration results. Fuel accumulation, coupled with structures throughout wildland areas provide an excellent environment for the incubation of these unnoticed events.

Such discrepant events can only build up, unnoticed, if they remain unknown to most people or are misunderstood as to the resulting consequences. Residents and officials may perceive the fuel accumulation in a dense forest and be concerned about the tall trees present, yet not understand the relationship of ladder fuels to a crownfire. Several studies of rural/urban interface residents show a general feeling of security, safe from any possible disaster (Hulbert, 1972; and Freedman, 1980). In a Montana survey, 80% of the forest homeowners questioned believed the fire danger locally was low to moderate (Freedman and Fischer, 1980). Colorado residents felt much the same way with 75% saying the danger was low to moderate (Hulbert, 1972). Resident feelings could be summed up by one man's comments, "There hasn't been a fire for 30 years, why should we have one now." This illustrates a precautionary breakdown.

Lee (1980) gives five reasons why hazardous events are allowed to accumulate unnoticed.

1. People are reluctant to fear the worst, with the result that they dismiss evidence of hazardous conditions or fail to notice warning signs.
2. The violation of fire prevention laws and rules become accepted as normal when people are misinformed or fail to learn appropriate precautions.
3. "Information overload" in complex situations where people fail to attend to danger signs because of so many other events demanding their time.
4. People's attention may be directed away from warning signs to lesser or more immediate dangers. An example may involve attempts to secure local fire departments capable of fighting

individual fires that pre-empt attention from hazards in the interface that threaten all structures.

5. Destructive wildfires which occur at frequent intervals tend to give birth to the development of institutions suited to routine fires: Insurance companies, disaster relief agencies and large fire control agencies.

All of these factors aid in the breakdown of normal precautions and start the incubation period. Wildfire disaster incubation periods might best be described as starting with the first significant human settlement and the date when man first began to effectively control fuel reducing fires.

STAGE III

The incubation period of the disaster sequence culminates with a precipitating incident: the unnoticed hazards have been growing in severity and now an ignition occurs starting the disaster in motion - this could be children playing with matches or a bolt of lightning or any other natural or unnatural ignition source.

STAGE IV

The outbreak of an interface wildfire is followed by the onset of unanticipated problems not accounted for by existing fire prevention and suppression techniques. In an interface wildfire, the onset is represented by the intensity, rate of spread, area covered and lives and property lost.

STAGE V

The onset of an interface wildfire is accompanied by fire suppression, rescue and salvage operations. Roads unexpectedly become congested as fleeing residents encounter large emergency vehicles and groups of sightseers. Congestion is compounded by narrow, winding roads, and grades too steep for heavy fire suppression equipment. Water supplies for suppression forces are often exhausted as residents simultaneously attempt to wet down buildings or extinguish flames or no hydrants are present at all. Mutual aid suppression crews who are new to the area may lose their way in a maze of unmarked roads and streets. Equipment shortages, communications, manpower, logistics and so on are all problems that may be encountered during an interface wildfire.

STAGE VI

After the last flames have been extinguished and the community has recovered from the immediate shock of an interface fire, an inquiry may be conducted to determine why accepted precautions proved to be inadequate. Public forums investigate the causes and probe proposals for reducing the likelihood of recurrence. Unfortunately, this stage is too often Stage VI, instead of Stage III, where a disaster may be prevented.

Time and time again this six-step disaster sequence has been played through to its inevitable conclusion. In order to break the cycle we must look at the problems being made in all of the six stages, thus reducing the probability of an interface fire.

Chapter 5

Existing Hazards and Risks

In order to utilize the disaster sequence model to prevent interface wildfire disasters, planners and developers must understand the hazard and risk concepts fully. Even before the first human set foot on the proposed development site, wildfire hazards and risks existed.

The natural wildland hazards existing in the proposed rural development area can be classified into one or more of three major categories, those being fuels, weather and topography. These three categories are the major components controlling wildland fire behavior and must be reviewed in detail to understand their importance in classifying the wildland/urban interface wildfire hazard.

Fuels - Gaylor (1974) defines fuel as "any combustible material adding to the magnitude or intensity of a fire or combining with oxygen to contribute to the combustion process". Wildland fuels may take many forms, but all are or were a living component of the ecosystem. Fire behavior is affected by certain characteristics or properties of the native fuels (Brown, 1978).

1. Moisture Content - Moisture content is an important fuel property in predicting fire behavior. For hazard evaluation, as moisture content drops, hazard increases.
2. Particle Size - Size is usually expressed as thickness or the ratio of surface area to volume. Thin particles have large surface-to-volume ratios. This ratio is important because it relates to heat and moisture exchange. Fine fuels will dry faster and ignite more readily.

3. Quantity - Quantity of fuels determines potential fire intensity. High intensity fires occur in heavy fuel accumulations and are more difficult to control. Increasing the fuel load may also mean a higher rate of spread.

4. Compactness - Compactness refers to the crowdedness of fuel. Combustion occurs at a maximum rate when particles are close enough to receive intensive heat radiation, yet not block the flow of oxygen.

5. Continuity - Continuity refers to the distribution of fuels both horizontally and vertically. Continuity partly controls where a fire can go and how fast it will spread.

6. Flammability - Native fuels vary in the degree of flammability. Moisture content and the chemical composition of the existing vegetation are important factors in determining plant flammability.

Plant communities that possess chemical substances which yield a readily available energy source would tend to be highly flammable and have a frequent incidence of fire, while those possessing chemical inhibitors would be naturally less prone to fire. The energy level establishes the potential flammability, but moisture content of plant communities determine fire seasons with peak flammability (Mutch, 1970). Flammability is directly related to the plant communities' dependence on fire to maintain the seral state.

Topography - the "lay of the land" affects the spread of wildland fire. Topographic components of fire behavior can be broken down into three categories (State of Utah, 1978).

1. Slope - the steeper the slope, the faster a fire will spread. On steep slopes, fire burns sixteen times faster uphill than downhill. As the steepness of the slope increases, the rate of spread increases. The fuels up the slope are closer to the fire's flames than fuels on a level surface, providing for pre-heating and drying by radiation and convection. Fire suppression activities are much more difficult on steeper slopes.
2. Aspect - aspect is the direction that a slope faces. Solar radiation dries out fuels on south and west facing slopes to a greater extent than on north and east facing slopes.
3. Elevation - the elevation above sea level has a direct effect on fire danger through precipitation, temperature and humidity. The higher the elevation, the less the fire danger. Elevation does not play as important a role in the rural/urban interface as most homes are built at lower elevations, yet the effects must be considered.

Weather - weather is the most important factor in determining fire behavior. With a few exceptions, wildfires burn only during the summer months. This is because temperatures are higher and humidity is lower during the summer. Wind, temperature and humidity are the major factors of weather that influence fire behavior.

1. Wind - wind pressure is the driving force giving direction and

high rates of spread. Wind also will carry the radiant and convective heat into unburned fuels and is the causative agent of spot fires. Wind also plays a big role in the drying of fuels.

2. Temperature - the sun or hot winds can heat fuels and cause them to become more flammable by reducing fuel moisture. (See fuel moisture above)

3. Humidity - the amount of water vapor in the air has a direct influence on how easily fuels will ignite and how intense they will burn. Fuel moisture decreases proportionately as the relative humidity of the air decreases. Long extended periods of hot, dry weather create extreme fire danger conditions.

The components listed above influence the ease or difficulty of fire control. Two characteristics of a fire that demonstrate the severity of a fire are rate of spread and flame length.

Rate of spread is used to describe the fire's growth. The term is sometimes used two ways - the forward rate of spread is used to indicate headfire linear rate of advance, and rate of spread-permimeter which gives the length of the perimeter around the fire. (Albini, 1976) The rate of spread is influenced by the steepness of slope, velocity of wind and the fuel complex. A fast "running fire" presents a difficult situation to suppression forces as fire control is difficult and very dangerous.

The flame length is dictated by height and density of the burning fuels, wind speed, steepness of the slope, live and dead fuel moisture, fire spread and other fuel characteristics, such as their arrangement and amount of fine fuels present (Radtke, 1981). Flame length is an indicator of the fire intensity. Byram (1959) defined fire intensity as "the product of the available heat of combustion per unit area of the ground and the rate of spread of the fire". This measure of intensity can be interpreted as the heat released per unit of time for each unit of length of fire edge.

Ability to suppress a wildland fire can be estimated by fireline intensity or flame length. Wildland fires that produce flame length in excess of 30 feet are considered to be burning out of control. Controllability using Byram's intensities are given in Table 2.

These figures help demonstrate the dangers when during a wildfire, flames in excess of 100 feet long can soar over homes located at ridgetops and consume seemingly safe homes a distance away. It has been estimated that 40 acres of heavy chaparral fuels, when oxidized by fire, has the same energy as the atomic bomb dropped over Hiroshima (Radtke, 1981).

Table 2. Fire Behavior, Controllability, and Fireline Intensity

BI-1978	Flame Length (ft.)	Fireline Intensity (BTU's/ft.)	Narrative Comments
0-30	0-3	0-55	Most prescribed burns are conducted in this range.
30-40	3-4	55-110	Generally represent the limit of control for direct manual attack methods.
40-60	4-6	110-280	Machine methods usually necessary or indirect attack should be used.
60-80	6-8	280-520	The prospects for direct control by any means are poor above this intensity.
80-90	8-9	520-670	The heat load on people within 30 feet of the fire is dangerous.
90-110	9-	670-1050	Above this intensity, spotting fire whirls, and crowning should be expected.

Source: Deeming et al., 1977.

Chapter 6

Predicting Wildfire Danger and Behavior

Over the years, numerous systems have been developed for estimating fire danger and predicting expected fire behavior. Development over the last half century has included an attempt in 1914 in California to classify fuels by forest cover types. This system had a simple numerical value attached to cover type, relating acres burned in one hour's time. In 1936, the adjective rating system for the Northern Region was created. Four adjectives - low, moderate, high, and extreme - were used to rate fuel beds for "resistance to control"[1] and "rate of spread"[2]. Areas were rated on weather conditions of the average-worst day. This was the first attempt to look solely at fuels without regard to cover type (Schmidt, 1978). This system is the best known and understood method of informing the masses of local fire danger and is currently still used by all regions to one degree or another.

Wildland managers, however, need a more detailed and explicit method of predicting the day's fire danger. To fill this need the National Fire Danger Rating System (NFDRS) was created utilizing the fuel modeling approach to classifying fuels (Deeming et al. 1972). The fuel modeling approach established the numerical data necessary to describe the fuel complex used in solving Rothermel's mathematical

---

[1]The relative difficulty of constructing and holding a control line as affected by resistance to line construction and by fire behavior.

[2]The relative activity of a fire in extending its horizontal dimensions. It is expressed as rate of increase of the total perimeter of the fire, as rate of increase in area, depending on the intended use of the information. Usually it is expressed in chains per hours or acres per hour for a specific period in the duration of the fire (Gaylor, 1974).

formula for determining fire spread (Rothermel, 1972). Rothermel's model is the basis for most of the current fire management modeling. Albini (1976) expanded on Rothermel's formula in his fire behavior nomograms.

The integrator of the three fire behavior influences - fuel, weather, and topography - is the fire itself (Schmidt, 1978). The integrated approach requires the description of the three fire behavior influences. Fuel can be described through a fuel inventory or by using the fuel model key to describe to the nearest fuel model (Deeming, et al., 1978). Weather elements can be defined at a fixed planning level, such as the 90th percentile of the "worst fire weather day" or "an average bad day". Topographic influences can be measured, averaged or determined through the use of topographic maps.

With the fire behavior models available, it is an easy step for forest managers to compute the fire danger or the expected fire behavior for their area of responsibility. The computation of the NFDRS figures can be done manually (Burgan, 1977) or through the interactive computer program AFFIRMS (Helfmen et al., 1975). The AFFIRMS program has a link called "firecasting" that will solve Rothermel's complicated spread model or the TI-59 calculator can be used with a preprogrammed chip for on-the-site calculations (Burgan, 1979). Or Albini's nomograms can be very useful for predicting the expected fire behavior using site specific data.

Using the above mentioned models, the probability of a fire and its behavior once started can be predicted. Yet an effective method of assessing the overall hazard was needed. Fire hazards are relative and range from a base level hazard found in any urban area to the extreme hazard found amid heavy chaparral on a steep side hill in an area where extreme fire weather occurs. Thus classification systems have been developed to identify those areas which present varying degrees of fire hazard, including those so hazardous that no construction or development should be allowed. Many land fire hazard classification systems are being utilized today with some meeting the total fire safety needs better than others. Four of the classification systems seem to meet the country's needs quite well and could serve as models for local classification systems to better deal with the wildland/urban interface fire problems.

Colorado - The Colorado State Forest Service contracted an agreement with Fahnestock (1971) to compose a system to rate the forest fire hazard of residential developments in Colorado. Fahnestock compiled five fuel classes to distinguish different levels of fire hazard on the basis of expected fire behavior. (See Table 3). The likelihood of a crown fire occurrence is the prime criterion for defining three classes. A fourth class represents non-arboreal fuels that can support high-intensity fires under some circumstances. Fahnestock completed his classification system with a fifth class which includes all examples of no hazard.

The disaster potential increases through the classes O, X, A, B, C. Class A and X are likely to have fast-spreading fires due to the abundance of fine surface fuels. The usual fire in classes B and C is a slow-spreading, low-intensity and easily controlled affair. However, dry conditions coupled with wind or slope could produce an inferno that could wipe out a residential development. Slash is not given as a hazard class but because of the danger it creates, increases any hazard class where slash is present to a class C (Fahnestock, 1971).

Table 3. Fire behavior and vegetation characterizing fire hazard classes.

Hazard Class	Expected Fire Behavior	Vegetation (Fuel)
0	None	None (open water, bare rock, cultivated field, etc.)
X	Flames 5-20' high, of brief duration; fire spread usually fast, at least 40 acres per hour; human being cannot safely pass through flames but can occupy just-burned area within about 15 minutes; short range spotting common from blowing leaves.	Dense to moderately dense flammable vegetation $\leq$ 10' high, including Gambel oak (in fall), big sagebrush, conifer reproduction; abundant litter and/or herbaceous fuel; scattered conifer stand may be present.
A	Flames $\leq$ 5' high, higher flare-ups rare; duration of highest flames brief; fire spread slow to fast, 1-40 acres per hour; human beings can run through flames without serious injury and can occupy just-burned area; spotting generally rare, short range.	Grass, weeds, brush $\leq$ 1' high deadwood in contact with ground; open conifer stand may be present; includes aspen, cottonwood, willow, grassland, brush other than oak, sage or ceanothus.
B	Intermittent flare-ups occurring to many feet above tree tops; short and medium-range spotting common; behavior between flare-ups as in Class A; passing through fire front sometimes possible but chancy; parts of burned area can be occupied within ½ hour.	Medium-density conifer stands surface fuel mainly herbage and litter; some patches of reproduction and deadwood; becomes Class C if slash is present.
C	Flare-ups higher than trees frequent to continuous; spread up to several hundred acres per hour; fire front impassable; spotting several hundred yards common, possible to a mile or more; just-burned area untenable for an hour or more.	Dense conifer stands with any surface fuel; medium-density stands with Class X fuels or much deadwood from blowdown, bug-kill, or logging.

Source: Fahnestock (1971).

California - Some areas of California have recognized the severity of the wildland/urban interface fire problem long ago and have had crude hazard classification systems. More recent attempts to classify fire hazard are based on three weighted values, each of fuels, weather and topography (Helm et al., 1973). This is probably a better approach to fire hazard classification or zoning from the standpoints of both technically correct theory and practical application (Moore, 1981).

Helm's hazard classification breaks environmental factors into three groups each. (See table 4) Fuel loading is stated as light (grass), medium (scrub) and heavy (woods-chaparral). Slope is broken down into three groups by steepness, 0 to 40 percent, 41 to 60 percent, and above 60 percent. The critical fire weather is divided up into three groups I, II, and III based upon the number of days of critical fire weather expected each year. The weather elements responsible for extreme fire danger are high temperatures, low humidity and strong winds. In California, the foehn winds play the biggest role in determining critical fire weather.

Table 4 - Fire hazard rated on three weighted values of weather, fuels, and topography in California wildlands.[1]

Critical fire weather frequency	I			II			III		
	Slope (pct.)			Slope (pct.)			Slope (pct.)		
Fuel loading:	0-41	41-60	61+	0-40	41-60	61+	0-40	41-60	61+
Light (grass)	M	M	M	M	M	M	M	M	H
Medium (scrub)	M	M	H	H	H	H	E	E	E
Heavy (woods-brushwood)	H	H	H	H	E	E	E	E	E

Source: Helm and others (1973)

[1] M = moderate hazard, H = high hazard, E = extreme hazard.

Utah - The hazard system in use by Utah is quantitative in nature. The system considers five separate factors, slope, aspect, weather, response time from nearest fire department and fuel type. Each factor is calibrated into five separate ratings. The ratings are based upon the relationship to the rate of fire spread and resistance to control. (See table 5) (State of Utah, 1978).

To use this fire hazard severity scale the builder, local fire authority or planning commission reviews a proposed building site and rates the development by the five factors to arrive at a composite score.

Slope - is measured in percent
Aspect - is the cardinal direction in which the ground surface faces
Weather - is measured in number of critical fire weather days per year for a given area.
Response time from the nearest fire department - is measured in minutes it takes the nearest responsible fire department to respond to a fire alarm in the given area.
Vegetation - is categorized by fuel types. Rate of spread, resistance to control and potential to cause structural damage are the criteria for rating severity.

Utah's hazard classification is tied directly to the wildland subdivision regulations. Development services, construction restrictions, and building densities become more restrictive as the hazard rating class increases in severity.

Table 5. Wildfire Hazard Severity Scale

Rating	Slope	Aspect	Weather	Response Time From Fire Dept.	Vegetation
1	≤10	N	≤1	≤15	Pinyon-Juniper
2	20	E	3	30	Grass and Sagebrush
3	30	Level	5	45	Hardwoods
4	45	S	7	60	Mountain Brush
5	≥60	W	≥9	>60	Softwoods

Wildfire Hazard Classification Table

Rating	Hazard	Classification
5 to 11	Moderate	1
12 to 18	High	2
19 to 25	Extreme	3

Source: State of Utah (1978).

Montana - In recent years, researchers and land planners have recognized the need for western Montana's rural areas to be hazard classed. Fischer (1978) compiled the "Proposed Fire Hazard Classes for Montana Wildlands" to provide an aid to land planners. Fischer's fire hazard classes are styled after Fahnestocks system with five classes distinguishing different levels of fire hazard. (See Table 6) Class "0" fuel consists of no fire hazard. The classes then range through increasing fire hazard to class "4" which consists of a dense conifer stand greater than 55 percent crown coverage and having vertical fuel continuity into the tree crowns.

Hazard classification systems provide land developers and land-use planners with a much needed tool to quantify the wildland fire danger in rural areas. To be employed as a tool in zoning and regulating areas, the classification system must be easy to understand yet detailed enough to provide sound information. As a regulatory aid, hazard classification systems must be based on the present state of knowledge and minimize any bias in order to withstand legal scrutiny.

Various tools are available to assist the hazard classifier in his duties. The more obvious ones being a compass and clinometer for determining aspect and slope. Weather records are kept in some manner for the majority of the country. Recently a series of photo guides for appraising downed woody fuels in Montana forests was published by the U.S.D.A. Forest Service (Fischer, 1981). The photo guides provide an estimate of the downed woody fuels as well as an estimate of: rate of spread, intensity torching, crowning, and resistance to control for an average bad day (85-90° F. temperature, 15-20% R.H., 10-15 mph wind and four weeks since last rain). The photo guides also give the fire ecology group as defined by Davis and others (1980). This type of ready-made information is invaluable to land-use planners as it is easily shown and explained to developers and homebuilders. By substantiating hazard classification systems with accurate and current data, the relative fire safety will grow.

TABLE 6

VEGETATION AND FIRE BEHAVIOR CHARACTERIZING PROPOSED FIRE HAZARD CLASSES FOR MONTANA WILDLANDS

Hazard Class	Vegetation (Fuel)	Expected Fire Behavior
0	None (open water, bare rock, cultivated field, etc.	None
1	Grass, weeds, shrubs, 2 feet or less in height; deadwood in contact with ground; open conifer stands with 0-35% crown coverage; also stands of aspen, just-burned willow; grassland and shrublands other than ceanothus. Where slash is present these stands become Class 3.	Flames less than 5 feet high, higher flareups rare; duration of highest flames brief; fire spread slow to fast, 1-40 acres per hour; human beings can run through flames without serious injury and can occupy just-burned area; spotting generally rare, short range.
2	Dense to moderately dense flamamble vegetation 2 feet or greater in height, including shrubs, conifer reproduction, abundant litter and/or herbaceous fuel; scattered conifer stands may also be present.	Flames 5 to 20 feet high, of brief duration; fire spread usually fast, at least 40 acres/hour; human beings cannot safely pass through flames but can occupy just-burned area within about 15 minutes; short-range spotting common.
3	Medium density conifer stands with 35-55% crown coverage and surface fuels of mainly herbage and litter and some patches of conifer reproduction and deadwood. Includes old-growth conifer stands with light surface fuels regardless of crown coverage. Where slash is present or where surface fuels extend to lower part of tree crowns, these stands become Class 4.	Intermittent flare-ups occurring to many feet above treetops; short and medium range spotting common; behavior between flare-ups as in Class 1; passing through fire front sometimes possible, but chancy; parts of burned area can be occupied within one-half hour.
4	Dense conifer stands greter than 55% crown coverage with vertical fuel continuity into tree crowns. Also includes medium-density stands with dense to moderatley dense understories of flammable shrubs, conifer reproduction, abundant litter and/or herbaceous fuel.	Flare-ups higher than trees frequent to continuous; spread up to several hundred acres per hour; fire front passage impossible; spotting several hundred yards common, possible to a mile or more; just-burned area untenable for an hour or more.

SOURCE: Fischer (1978).

Chapter 8

The Regulation of Subdivisions

Every state in the Union has restrictions as to how land can be developed. Some states have very detailed and restrictive planning laws protecting wildlands from the scars of urban sprawl. Many states, however, are just realizing the rural revival impact and are struggling to maintain order by implementing land use planning.

Montana is one western state that is seeing an accelerated rural growth and corresponding demands being placed on resources. During the past decade of growth in Montana, there has been a growing public interest in private decisions relating to land use. Montana is an excellent example of a state where land planning is deficient and reform and improvements needed.

Recognizing the statewide impacts of land development, the Montana Legislature passed the "Subdivision and Platting Act" in 1973. Also in 1973, the "Sanitation in Subdivisions Act" was enacted to require that the Department of Health and Environmental Sciences approve sanitary facilities for all new subdivisions (Burden, 1980).

The Subdivision and Platting Act was designed to prevent haphazard, unplanned development by subjecting subdivisions to public scrutiny and minimum standards through a comprehensive review process. The Act set forth explicit subdivision design criteria which had not existed before and created an involved review process to insure subdivisions met design standards and were in the public interest. The Act is administered by the State Department of Community Affairs and local municipal and county governments. The introduction of the Subdivision and Platting Act clearly states its intent, "It is the purpose of this act to promote the public health, safety, and general welfare by regulating the subdivision of land; to prevent overcrowding of land; to lessen congestion in the streets and highways; to provide for adequate light, air, and water supply, sewage disposal, parks and recreation areas, ingress and egress, and other public requirements; to require development in harmony with the natural environment; to require whenever necessary the approval of subdivisions be contingent upon a written finding of public interest by the governing body." All local governments were required to adopt subdivision regulations within their jurisdictions by 1974 or the State Department of Community Affairs would set regulations for them.

"Subdivision" as defined by the act is a division of land creating one or more parcel of less than 20 acres. Before a 1975 amendment "subdivisions" were parcels less than 10 acres. All subdivisions would be subject to review.

Because the regulation of subdivisions is also political, the laws are subject to intense differences of opinion and to public controversy. The law included many exemptions to the review requirements. The exemptions were intended to allow some flexibility in the law for people who were not developers but wished to make occasional sales of land. The exemptions used most often include:

1. Acreage Exemption: The Subdivision and Platting Act of 1973 specified that any parcel 10 acres or larger was not considered a subdivision and, therefore, was exempt from review. In 1975, the acreage qualification was increased, and parcels need to be 20 acres or larger to be exempt.

2. Family Conveyance: Parcels of any size may be given or sold (without review) to members of the landowner's immediate family. One parcel per family member per year is permitted; a second parcel must be approved by the governing body.

3. Occasional Sale: Landowners may sell one parcel of land of any size once a year. This definition has been interpreted to apply only to the land, not the owner. Thus, a person owning two, noncontiguous pieces of land may make two occasional sales within one year, one per piece of property.

4. Agriculture Covenant: Parcels created with a covenant running with the land that the land will be used exclusively for agriculture purposes are exempt from review. The covenant is only revocable by mutual consent of the property owner and the governing body.

5. Court Order: Division of land by an order of the court in absence of agreement between the parties to a sale are not considered subdivisions.

Parcels qualifying for one of the above exemptions to the review process are still required to be surveyed with proper monumentation. A proposed parcel then goes through an informal review by the county attorney and the planners. A formal review by the county sanitarian is requested on all parcels of less than 20 acres in size to lift the sanitary restrictions. The parcel is then documented on a certificate of survey which must be properly filed with the clerk and recorder before a sale can officially take place.

The exemptions cover land division in cases where little or no impact should occur, provided they are not used to evade the purpose of the law. However, individually and in combination, the exemptions (these five in particular) are used chronically by developers who do not wish to have their subdivision reviewed. If these exemptions were used in subdivisions here and there, infrequently and in isolation, there might be little cause for public concern. However, they are being used to an alarming extent. For example, Department of Community Affairs statistics show that for nine Montana counties, 70% of the total acreage subdivided into parcels 20 acres or less since 1974 was divided by exemption - without public review and with no assurance that the potential impacts of these subdivisions would be minimized (Burden, 1980). In certain counties, unreviewed subdivision accounts for 90-93% of the total acreage subdivided in recent years. (See Table 7)

Is the use of exemptions making the Subdivision and Platting Act an ineffective tool to "improve the quality of land development" as described by law? The large percentage of unreviewed subdivisions in Montana in past years implies that it is. It is impossible to judge the quality of unreviewed developments as their design and impacts cannot be evaluated on the basis of information provided on certificates of survey filed with local governments. A certificate of survey shows only that the land division has qualified for exemption, has been surveyed by a registered surveyor, and has met the sanitary requirements of health officials.

State planning officials believe there has been improvement in the quality of land development which has been reviewed since the passage of the subdivision law. In-depth examination of proposed subdivisions by professional planners as well as environmental assessments and community impact studies have provided useful information for public and governmental evaluation of subdivision activity.

By using the exemptions to the subdivision law, developers circumvent any public review, but would the review process provide the protection and regulation needed. In Missoula County, Montana, the written guidelines for subdivision review are contained in "The Subdivision Regulations of the County of Missoula, Montana" as authorized by the Montana Subdivision and Platting Act (Missoula County Subdivision Regulations, Resolution 78-68, 1978). Missoula's subdivision regulations consist of guidelines to assist the county commissioners in deciding to allow or not allow a subdivision. The procedures go into great detail as to the survey of land, monumentation, plans and fees. The "Design and Improvement Standards" include six pages dealing with road construction; two pages for parks and open spaces; sewage, solid waste and drainage are dealt with as well as a two-page appendix for flood hazard evaluation. These items all serve to provide for a quality and safe community environment. Yet the areas covered by the Missoula County Subdivision Regulations are lacking body and have almost totally ignored the area of fire protection for the proposed community. Wherever the regulations discuss the water supply for the proposed subdivision, the statement: "Any system shall be designed to provide an adequate and accessible water supply for fire protection purposes." At no time do the subdivision regulations make reference to any ater supply standards such as NFPA-1231, "Suburban and Rural Water upplies" (National Fire Protection Association, 1981).

The one point that the local fire protection agency is allowed input nto the subdivision review process occurs during the "Environmental and ommunity Assessment" Review. The outline for this review covers six ages of topics ranging from surface water to wildlife to housing. The opic of fire protection is summed up in one sentence, "Discuss provi-ions for fire protection in the proposed subdivision." No emphasis is laced upon the surrounding natural hazards, past fire occurrences, or otential for extreme fire behavior.

The review of fire protection for a proposed subdivision is intended o expose any existing fire problems and bring them to the attention of he county commissioners. A detailed method to document the extra load hat a new subdivision will place on existing fire protection services s not presently in use. Some developers will work freely with the ocal fire chief to evaluate fire protection while others will deliber-tely refuse to provide any assistance. When the fire protection review s completed, the fire department enjoys no authority other than a ecommendation made to the county commissioners. The commissioners eva-uate all recommendations and make a final decision allowing or isallowing the proposed subdivision. (Personal communication, hief Bruce Suenram, 1983). In addition to the possibility that only a uperficial review of fire protection will be completed during the nvironmental and Community Assessment, the Missoula County Subdivision egulations contain an exemption to the assessment review. As stated Section II, A.9., of the Missoula County Subdivision Regulations:

"Subdivisions in compliance with the following criteria are deemed to be in the public interest and are exempt from the requirement of an environmental assessment:

1) Within the Missoula Urban Area or Missoula County Comprehensive Plan as adopted pursuant to Sections 11-3801 through 11-3856, R.C.M. 1947.*

2) Where zoned pursuant to Sections 11-1701 through 11-1709 or Sections 16-4701 through 16-4711, R.C.M. 1947.

3) Where a long-range development program of public works projects pursuant to Section 11-3831, R.C.M. 1947, has been adopted.

This exemption has never been used (so stated by Missoula County Planning Board) but remains in the law as a potential loophole.

Thus, the problems within the Missoula County review system are two-fold. First, the large number of acres that go unreviewed each year (between 1974 and 1979 almost 39,000 acres or 91% of the total) and the superficial review of fire protection for those subdivisions which are properly platted. The average time period for fire protection review (from the date first notified to when recommendations are needed) averages less than ten days.

These types of problems plague not only Missoula County, but most rural counties in the state of Montana and all across the United States.

*All of Missoula County is covered under the Missoula County Comprehensive Plan.

Table 7. Acres Subdivided in Three Western Montana Counties

MISSOULA COUNTY
Acres Subdivided by Plat (Reviewed) & Certificate of Survey (Unreviewed)

Year	Plats	COS*	Total Acres (Plat & COS)	% Unreviewed
1973	1,077.44	4,642.05	5,719.49	81.1%
1974	70.01	8,787.04	8,857.05	99.2%
1975	104.48	1,810.46	1,914.94	94.5%
1976	110.06	2,530.14	2,640.20	95.8%
1977	399.88	5,464.99	5,864.87	93.1%
1978	888.10	8,485.43	9,373.53	90.5%
1979	1,049.94	7,203.003	8,252.94	87.2%
TOTALS	3,699.91	38,923.113	42,623.02	91.3%

*COS = Certificate of Survey

RAVALLI COUNTY
Acres Subdivided by Plat (Reviewed) & Certificate of Survey (Unreviewed)

Year	Plat	COS	Total Acres (Plat & COS)	% Unreviewed
1974*	74.69	2,008.13	2,082.82	96.4%
1975	30.36	4,437.38	4,467.74	99.3%
1976	308.79	3,253.59	3,562.38	91.3%
1977	500.16	7,134.36	7,634.52	93.3%
1978	1,275.03	10,822.24	12,097.27	89.0%
1979	537.35	6,799.86	7,337.21	92.7%
TOTALS	2,726.38	34,455.56	37,181.94	92.7%

*July - December

GALLATIN COUNTY
Acres Subdivided by Plat (Reviewed) & Certificate of Survey (Unreviewed)

Year	Plat	COS	Total Acres (Plat & COS)	% Unreviewed
1974	1,239.20	7,878.33	9,117.53	86.4%
1975	1,041.53	4,175.21	5,216.74	80.0%
1976	99.41	5,644.70	5,744.11	98.3%
1977	867.16	9,648.54	10,515.70	91.8%
1978	634.70	8,122.28	8,756.98	92.8%
TOTAL	3,882.00	35,469.06	39,351.06	90.1%

Source: Burden (1980).

Chapter 8

Subdivision Design

To better discuss the fire protection shortcomings within a new subdivision, the subdivision plans should be reviewed for design problems which may compound fire protection difficulties.

Property Development and Planning

The developer of a property can provide some of the vital means of fire protection, such as access and water supply. It is the developer's responsibility to know about them and to design them into the property before any structures are erected. All development plans should employ the master planning concept in order to properly assess the interactions between various elements.

Access

One of the most important aspects of land development from the fire protection viewpoint is access. It involves a great deal of engineering and expense and is impossible to improve or alter after development is complete. If inadequate, access can become a critical factor during a conflagration, both from a firefighting standpont and with regard to life safety (Moore, 1981).

Adequate ingress and egress are necessary to allow safe and rapid passage of both fire equipment and private vehicles in opposite directions simultaneously.

The review of past fires has demonstrated the road network has proven to be the downfall of many suppression activities. Roads become clogged by families trying to escape the fire while suppression forces are bogged down by steep grades on narrow roads. Developers often save noney by constructing bridges to support only light vehicles and small trucks. This construction would not support heavy fire equipment and large water tankers. This limits the access of fire control forces to the fire. Road construction contractors building in timbered areas have traditionally piled slash from the clearing activities on the downhill side of the new road. This clearly creates a severe fire hazard when this slash is ignited during a wildfire situation.

Water Supply

Water is still the most effective tool for fighting wildland fires when and where it can be obtained in sufficient quantity. It is really the only effective tool for fighting home and other structural fires. Therefore, a large, dependable source of water above that required for normal daily domestic purposes must be provided for at the time a subdivision is planned and developed.

The amount of water reserved for firefighting purposes and the size and type of delivery system depend on the required fire flow as determined by the local fire department. The water requirements for multiple occupancies are usually stipulated by the insurance carrier or local fire department, or both. Although normally based on requirements for fighting an interior fire, they are usually adequate for protecting the building from an encroaching wildland fire as well.

Adequate water for firefighting purposes, either by a fire department or by the occupant has been unavailable and unreliable on many occasions where homes were involved. In some cases, adequate water was available but not developed, as the potential fire problem was not recognized. In other situations the problem was recognized but considered a remote possibility. Sometimes the cost was considered too high. Sometimes a sufficient water supply was not available at any price. A common cause of water deficiency is the practice of extending or adding on to a subdivision where the water system was adequate for the original development and is adequate for domestic service to the addition, but is insufficient to provide fire flow both to the original and to the additional developments (Alger, 1971).

In contrast to normal daily use, consumption of water for firefighting purposes is of relatively short duration, but of high volume. Water is also used during emergency conditions when electric power service may well be interrupted. Different engineering, therefore, is required than would be needed for a purely domestic water system. Water supplies for firefighting involve large storage facilities, high volume mains and dependable delivery. Many developments rely on the fire department to provide their own water. This normally takes the form of large cumbersome tankers which easily tax the limitations placed on bridge capacity and roads constructed in the development.

Spacing and Building Density

To provide a reasonable degree of fire safety, building spacing and density must be different in mountainous areas, wildlands, and rural areas than they are in urban areas. This differentiation is needed because the usual source of ignition of the structure in the wildland or rural setting is external, while in the more developed city situation it is internal (Alger, 1971). In addition to being subject to external ignition and long response times, structures built on sloping ground are affected by the same fire behavior phenomenon discussed earlier in relation to the wildland fuel. The slope creates an effect similar to that of wind and causes fire to spread faster uphill than downhill or on the level. Buildings situated on slopes are exposed to more intense heat for longer durations and therefore are more likely to become involved with fire during a wildfire situation.

Electric Power Distribution

Overhead transmission and distribution of electric power is a major source of ignition for the wildland fires that have destroyed many hundreds of homes in California and elsewhere in recent years. Contrary to popular belief the large high voltage transmission lines are not the worst offenders. In one study they accounted for less than 8% of the fires over 5,000 acres in size. They are commonly built of sturdy materials, maintained with adequate vegetation clearances, and inspected frequently and thoroughly (Moore, 1981).

Distribution circuits accounted for nearly 17% of California's wildland conflagrations. Distribution circuits are of two types: primary and secondary. Primary circuits bring the power from the substation to the user's transformer. Primary electric power distribution circuits are a major serious cause of wildland fires. The thousands of miles of these lines present a tremendous exposure and an almost insurmountable problem of inspection and maintenance. Secondary circuits, which convey power from the transformer to the point of use, usually cause fires because of inadequate vegetation clearance which is not now regulated by any state or local laws. Secondary circuits cause nearly one fire for every two caused by primary distribution lines (Moore, 1981).

Street Names and Numbers

Subdivisions are usually provided with visible street names and numbers and lot or building numbers as a convenience to the buyers and visitors. Often, however, the signs are hard to read, sometimes even difficult to find. Many rural and mountain areas have become essentially urbanized through lot-splitting and other sale of individual parcels and subsequent construction, and in these situations there is no developer to assign names and numbers.

Positive identification of location is not merely a convenience to a firefighter or other public safety officer responding to a reported emergency or radioing for help; it is an absolute necessity. Neighboring fire departments responding to a mutual aid emergency will become easily disoriented or lost without positive identification of roads and addresses.

Rural Fire Protection

Very little consideration for fire protection is given during the planning process. Many developers feel that fire protection will be provided by existing fire departments. This increase in service demand may quickly overtax the capabilities of the existing department, causing a reduction in service quality. Existing fire stations in wildland areas usually are not located correctly, nor are they manned and equipped adequately to provide structural fire protection to subdivisions and other developments. Developers of large subdivisions should recognize this deficiency and dedicate one or more sites for structural fire stations at the outset. After development is complete, suitable sites will no longer be available.

The role of protection agencies must be understood by planners and developers. Most wildland fire protection agencies are not charged with the responsibility for, nor equipped to deal with, structural fires. Their job is to prevent and extinguish forest and other wildland fires.

Their standards of attack time and pumping capabilities are much different than those of city fire departments. Typically, they have response times of one-half hour or more. Other fires in the protection area can lengthen this response time. Their trucks arrive with tanks containing 500 gallons of water or less which is pumped at 60 to 70 gallons per minute. By contrast, structural firefighting requires response time of less than 10 minutes and high volumes of water produced at high pressures.

In the Northwest, state fire protection agencies providing wildland fire protection are funded primarily by assessments on forest landowners. Local non-forest landowners pay little or nothing to support these agencies. The U. S. Forest Service, Bureau of Indian Affairs and Bureau of Land Management are charged with the protection of the federally managed forest and rangelands. These federal agencies are not responsible for providing fire protection to private lands, except when a fire might threaten federal land.

Another limiting factor is that forest and wildland fire protection is available only during the summer fire season. Once fall rains start, crews are terminated and equipment is assigned to other work or placed in storage. Current forest and wildland fire protection does provide an adequate level of protection to these resources, but it does not offer dependable and adequate protection for homes located within other wildland/urban interface areas.

Between the two extremes of the urban fire department and the forest ire protection agency, exists the rural fire protection district. The fficiency of these departments varies greatly. Those that exist next o urban areas are as capable as neighboring city fire departments. hose far removed from population centers may have inferior equipment ianned strictly by volunteers with long response times and provide only iinimal protection. The advantage the rural fire districts have over wildand fire protection agencies is that they are providing services the ear round.

Structural Design and Construction

Because of the behavior of wildland fires, how a building is lesigned and constructed is the most important factor in providing fire afety to that home or structure. Homes built by fire-safety-conscious ontractors can survive conflagrations even if many other protective easures are absent. Even homes apparently well separated from wildland egetation will be destroyed if poorly designed and if constructed without egard to fire safety. The architect and building contractor, thereore, are key figures in providing safety. Building inspectors, financiers, insurers and buyers need to be knowledgeable and be able to exert ressure that will guarantee adherence to fire-safe practices in design nd construction (Alger, 1971).

oofing

The roof is the most vulnerable part of a building during a fire. ecause of its horizontal component, a roof can catch and hold the lying firebrands almost invariably associated with the strong winds and nvection columns characterizing wildland/urban wildfires. Unlike groundfire, these firebrands soar beyond any type of firebreak, natural or artificial, and thus endanger structures as far as a mile away from the wildfire (Alger, 1971, Moore, 1981).

A study by the Stanford Research Institute on homes burned in the 1961 Bel Air fire showed clearly that homes with wood shingle roofs unapproved by fire insurance standards fared much worse than homes with tile, composition, or flat modern roof types. The destruction rate for houses with wood shingle roofs was nearly three times the rate for houses with approved roofs. The importance of roof types becomes even more dramatic when the effects of roof type and brush clearance are considered simultaneously. For example, the rate of destruction for houses with unapproved roofs and brush clearance of less than 10 feet was greater than 50%; the comparable rate for houses with approved roofs and brush clearance greater than 100 feet was less than 1%. The difference is greater than a factor of 50 (North, et al., 1973; Radtke, 1981).

In his report on the Bel Air fire, Rexford Wilson (1966) made an even stronger conclusion about the importance of roof type and brush clearance. Wilson held that spotting by wood shingles was an important contributor to fire spread, and the existence of wood roofs increased the probability that other homes would be destroyed:

> "Had there been no combustible roofs on the buildings in Bel Air, fire would have been forced to burn buildings by direct exposure. This fast advancing fire line, even with normal spot fires, could be identified, followed and usually defended against. Had roofs been fire retardant, each fire firefighter would have been able to defend more homes, thus, available forces could have stretched significantly further.
>
> Had the wood shingles not been present, there would not have been the three major jumps far ahead of firefighters. As a result, in my judgment, had wood shingle and shake roofing not been present, there would have been between 350 and 430 homes saved. Thus, with all the other factors the same but with fire retardant roofing, the

> building loss in this fire probably would have been reduced to between 50 and 130 homes. The serious brush fire in Bel Air would have remained a serious threat, but with proper design an estimated 450 to 470 homes could have been spared destruction."

Another example of the hazard wood roofs pose is evident in the Rolling Hills fire, 1973. The fire burned 897 acres and destroyed 12 homes south of Los Angeles, mostly in the city of Rolling Hills. Of these 12 homes destroyed, it was determined that at least 9 had roof ignition. In three cases, this was determined from neighbors who had observed the fire. Six of the other homes had so much green vegetation remaining around them that they must have been ignited by embers landing on the roof. Brilliant flowers were still blooming less than four feet from the foundation of one house (North, et al., 1973).

Shake and shingle roofs were an important factor in the overall damage. The only remaining house on Running Brand Road had an asbestos roof, while the three houses destroyed there all had shake or shingle roofs. What makes the surviving house even more dramatic is that it had a birdhouse sitting on the roof, which was destroyed by fire. The birdhouse had a shake roof.

Recognizing this vulnerability to fire from external sources, the uniform building code requires "fire retardant roof coverings" in fire zones 1 and 2, the high value and high life hazard areas in or near the business sections of cities. Many local jurisdictions have adopted the UBC by reference or by basing their own code on it. A few local jurisdictions have amended the Uniform Building Code (UBC) or their own codes to require "Class C" or better roofing (as defined in UBC Standard 32-7 in wildfire hazardous areas. Most wildland areas still ıave no requirements regarding roofing materials (International :onference of Building Officials, 1976; Moore, 1981).

Most structures at or near the wildland/urban interface are either ıot covered by a building code, are in fire zone 3, or are permitted to ıave any type of roofing material, or at most, Class C roofing. (See Appendix D) In the past 30 or 40 years, wood shingles or shakes have become popular with architects and buyers alike. Various fire retardant treatments have been available for 20 years, but only in the past ten years or so have any of them been made relatively permanent. Although shakes and shingles with Class C ratings are available, none meets the Class B requirement for "fire retardant" roofs as defined in UBC standard 32-7. Treated shakes or shingles cost more than untreated, and in the absence of local codes requiring them, are seldom installed. Thousands of homes and other buildings exposed to the threat of wildland fires, therefore are roofed with either untreated shakes or shingles, with ones that were merely dipped in fire retardant chemicals, or with ones that the treatment has been leached by the weather. These roofs are not only serious hazards to the buildings on which they are installed, but also to other buildings downwind from them which are similarly roofed. Once a shake or shingle roof catches on fire, shakes or shingles peel off and are carried as new firebrands n the convection column and the wind (Oregon State Dept. Forestry, 978).

ents

Another front open to the attack of homes by wind-born firebrands is ı unprotected attic or underfloor vent. Although unprotected vents are ɔt as well documented as a cause of structure fires as flammable roofs, lying embers can easily enter a structure through such vents. If they and on any ignitable material, the inaccessibility of the interior to uppression efforts almost certainly will lead to the destruction of the ouse.

verhangs and Stilt Construction

Two other common architectural practices present serious fire azards to a home built in or near the wildlands: (a) overhanging or rojecting members, such as eaves, balconies, and raised sundecks, which re likely to be found anywhere and are always dangerous; and (b) stilt onstruction. The latter, although dangerous anywhere, is particularly o on sidehill sites because the uphill side forms a trap for onvective heat and flames. The danger is caused by flammable aterials and vegetative fuels being under the building and is aggra- ated by uphill winds (Moore, 1981).

Structures with overhangs or stilt construction, or both, are sually ignited by flames sweeping against the underside of the projec- ion or the building itself. A wildfire running uphill ahead of a strong ind through heavy brush or timber to within a few feet of a house built ı stilts and with a cantilever balcony and with 4 to 5-foot eaves is a ɔsitive prescription for disaster. This sequence is not as uncommon ; it might sound. Hillside homes often offer spectacular views, and ılconies are often provided to take full advantage of the view. Wide ıves are commonly built to shade windows. On a hillside, one side of a ıuse may be at ground level or below while the other side is 15 or 20 ·et, or possibly more, above ground level (Deeming and others, 1977).

Glass

Windows can easily be a weak point in the fire protection of a home for two reasons. They allow entrance of radiated heat of such intensity that interior materials are ignited. And they admit convective heat, firebrand, or flame when they are open or broken. Large picture windows and sliding glass doors are particularly vulnerable to these hazards. The orientation of the glass surface will determine the degree of hazard it represents. If it is on the windward side of the building or is facing toward a concentration of vegetative fuel, the danger is heightened. This is common as most people wish to catch the view on the downhill side of the home.

Windows cannot be abandoned or prohibited. The opportunity to enjoy a spectacular view or the feeling of spaciousness afforded by a sliding glass door opening onto a patio, sundeck, or swimming pool is hard to give up.

Siding

Most home fires in urban areas have internal sources of ignition. Therefore, the materials of which their exterior walls are constructed are of relatively minor importance from a fire protection standpoint. The architect, therefore, has considerable latitude in design. By contrast, home fire ignitions during a wildfire are almost entirely external (assuming all openings are protected). Thus, fire resistancy of exterior walls becomes of great importance, and the choice of materials is critical. Contrary to this safety requirement is the strong tendency on the part of both architect and buyers toward an increasingly rustic appearance as the homesite gets deeper into the woods. As a result many structural fires in rural areas have started by direct ignition of exterior wood siding, garage doors, and porches. This hazard is heightened by rough-cut timber utilized as exterior siding.

Landscaping

The proximity of a structure to native vegetation is the direct measure of the probability of its destruction by wildfire sooner or later. Flammable roofs and inadequate brush clearance are by far the most significant contributors to hazards and their elimination would provide the most cost-effective prescription (Radtke, 1981; North, et al., 1973; Moore, 1982). Non-flammable roof and brush clearance are not the only protective measures needed; however, they are the most critical and, if resources are limited, should receive top priority (Alger, 1971).

Total removal of all vegetation for a specified distance from a house is impractical for several reasons. Not only would the resulting denudation be unsightly, but it would create several other problems. The obvious alternative is suitable landscaping. In its simplest and least expensive form, such landscaping would be essentially the removal and reduction of flammable fuels around the construction site. In its most advanced form it might take the shape of an irrigated and shaded lawn or an intricately designed planting of carefully selected fire resistant or low fuel-volume plants (Radtke, 1981). In any event, the purpose is the same: to reduce heavy loading of vegetative fuels sufficiently far from the structure to avoid ignition of the building by radiated heat or direct impingement of flames and to allow firefighters a place in which to work when it becomes necessary to save the house (Alger, 1971, Moore, 1981).

Native Vegetation

The first step in landscaping for fire protection is to remove flammable native vegetation, including all slash and vegetation waste created during the construction phase. California state law, (Section 4291, Public Resources Code) and ordinances of several local jurisdictions require minimum clearance for 30 feet (Moore, 1981). A few local ordinances require it for 100 feet, but these laws and ordinances generally do not mean complete denudation of the land. The key word is flammable, usually interpreted to mean all dead vegetative matter and enough live crowns to avoid the direct spread of fire from one tree or bush to another. To complete the job properly, remaining crowns should be pruned enough to avoid their ignition by a groundfire.

Seldom is a 30-foot vegetative clearance adequate to protect a home from wildfire. California state law recognizes this fact by providing for an extension to 100 feet upon a finding of necessity by the Director of Forestry. Likewise, several local ordinances in southern California require a minimum clearing of 100 feet. Even these distances may not be enough. Several fuel break planning and design studies on intensity of radiated heat and on flame lengths under high wind conditions indicate that 200 feet may be more appropriate under severe wildfire conditions. Actual brush clearance needs on the ground cannot be legislated. They are determined by native fuel loading, slope, expected wind velocity, and type of building material to be protected. In certain situations, a 400 foot clearance may be barely adequate (Moore, 1981). Figure 1 below shows that the breaking up of the fuel load and fuel continuity reduces the amount of thermal radiation a home and a firefighter

Figure 1. Landscaping to Reduce Radiant Heat

receives. For a point-source of radiation, this heat intensity decreases with the square of the distance form the source. The radiation intensity 100 feet from the burning brush or landscaping plants is therefore only 1/4 that at 50 feet, and the intensity 20 feet from a burning tree is also only 1/4 that at 10 feet. The number of points from which the home can receive the radiation will also increase rapidly with the area of the radiating source. Increasing the number of flammable landscaping plants around the home and/or increasing the number of trees will make a home more fire-prone despite legal brush clearance (Radtke, 1981). In areas of tall brush or standing timber, a 20-mile-an-hour wind can produce flame lengths well over 60 feet and some as long as 100 feet (Albini, 1976). For this reason the 100-foot clearance should be a minimum and a set-back on the hillside encouraged.

Any of several methods of vegetation removal may be used, depending on cost, timing, and final result desired. These may take the form of hand-chopping, bulldozing, discing, and the use of control fire. In timbered areas, debris left from logging and silvicultural treatments is often reduced by burning or mechanical treatment. Prescribed fire is used in forest stands in the southern United States and parts of the west to reduce the amount of fuel. In some regions, extensive areas of brush have been converted to grass through the use of controlled fire (Countryman, 1974). Although fire can be a dangerous tool at best, it should be considered along with hand-thinning and mechanical clearing as a viable method for reducing flammable vegetation around the building sites. As each homeowner protects his own property the community as a whole experiences an increase in fire safety and a reduction in fuel hazard.

New Home Landscaping

In replacing the cleared vegetation, keep and augment the benefits of the fuel reduction. Planted, as well as retained, native trees and bushes should be spaced far enough apart that their crowns will still be separated when full-grown. Crowns overhanging the house should be thinned or removed.

Much research has been done recently on so-called fire-resistant plants for home, fuel-break and roadside planting. The research has included both native plants and introduced species, the latter coming primarily from areas of the world with Mediterranean climates. In recent years, the focus has, therefore, been on finding plants with low fuel volume and height and therefore with low heat output, as well as some degree of fire retardance (Radtke, 1981; Curran, 1978; Moore, 1981). Probably the most beneficial landscaping to provide fire safety is the maintenance of a green lawn. The lawn that is well cared for provides minimal fuel loading as well as an increase in the humidity around the home. To maintain a green lawn in a fire-prone area requires consistent sprinkling or irrigation. Thus by providing for a lush, green lawn, homeowners not only provide for a recreation area, but also maintain a fire barrier.

Although many of the most important actions in providing fire safety for a structure located in a wildfire hazardous area take place during the planning, designing, constructing and landscaping phases, they do not end there. Maintenance must begin the day the occupant moves in and continue so long as the building stands, or all the original built-in protection may be in vain. Many cases have been documented wherein a

:ructure, once reasonably firesafe, burned down after the fireproofing : the area around it had been allowed to deteriorate (Alger, 1971; oore, 1981).

Chapter 9

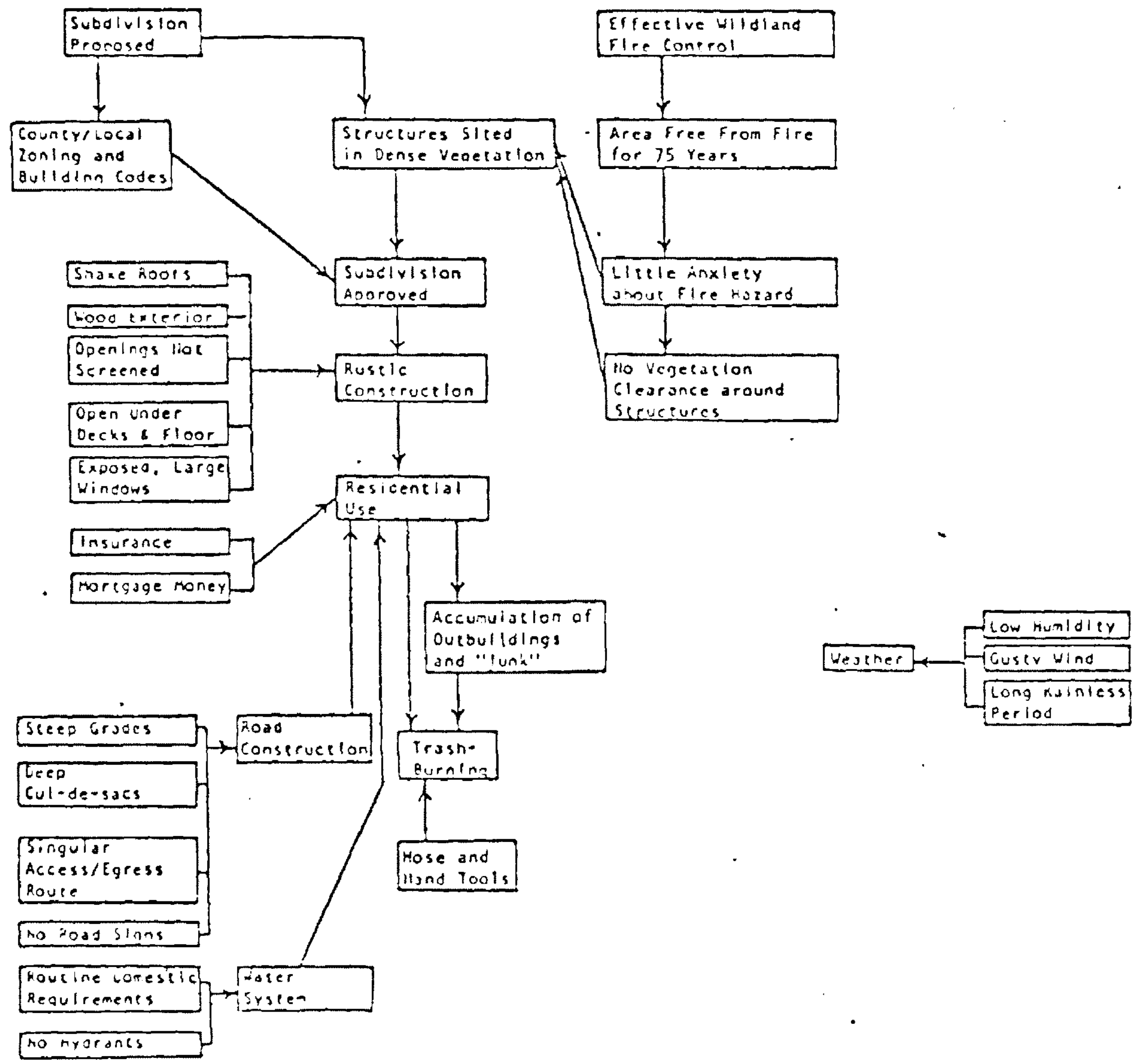
Creating The Wildland/Urban Interface Conflagration

A more detailed description of the relationships underlying the development of a catastrophic interface wildfire is needed as a basis for discussing new practices that reduce interface hazards. Figure 2 presents a schematic representation of a generalized interface wildfire hazard situation prior to a major conflagration. Figure 3 presents a revised picture of this same situation as it might appear during or after the conflagration. By comparing the two it is possible to see the areas in need of change.

The wildland/urban interface wildfire hazards begin when a subdivision is proposed where structures will be sited in dense vegetation. Effective wildland fire control has kept the area free from fire for many years, allowing a vegetation build-up. This same effective wildland fire control promotes the concept that there is little to fear from the wildland fire hazard. The county and local zoning and building codes are met and the subdivision receives approval from the local governing body. The lack of hazard classifications allow construction in wildland fuels that are destined to burn. Many plans are only required to conform to standards established for the central urban areas in which the need for stricter standards has originated (Lee, 1980). Thus, many plans meet existing fire codes that have been developed for subdivisions in urban areas; such codes fail to control fuel coupling that occurs with residences in wildland sitings.

Figure 2

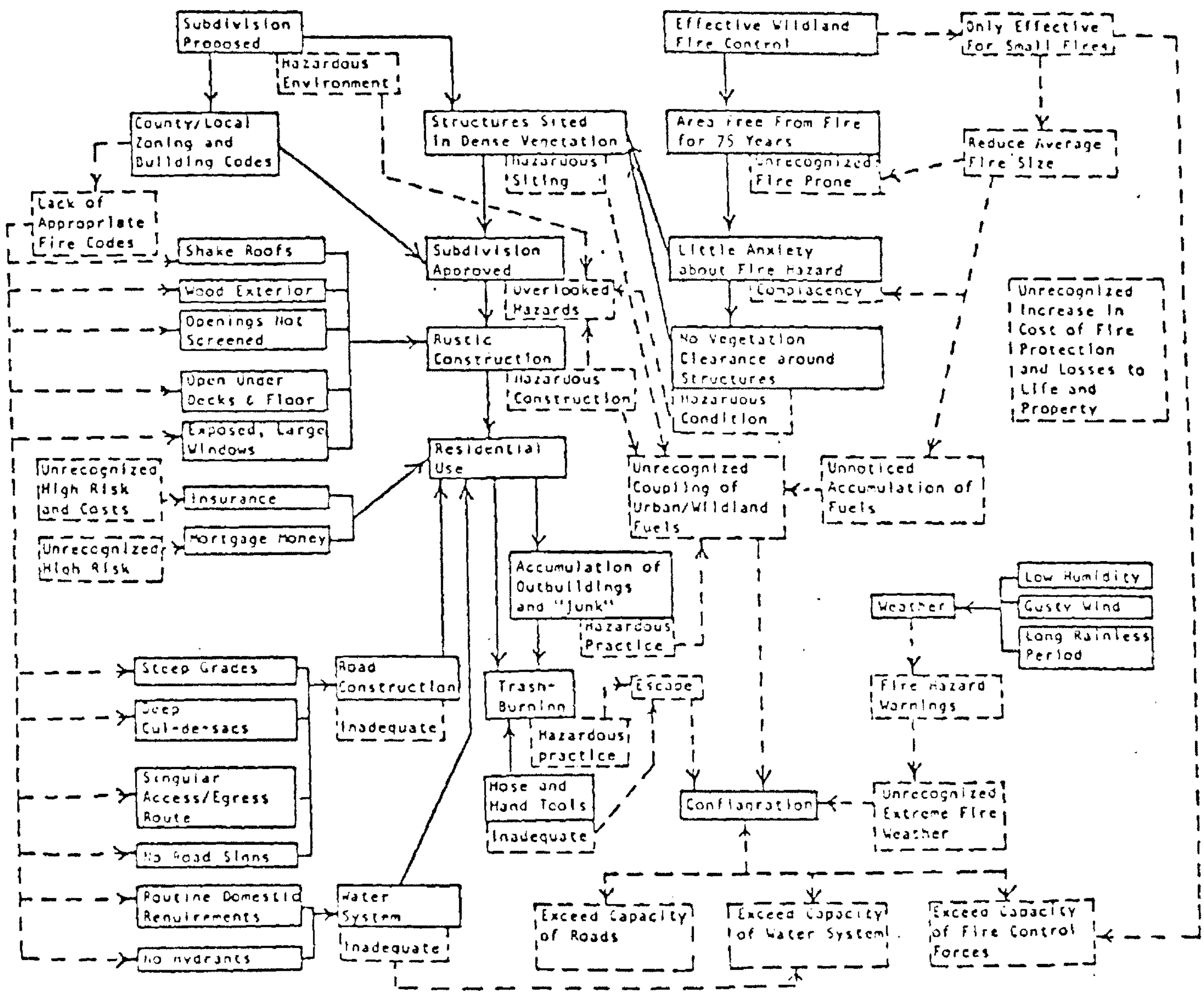
Schematic Representation of a Hypothetical Interface Wildfire Hazard Situation Immediately Before a Conflagration.



Source: Lee, 1980

Figure 3

Schematic Representation of the Hypothetical Interface Wildfire Hazard Situation Immediately After a Conflagration.



Source: Lee, 1980

With the start of construction begin the mistakes made during the design phase. Developers maintain strict architectural standards requiring buildings to conform to rustic design that blend into the natural environment. Natural wood walls and shake and shingle roofs are often required. Large windows are provided, areas under floors and decks are not boxed in and screens over windows and other openings are avoided to prevent obstruction of views.

Access roads are designed to meet the routine peak needs of residents. Some steep grades are occasionally permitted so as not to scar the land with roads, as well as to cut costs. Deep cul-de-sacs and deadend roads afford residents a sense of privacy and reduce traffic to a minimum in front of residencies.

Water systems are designed to meet the routine peak requirements of residents. Fire hydrants are often not installed because of the large lots and distances between structures. Water requirements for fighting individual structural fires are instead provided for by adding a large tanker truck to the local rural fire department. Steep access roads and culverts with minimum load capacities restrict these large tanker trucks.

Outbuildings are routinely accumulated by residences as garages, shops, and toolsheds. And, according to many restrictive covenants, these secondary structures often have to conform to the same standards governing rustic design. In addition, residents store firewood, recreation vehicles and accumulated junk (yard trimmings, gardening supplies, etc.). Firewood is often stacked in the open areas under buildings or decks. These practices place manmade fuel together with wildland fuel surrounding the homes.

Homes located on steep, narrow, winding roads may find trash disposal by conventional methods unrealistic. Large disposal trucks may not be able to negotiate the access roads. These residents sometimes make a practice of disposing of combustible junk by trash burning. Most people are informed about how and when to burn, and follow standard precautions recommended by the local rural fire department. This still poses an ignition hazard to wildland fuels.

Thus, as people accumulate and store more flammable items near and around their homes the fire hazard increases. The longer an area goes without a fire the more lax residents become in fire safety.

Figure 3 illustrates how an interface wildfire disaster in a hypothetical subdivision might be reconstructed following a conflagration set off by yard burning during an unusually dry and gusty fall day. Erroneous beliefs and precautions are illustrated by dashed boxes, as also are mistakes attributable to omission of necessary beliefs and precautions. Omissions of necessary cause and effect relationships are indicated by dashed lines terminating in arrows. Taken together, the scheme shows how the conflagration came about as a result of an accumulating network of errors (Lee, 1980).

One chain of errors begins with the belief that wildland fire control forces are adequate. (Phillips, 1977) The conflagration forces general acceptance of the fact that wildland fire control has been <u>most</u> effective for suppressing small fires. Hence, its effect shows up as a sharp reduction in the average size of wildfires. Generally unnoticed is the fact that fire control has been only marginally effective at controlling fires which burn under more severe fire weather conditions.

A false sense of security from destructive wildfire is often widely shared because the performance of fire control organizations has been based on their success during periods of "normal weather". Thus, an area of land taken at random is often less likely to burn on any given year than was the case under natural conditions. Vast areas may be free from fire for very long periods because almost all fires were contained while small.

However, the relative success of fire control also permits vegetation to accumulate unnoticed as large expanses of unnaturally heavy, explosive fuels. Wildfires burn with unexpectedly high intensity in these fuel accumulations, sometimes erupting into firestorms. The amount of energy released from these intense wildfires far exceeds that found under the average natural conditions (Radtke, 1981). The resulting fire far surpasses the capabilities of human fire control.

Fuels also accumulate unnoticed adjacent to residences in subdivisions. Trees grow taller, and provide a micro-climate favoring a dense understory of trees and shrubs. Residents often like the natural screening provided by this understory, thus, permit it to grow uncontrolled. The hazardous condition created by this "ladder of fuel" usually remains unnoticed.

A second chain of errors begins with the siting and approval of the subdivision itself. The hazards associated with siting structures in dense vegetation go unnoticed, or at least underestimated by both the developers and the governmental authorities responsible for approving the subdivision. This error is reflected in the absence of fire codes suited to residential use of fire hazardous wildland environments.

Successive errors are made in the developer's selection of a rustic design for housing construction. Wood exteriors and roofs, together with the lack of screening and unboxed decks and subfloor spaces, unknowingly compound the wildland/urban interface fire hazard by effectively coupling structural fuels with the accumulating vegetative fuels. This is further compounded by the addition of outbuildings and hazardous fuel build-up common to residential structures. Building codes are frequently in error by failing to specify building design and construction material that would minimize the natural fire danger and reduce the coupling of structural and vegetative fuels.

The third chain of errors originates in accepted patterns of residential use. Both insurance underwriters and lenders fail to assign high risk to residents using interface fire-prone structures. Residential property losses in hazardous areas increase without adequate notice, resulting in inequitable insurance rates for homeowners living in non-hazardous environments. Similarly, unrestricted mortgage money for homes in hazardous areas errs by encouraging development in locations where losses are far more likely to occur.

Thus, the dynamic buildup of fuel increases the fuel loading until a point when an ignition source comes in contact with the fuel. This precipitating event of the wildland conflagration is the inevitable conclusion to the chain of errors listed above.

A final chain of errors interacts with the onset of the conflagration to substantially increase losses of life and property: Intensity of the conflagration exceeds the capability and intended function of roads, water supplies, and fire suppression forces (Task Force on California's Wildland Fire Problem, 1972).

Emergency vehicles have difficulty with access and ingress because of congestion created by fleeing residents, narrow streets, unmarked cul-de-sacs, steep grades, and the lack of street signs. Residents are horrified by the lack of fire protection and their inability to achieve speedy egress. Many who are trapped in cul-de-sacs by walls of flames may ultimately perish in the fire.

Water supplies may unexpectedly prove insufficient when hundreds of residents simultaneously attempt to water down their roofs and yards. Early depletion of water reserves leave no local water sources for fire control forces attempting to save structures; all water has to be transported in by truck, and most trucks lack the holding capacity to combat the intense structural fires and threatening hotspots in the wildfire.

Fire control forces have been designed to provide protection against occasional structural fires and small forest fires. So when faced with the onset of a conflagration, local forces are often totally inadequate. Mutual aid agreements with adjoining districts and fire control agencies sometimes help, but are often weak and are slow to mobilize if they are in effect. These neighboring districts may be unfamiliar with the local terrain and also may not be able to communicate with the local fire districts calling for help. Many lives and structures may be lost because fire control forces prove to be inadequate (Lee, 1980).

After the fire's control, two events which are indirectly related to the wildland/urban interface fire could contribute to another source of financial disaster in the future. Losses are not always noticed by insurance rate payers because they are spread over a very large population and have only an increment impact on premiums. However, a series of such interface fires could surprise both the insurance underwriters and rate payers with rising costs of sharing interface losses. The second event involves the inevitable increase in the cost of fire prevention and control resulting from attempts to provide adequate fire protection to rural areas. A purely technological solution involving a substantial increase in fire trucks, crews, water mains and other facilities may prove to be exceedingly costly as well as marginally effective. Taxpayers who support these services would someday discover the burden of this unnoticed cost and demand that residents enjoying the benefits of remote living also pay the high cost of fire protection. For these reasons, people living in the wildland/urban interface must make every attempt to fire-safe their homes to local standards. Local government must provide fire protection to all taxpayers at the lowest possible cost. This can be accomplished by composing and enforcing fire-safe regulations for rural areas.

CONCLUSION

The solution to fire protection in the wildland/urban interface is a complex and very emotional issue. Techniques that will reduce the hazard and lessen the risk are now available. Fire-safing rural areas should be broken down into three major categories, technology, education and economy.

Technology

In dealing with wildfire, county or city plans vary greatly between one local government and another. Some plans merely recognize the fact that a fire problem may exist; other plans provide a detailed exposition of the nature and extent of the problem and a timetable for coping with it. General plans are prepared by the planning staff and approved by the planning commission and the governing body of political subdivision of the state, county or city. They generally include land use, transportation, public safety, and other elements designed to promote orderly growth and development. One vital element of these plans is public safety. In the past there has been no standards within public safety to which this wildfire problem is addressed. These plans should require that fire protection elements of general and specific plans cover both basic structural protection and protection from wildland fires, that protective measures enumerated in these plans should correspond to the level of fire hazard severity found to exist in the area covered by each plan, and that the fire department participate in reviewing plans.

One important facet of the general plan is the land use element. It establishes the areas that can be devoted to different uses, (i.e., residential, commercial, manufacturing, etc.) This element has great potential for enhancing structural fire safety in wildland areas if wildland fire hazard severity classes are accounted for during its development. So far this potential has rarely been considered and no case has been found where the land use element of the general plan was actually implemented in this manner.

One solution to the threat posed by the vast areas of vegetative fuels is to treat them so as to reduce the fire hazard they represent to an acceptable level. Reduction of the available fuel (dead and fine limbing) on broad areas for blocks is one method that can be used. Conversion of the vegetative type to a less hazardous type in long strips (fuel breaks) strategically located in such a manner as to assist firefighters in controlling fires that do start is another. Such fuel breaks have proved effective in saving lives, property, and suppression costs.

Hazard reductions on large areas would be prohibitively expensive. Its use is, therefore, limited to relatively small areas in locations where the values to be protected are high. Fuel breaks are also expensive, but their cost:benefit ratio over the millions of acres of concern is much more favorable, especially if they are planned, built, and maintained for multiple use.

Several matters concerning the fire safety of structures in wildlands as affected by off-site activities can be solved only by legislative action at either the state or local level. State governments need to recognize the public interest in and benefit from fuel breaks, hazard reduction, and block-type conversion work, whether done on public or private land. Fire hazard reduction should be given environmental protection status equal to air and water pollution and herbicide control.

Only the developer of a property can provide some of the vital means of fire protection, such as access and water supplies. It is the developer's responsibility to know about them, and to design them into the project before any structures are erected. But others have related responsibilities. Planning Departments should develop and legislative bodies should adopt minimum standards. (See Appendix C) Planning Departments, with advice and assistance from operating departments should enforce the standards even if they must deny approval of non-conforming proposals. All developmental plans must employ the master planning concept in order to properly assess the interaction between various elements.

The owners of structures in or near wildland fuels cannot depend on the fire suppression efforts of public agencies to protect their buildings from destruction by wildfire. The use of tax funds to pay for enough firefighters and equipment to contain every fire that starts on the few days of very high and extreme fire conditions is most economically and politically infeasible. It is also, in fact, physically impossible under typical conflagration conditions of very strong, hot, dry winds.

Firefighting is at best one of the most hazardous activities of man. Under conflagration conditions, the risks of entrapment, asphyxiation, heat exhaustion, falling, and other injuries become so great that chief officers and other leaders should not allow their men to be at the head of the fire. The strategy of wildland fire control requires perimeter control, containment of spread, and eventual extinguishment. Due to the scarcity of water, the tactics of wildland fire control usually consist of constructing fire lines, either by hand or with machines, burning out prepared or pre-existing control lines, cooling limited areas by airdrops of fire retardants and similar measures. Such work cannot be carried out safely or effectively on steep hillsides or in close proximity to a high intensity fire in heavy fuels.

The control of major wildland fires, especially those involving structures, is further complicated by the communication and coordination problems inherent when fire is being fought by multiple agencies, which is usual for two reasons. First wildland fires simply do not respect political, jurisdictional, administrative, or ownership boundaries. A fire of any appreciable size will usually spread from the protectional jurisdiction of one agency to those of several other agencies. Secondly, no single agency, even the largest, has the resources to handle a conflagration alone. Aid from other agencies, often from considerable distance, must be called in. As a result, differences in training, equipment, and radio channels regularly exist. The effect of these differences can be minimized with joint training, and common command systems. One such common command, the Incident Command System, is being taught at the National Fire Training Academy. This common command system will help minimize problems existing through automatic mutual aid of departments.

A total fire defense system includes all the manpower, equipment, and real property and organization necessary to provide fire prevention and suppression for a given area or jurisdiction. The term is used here in the more limited sense of those improvements needed to aid firefighting forces to contain a wildland fire before it becomes a conflagration endangering homes and other structures. These improvements consist of fuel breaks, fire roads, and similar items.

Such systems, to be effective, require detailed planning and large expenditures of manpower and money.

Another important aspect of fire-safing and maintaining fire safety, is through regular home inspections. The local fire department should be provided with enough fire prevention personnel in numbers that are adequate to properly inspect wildland residences and to make personal contacts with wildland residents and other users, especially during critical fire weather. This will help insure that home maintenance will continue to provide fire safety to a structure located in the wildland/urban interface.

Economic Incentives

It is neither feasible nor desirable to accomplish all the above recommendations and standards by governmental action through laws and regulation. Yet they all have a price, either in money or in labor, and it is not likely that more than a small portion of the homeowners will carry out these recommendations voluntarily unless the benefit can be seen to outweigh the cost. The thousands of property owners cannot be expected to be informed adequately of the hazards and risks involved in home ownership over long periods of time in areas of varying fire hazard. On the other hand, the few hundred people who control insurance rates, loan terms, and taxes can and should be so informed and take the action to set those rates in such a way as to reflect true probabilities of loss and costs of fire suppression.

A so-called brush surcharge has been published by Insurance Services Office (ISO) for a good many years. Actually it is based on a combination of factors only one of which is the amount of brush clearance. The other factors used are: type of roof, fire protection class, and response time. Although a step in the right direction, the program is only partially effective for several reasons. Most important is the fact that the surcharges do not reflect the actual probabilities of destruction by fire, and in particular show unrealistic differences between approved and unapproved roofs (20% difference in rate, compared to 95% difference in loss actually measured) (Moore, 1981). Because of this, owners with fire-safe properties are subsidizing those with unsafe property. Secondly, the surcharge schedule does not take fire hazard severity classification into account. Thirdly, not all underwriters subscribe to the services of ISO, or they are not guided by its recommendations. A revised rate schedule could easily be prepared to incorporate surcharges for substandard installation and rate reduction for those with protection in excess of the standard, and based on true probabilities which would take into account the experience gained from the thousands of buildings destroyed by wildland fires in the past ten or fifteen years. In order to apply to all insurance companies rather to only those affiliated with ISO, such a rate schedule could be established by the state or local government.

Mortgage rates and other conditions of loans could be adjusted to encourage fire-safe practices in much the same manner as suggested for insurance rates. High interest rates and other unfavorable conditions for loans on substandard projects and installations coupled with lower rates and favorable conditions for those which exceed the standards would encourage the latter. Such practice is perhaps not entirely consistent with current money market practices. But since the risk is never completely eliminated by insurance coverage, such practice would represent a judicious assessment of the risk to the lender and would be effective with home buyers. From the standpoint of public safety it would be even more effective if applied to the large loans to developers and builders. If builders sell only fire-safe homes, subdivisions and mobile home parks, the purchasers of their products will start, at least, with lower risk situations.

Fire-safe practices by property owners reduce the cost of public fire protection services. The lack of such services exposes the property of the owner or occupant and neighbors to increased risk of destruction by wildfire, it also makes the task of firefighting much more difficult and therefore more costly. Encouraging fire-safe practices through tax incentives would not be a new concept. Tax incentives are already used by both state and federal governments to promote energy conservation measures, and they have been used in the past for other purposes. There is no reason then why such incentives should not be used by local or state governments to encourage fire-safe practices in or near wildland areas. This approach would be accepted by property owners and occupants with much more grace than a regulatory approach.

Education

Educating the public is by far the most difficult task that fire prevention officers must face. Education of forest recreation users has been going on for many years. The "Smokey the Bear" program is quite visible yet a large portion of wildland fires continue to be man-caused.

The education program can be broken down into three areas: The control of sources of ignition, modification of hazards, and modification of losses.

The first involves modification of the source of fires, herein simplified to cover attempts to control man-caused sources of ignition. This must include such sources as accidental, carelessness, and arson. Local residents must understand the importance of preventing ignition sources.

The second topic for education of the public in wildland/urban interface areas involves modification of hazards. Interface wildfire hazards can be reduced most effectively by avoiding the unrecognized coupling of urban and wildland fuels that makes vegetative resources, human lives and residences highly susceptible to losses by fire. Reducing the vulnerability of structures and residents to fire losses should be the number one program for fire prevention officers and building inspectors. A comprehensive education program is required for homeowners to understand the reasons behind zoning regulations and fire-safing of homes.

The third topic for education involves the modification of losses. Interface wildfire losses can be reduced most effectively by developing capabilities for controlling wildfires and preventing conflagrations in settled areas. Losses may be reduced by educating homeowners in the following sorts of capabilities: initial fire detection and suppression on the parts of the residents themselves, regional fire hazard warning systems, fire breaks and fuel breaks built in anticipation of fires, wildfire detection systems, water supplies and road networks adequate for meeting emergency needs, and emergency communication systems, as well as fire control forces adequate for emergency conditions.

The fire prevention problem goes well beyond having to deal with the careless smoker and the unextinguished campfire. Fire prevention specialists must deal with a seemingly endless list of potential ignition sources. The public is often apathetic. Fire prevention must be taken much more seriously both by residents of wildland areas and their city neighbors. This can be accomplished through education.

LITERATURE CITED

Albini, F.A. 1976. Applications of wildland fire behavior models. U.S.D.A. Int. For. and Range Exp. Sta., Ogden, Utah. 23 p.

Albini, F.A. 1976. Estimating wildfire behavior and effects. U.S.D.A. For. Serv. Gen. Tech. Rep. INT-30, 92 p.

Alger, R.S. 1971. The great Oakland, Los Angeles, and San Diego Fires, September 22 to 19, 1970. U.S. Naval Ordinance Lab., Silver Springs, Md. 4 p.

Arno, S.F. 1980. Forest fire history in the Northern Rockies. J. For. 78(8) 460-465.

Arno, S.F. 1976. The historical role of fire on the Bitterroot National Forest. U.S.D.A. For. Serv. Res. Pap. INT-187. 29 p.

Bowman, R.M. 1979. Rural fire prevention and control - a time of awakening. Inter. Fire Chief 45(3) 10-12.

Brown, J.K. 1978. Appraisal of fuels and fire potential. U.S.D.A. Fire Management Training. Unpublished. Int. For. and Rang. Exp. Sta., Ogden, Utah. 15 p.

Burden, L. 1980. Missoula County subdivision inventory report. Missoula Environmental Information Center, Missoula, Montana. 75 p.

Burgan, R. E. 1979. Fire danger/fire behavior computations with the Texas Instruments TI-59 calculator: user's manual. U.S.D.A. For. Serv. Gen. Tech. Rep. INT-61.

Burgan, R.E., J.D. Cohen, and J.E. Deeming. 1977. Manually calculating fire-danger ratings--1978 National Fire-Danger Rating System. U.S.D.A. For. Serv. Gen. Tech. Rep. INT-40. 51 p.

Byram, G.M. 1959. Combustion of forest fuels. In: Forest Fire Control and Use. K.P. Davis, 1973. McGraw Hill, New York. pp. 173-175.

Countryman, C.M. 1974. Can southern California wildland conflagrations be stopped? U.S.D.A. For. Serv. Gen. Tech. Rep. PSW-7. 11 p.

Cowles, R.B. 1973. Smokey the Bear meets Satan's wife. Natural History 82(4) 9-16.

Curran, C.W. 1978. Wildfire hazard management in the urban/wildland interface in southern Oregon. Prepared for Rogue River National Forest. U.S.D.A. For. Serv. 55 p.

Davis, K.M., B.D. Clayton, and W.C. Fischer. 1980. Fire ecology of Lolo National Forest habitat types. U.S.D.A. For. Serv. Gen. Tech. INT-79. 77 p.

Deeming, J.E., J.E. Lancaster, M.A. Fosberg, R.W. Furman, and M.J. Schroeder. 1972. National fire danger rating system. U.S.D.A. For. Serv. Res. Pap. RM-84. 53 p.

Deeming, J.E., R.E. Burgan, and J.D. Cohen. 1977. The National Fire-Danger Rating System - 1978. U.S.D.A. For. Serv. Gen. Tech. Rep. INT-39. 63 p.

Fahnestock, G.R. 1971. Rating forest-fire hazard in residential developments in Colorado forests. Colo. State For. Serv., Colo. State Univ., Fort Collins, Colo. 29 p.

Fischer, W.C. 1978. Vegetation and fire behavior characterizing proposed fire hazard classes for Montana wildlands. 3 p. Unpublished.

Fischer, W.C. 1981. Photo guide for appraising downed woody fuels in Montana forests. U.S.D.A. For. Serv. Gen. Tech. Rep. INT-97. 133 p.

Fischer, W.C. 1977. Safeguarding Montana's forest homes: Lessons from the Pattee Canyon Fire. Reprint from Western Wildlands. Summer, 1977. 6 p.

Freedman, J.D. 1980. A fire and fuel hazard analysis in the Seeley Lake Area, Missoula County, Montana. Unpublished Master's Thesis, Univ. of Mont. 90 p.

Freedman, J.D. and W.C. Fischer. 1980. Forest home fire hazards. Western Wildlands. Summer, 1980. pp. 23-26.

Gaylor, H.P. 1974. Wildfires - Prevention and Control. Robert Brady Comp., Bowie, Maryland. pp. 2-9.

Gruell, G.E., W.C. Schmidt, S.F. Arno, and W. J. Reich. 1982. Seventy years of vegetative change in a managed Ponderose Pine forest in Western Montana. U.S.D.A. Gen. Tech. Rep. INT-130. 42 p.

Habeck, J.R. and R.W. Mutch. 1973. Fire-dependent forests in the Northern Rocky Mountains. Quarternary Research 3: 408-424.

Helfman, R.S., J.E. Deeming, R.J. Straub, and R.W. Furman. 1975. User's guide to AFFIRMS: time-share computerized processing for fire danger rating. U.S.D.A. For. Serv. Gen. Tech. Rep. RM-15. 107 p.

Helm, R.D., N. Barritt, and L. Taylor. 1973. A fire hazard severity classification system for California's Wildlands. Calif. Div. of For., Sacramento, Calif. 40 p.

Hulbert, J. 1972. Fire problems in rural suburbs. Am. For. 78: 24-27, 47.

International Conference of Building Officials. 1976. Uniform Building Code. Whittier, Calif. pp. 481-494.

Lee, R.G. 1980. Alternative institutional arrangements for reducing fire hazards on the residential/wildland interface -- a problem analysis and study plan. Unpublished. Univ. of Wash. 66 p.

Missoula County Commissioners. 1978. Missoula County Subdivision Regulations: Resolution No. 78-68. Board of County Commissioners of Missoula County, Missoula, Mont. 60 p.

Moore, H.E., 1981. Protecting residence from wildfires: a guide for homeowners, lawmakers, and planners. U.S.D.A. For. Serv. Gen. Tech. Rep. PSW-50. 44 p.

Muller, C.H., R.B. Hanawalt, and J.K. McPherson. 1968. Alleopathic control of herb growth in fire cycle in California chaparral. Bull. Torrey Bot. Club. Vol. 95, 225-231.

Mutch, R.W. 1970. Wildland fires and ecosystems -- a hypothesis. Ecology 51(6) 1046-1051.

National Fire Protection Association. 1981. National Fire Codes: Suburban and rural firefighting water supplies. N.F.P.A. 1231(12) 11-21.

North, D.W., R.A. Howard, F.L. Offensend, and C.N. Smart. 1973. Decision analysis of fire protection strategy for the Santa Monica Mountains: an initial assessment. Stanford Research Institute Project MSU-2275. Menlo Park, Calif. 159 p.

Oregon State Dept. of Forestry. 1978. Fire safety considerations for developments in forested areas: a guide for planners and developers. Salem, Ore. 18 p.

Phillips, C.B. 1977. Fire protection and fuel management on privately owned wildlands in California. U.S.D.A. For. Serv. Gen. Tech. Rep. WO-3. 5 p.

Radtke, K. 1981. Living more safely at the chaparral-urban interface. Written for U.S.D.A. For. Serv., Pac. Southwest For. and Rang. Exp. Sta., Berkeley, Calif. On file with County of Los Angeles Fire Dept., Forestry Bur. 101 p.

Rothermel, R.C. 1972. A mathematical model for predicting fire spread in wildland fuels. U.S.D.A. For. Serv. Res. Pap. INT-115. 40 p.

Schmidt, R.G. 1978. An approach to hazard classification. Fire Management Notes 39(4) 9-11, 19.

State of Utah. 1978. Wildfire hazards and residential development: identification, classification, and regulation. Dept. of Nat. Res., Section of Forestry and Fire Control, Salt Lake City, Utah. 82 p.

Suenram, B. 1983. Chief, Missoula Rural Fire District., Missoula, Mont. Personal Communciation.

Task Force on California's Wildland Fire Problem. 1971. Recommendations to solve California's wildland fire problem. Calif. Div. of For., Sacramento, Calif. 63 p.

Turner, B.A. 1976. The development of disasters - a sequence model for the origin of disasters. Sociological Review 24: 753-774.

United States Department of Agriculture. 1980. Advanced Fire Management. Unpublished text. National Advanced Resource Tech. Center. 600 p.

Wilson, R. 1966. Protecting your city from conflagration - by design. National Fire Protection Assoc., Quincy, Mass.

APPENDIX A. - Fire Department Details
Minimum criteria for a responsible fire department

Organization: The department shall be organized on a sound, permanent basis under applicable state and/or local laws. The organization shall include one person (usually with the title of Chief) responsible for the operation of the department.

Membership: The department shall have an active membership which provides a response of at least 4 members to alarms.

Training: Training shall be conducted for all active members.

Apparatus: Response to any alarm of fire shall be with at least one piece of apparatus suitably designed and equipped for fire service. Provisions shall be made for the housing and maintenance of apparatus.

Alarm Notification: Means shall be provided for 24-hour receipt of alarms and immediate notification of members.

To be effective, fire departments should be well organized, well-supervised, and suitable equipped for service commensurate with the fire suppression needs of the community. Operations should be governed by comprehensive regulations. The chief officer should be qualified and appointed (preferable through competitive procedure) for an indefinite term with removal only for just cause after proper hearing. Although not recommended, some departments select a chief by membership election. If this procedure is followed, there should be confirmation of acceptance by the local governing body. The practice of installing a new chief each year in order to give all members an opportunity to so serve is considered detrimental to organized protection.

All personnel, including officers and firemen, should be responsible citizens and if in other than a full-paid status, their occupations should be such as to insure reasonable availability for fire service and training. Selection of personnel should be with due regard to age and physical condition.

Arrangements should be made whereby a single definite location is established for receipt of fire calls reported by the public. This location should be constantly attended 24 hours a day. If this arrangement is not possible, suitable extensions (such as telephone) should be provided as necessary so that one or more alternate locations may be utilized for interim periods. Any location upon which receipt of alarm is dependent should be equipped with means for activating the devices used to notify firemen of an alarm of fire. These devices may be sirens, air horns, radio receivers, or a special telephone network. Irrespective of the nature of the device, arrangements should be such that a sufficient number of firemen receive the notification in order to provide an immediate response of a good working crew.

APPENDIX B. - Water Supply Details

A network of watermains should be able to supply continuous and uninterrupted quantities of water for fire (fire flow) over and above the quantity needed for normal maximum domestic demands. System capacity required for fire protection will range from 500 gpm up to 12,000 gpm for periods of from two to ten hours. As an example, a small settlement of a few hundred people would require 500 gpm in residential sections (well spaced or scattered small single family dwellings). Quantities in the 12,000 gpm range normally are required only in large cities.

Water mains supplying hydrants should be installed as to constitute a distribution system, frequently cross-connected in order to provide circulating flow and comprised of pipe not less than 6 inches in diameter. Smaller pipe may be of some use, but usually is deficient in carrying capacity even when system pressure is exceptionally high. Eight inch and larger pipe will be necessary where normal system demands and higher fire flows so dictate. Whenever practical, distribution pipe should be cross-connected at intervals of 600 to 800 feet so as to form a regular gridiron. Valves should be installed with sufficient frequency and spaced so that no large portion of the system will be out of service at one time during repair and new construction.

Fire hydrants should be designed and installed in accordance with the recommended practice of the American Water Works Association. A valved 6-inch street connection to the hydrant is considered good practice. Hydrants should have 2½" outlets for pumper use. Hydrant installation should form a good "pattern" with due recognition to road and block layout so the fire department will not encounter impractical hose lay distances. In general, good fire department tactics contemplate the availability of at least two hydrants for the protection of any structure.

A water distribution system should not be dependent upon a single supply line or connection and, insofar as possible, sources of supply should be multiple and reliable. Where supply is dependent upon pumps, there should be duplicate installations providing for continued service in the event of failure of any given unit. Where supply is dependent upon pumps and the pumps are electrically driven, reliability is improved through the installation of a standby electric power unit or through some type of auxiliary prime-mover such as a gasoline, diesel, or natural gas engine.

Where elevated storage is utilized it is considered good practice to locate the storage on the opposite side of the system when compared with the source (such as a well pumping directly into the system). Such an arrangement usually results in an improved flow capability and some available flow when part of the system is valued out for repairs or additions.

System operating pressure should be such that required fire flow may be obtained at not less than 20 pounds per square inch system residual pressure. As a general rule, the lower the normal operating pressure, the larger the water main size necessary to deliver the same quantity of water. Increasing system pressure at time of fire demand is not considered good practice.

Since engineering problems are encountered when designing a water distribution system and its related facilities, it is suggested that a community or developer utilize the services of competent consultants so that design and installation will be compatible with local needs and projected future demands.

APPENDIX C. - Suggested Wildland Subdivision Regulations

1. Vegetative Manipulations

   a. Fuel Breaks. Hazardous fuels in the form of native vegetation will be cleared to not less than 75 feet around structures and to not less than 100 feet around the perimeter of the development. Irrigated or fire-resistant vegetation will be planted in the fuel breaks to prevent undue soil erosion. In steep terrain, cleared or leveled slopes will be stabilized immediately following construction. Developers and lot owners will be required to construct retaining walls, water bars, check dams, terraces, or other forms of physical means of soil erosion control as determined by the local governing authority. Fuel breaks around structures will be maintained by the landowners. Fuel breaks may contain individual tree specimens, ornamental plants, or other similar vegetation to be used as groundcover; provided they will not readily provide a means of transmitting wildfire from native vegetation to structures. Fuel breaks around the perimeter of the development will be dedicated to this specific purpose by recording the land as common to the development. The development or local governing authority will maintain these fuel breaks.

   b. Lot Size. Lots will be at least one acre in size to permit the establishment of adequate fuel breaks around structures. Structures will be placed within lots so adequate fuel breaks may be established on all sides. Minimum lot sizes and fuel break widths will increase proportionately as the ground slope increases.

c. Chimneys, Stovepipes, and Outdoor Fireplaces. Fuels will be removed to a minimum of 25 feet around all chimneys, stovepipes, and outdoor fireplaces.

d. Dead Vegetative Materials. Structures will be kept free of dead vegetative materials. All trees left in fuel breaks for aesthetics will be kept free of dead or dying wood, and lower branches pruned to a height of 16 feet if the trees are over 35 feet. If the trees are less than 35 feet, the lower 1/2 of the trees will be pruned.

2. Structural Materials (only required in areas where native vegetation averages 3 feet in height or greater)

a. Roofs and Exteriors. Roofs and exteriors of structures will be constructed of fire-resistant materials such as asphalt rag felt roofing, gravel, tile, slate, asbestos cement shingle, sheet iron, brick, aluminum, or fire retardant treated wood shingles or shakes.

3. Disposal of Flammable Solid Wastes

a. Vegetation. All vegetation such as trees, branches, limbs, stumps, exposed roots, and brush disturbed during construction will be disposed of by chipping, burial, or removal.

b. Construction Materials. Excess flammable construction materials will be disposed of by burial, removal, or other means as specified by the local governing authority.

c. Trash. Disposal will be by methods other than burning. No open burning of garbage will be permitted.

d. Road Slash. No slash will remain along any road after construction. Slash will be treated as stated in 3a. (Burning will be allowed with a permit.)

4. Road Specifications

a. Access. A minimum of two dedicated access roads for separate ingress-egress will be provided.

b. Rights of Way. Major road rights of way will be a minimum width of 60 feet with minimum road widths of 36 feet; minor road rights of way will be a minimum width of 40 feet with minimum road widths of 24 feet.

c. Cul-de-Sacs. Cul-de-sacs will be a maximum of 500 feet in length, have minimum rights of way of 40 feet with minimum road widths of 24 feet, and have turnaround areas of not less than 90 feet in diameter. Cul-de-sacs will be designated as such with a warning sign within 50 feet of the outlet. Dead-end streets will not be permitted.

d. Public Access. All lots within wildland subdivisions will be provided with public access. Public access will be provided to areas beyond the development by means of at least one road to the edge of the development. Until such time that the road is extended into the adjacent property, a turnaround will be established at the property edge with a minimum diameter of 90 feet.

e. Radius of Curvature. Roads will be constructed with a minimum radius of curvature of 100 feet. Where extreme or severe topographic conditions make this impractical as determined by the local governing authority, variances to 75 feet will be made.

f. Identification. Roads will be uniquely named or numbered, and visably signed as such at each road intersection. Lots will be uniquely numbered on each road and visably signed as such. A map of the development with road and lot designations will be furnished to all local fire authorities.

g. Road Grades. Road grades will not exceed 8 percent except for short distances when topographic conditions make lesser grades impractical. Variances will be made to 10 percent as determined by the local governing authority.

h. Bridges and Culverts. Bridges and culverts will be constructed to support a gross vehicle weight of 40,000 pounds. Permanent culverts will be installed at all intermittent and perennial stream crossings. Specifications for bridges, culverts, and other stream crossing devices will take into account at least the 100 year frequency storm and upstream debris hazards.

i. Road Maintenance. Public roads not dedicated to the local governing authority will be maintained by the lot owners. Dedicated public roads will be maintained by the special service district (See 8) or by the local governing authority.

j. Road Base Specifications. All major roads will have a base consisting of a gravel fill at least 6 inches thick. Other types of bases may be installed if they meet with the approval of the local governing authority.

k. Locations. Roads will be located on geologically stable areas. Where practical alternatives exist, roads will not be permitted in steep, narrow canyons; slide areas; slumps; slopes in excess of 60 percent; marshes; meadows; or natural drainage channels.

l. Right-of-way Clearance. Public road rights-of-way will be cleared of natural vegetation including all overhanging branches, and stabilized by the planting of fire-resistant vegetation and by physical means in steep terrain.

5. Water Supplies (See Appendix B)

a. Water Distribution. A public water distribution system will be installed by the developer. The minimum size of mains on this system will be 6 inches in diameter. Fire hydrants will be installed on this system as follows: spacing will not exceed 330 feet with a minimum 2 hour fire flow of 500 gallons per minute with 20 pounds per square inch static pressure. In developments with a proposed population density exceeding two single family dwellings per acre (multi-family dwellings) minimum fire flows will be 750 gallons per minute.

b. Water Storage or Source. Water storage or source will be provided to support the required fire flow for a period of two hours in addition to maximum daily flow requirements for other consumptive uses. Public access will be provided to within 5 feet of stored water supplies.

c. Water Supplies to Lots. Single family dwellings will be provided with water mains with a minimum diameter of one inch. A minimum of one exterior, freeze-proof tap will be provided far enough away from each structure to permit hose protection for all sides of the building and roof. Single family water systems will have a minimum flow of 15 gallons per minute at an operating pressure of 50 pounds per square inch. Multi-family dwellings will be equipped with automatic sprinkler systems and 2 inch watermains.

6. Fire Department Authority (See Appendix A)

A proposed development that is located in an area where the average response time from the nearest responsible fire department is greater than one hour will be required to establish a responsible fire department within the developments. This facility will include a minimum of one vehicle designed and equipped to suppress structural fires; an all-weather structure to house the vehicle; and chartered, trained volunteer personnel consisting of at least 4 members to respond to fire calls at one time.

7. Structural Designs (only required in areas where natural vegetation averages 3 feet in height or greater)

a. Openings. Roofs, attics, and underfloor openings will be closed off.

b. Chimneys and Stovepipes. Chimneys and stovepipes burning solid or liquid fuels will be equipped with screens over the outlets. These screens will be made of gauge 16 wire and have 1/2 inch holes.

c. Utilities. Telephone and power supply systems will be underground wherever possible. A fire alarm system will be considered in remote areas.

d. Flat-Top Structures. Structures with horizontal roofs will be prohibited in areas where vegetation is higher than the roof.

8. Special Service Districts

In remote areas, the county will consider the establishment of a special service district according to the Utah Special Service District Act of 1975, to carry out routine maintenance of common properties, and to provide for public services.

9. Assurance of Performance

The developer of a wildland subdivision will be required to post a performance bond with the county or municipality guaranteeing that the required improvements will be installed. The amount of the bond will be equal to the cost of providing the required improvements.

SUMMARY OF WILDLAND SUBDIVISION STANDARDS

1. Vegetative Manipulations

   a. Fuel Breaks:

      Structures - 75 feet
      Perimeters - 100 feet

   b. Lot Size* - one acre

   c. Chimneys, etc. - 25 feet

   d. Dead Vegetation - Clear & Prune

2. Structural Materials

   a. Roofs & Exteriors Fire Resistant

   b. Projections - Fire Resistant

3. Disposal of Flammable Solid Waste

   a. Vegetation - Chip, bury or remove

   b. Materials - Bury or remove

   c. Trash: Clearance NO OPEN BURNING ALLOWED

4. Road Specifications

   a. Access - Two Roads

   b. Rights of way:

      Major roads - 60 feet
      Minor roads - 40 feet
      Major road widths - 36 feet
      Minor road widths - 24 feet

   c. Cul-de-Sacs:

      Length - 500 feet
      Turnaround diameter 90 feet

   d. Public Access - to each lot

   e. Radius of Curvature 100 feet

f.	Identification	Roads & Lots
g.	Road Grades	8%
h.	Bridges and Culverts	40,000 lb.
i.	Road Maintenance:	
	Public Roads	Co. or City
	Private	Landowners
j.	Road Base Spec's.	6 inches
k.	Locations	Stable areas
l.	ROW Clearance	Public roads

5. Water Supplies

a.	Distribution:	
	Mains	6 inch
	Hydrant spacing	330 feet
	Flow	500-750 gpm
	Pressure	20 lbs/s.i.
b.	Storage	2 hr. flow + normal use
c.	Supply to lots 50 lbs. pressure	1 inch main 15 gpm
d.	Multi-family dwelling	2 inch mains sprinklers

6. Fire Department Authority

a.	New department required if over	1 hr. away from existing departments

7. Structural Designs	
a. Openings	Screened or closed
b. Chimneys	Screened
c. Utilities	Underground
d. Flat tops	Prohibited where vegetation is above roofline
8. Special Service District	Considered Establishment
9. Assurance of Performance	Bonded Developers

APPENDIX D. Typical Prepared Roof Coverings

Description	Minimum Incline In. to Ft.	CLASS A	CLASS B	CLASS C
Metal Roofing	12	Sheet roofing of 16-oz copper or of 30-gage steel or iron protected against corrosion. Limited to noncombustible roof decks or non-combustible roof supports when no separate roof deck is provided.	Sheet roofing of 16-oz copper or of 30-gage steel or iron protected against corrosion or shingle-pattern roofings with under-lay of one layer of Type 15 saturated asbestos-felt, or one layer of Type 30 or two layers of Type 15 asphalt-saturated organic felt.	Sheet roofing of 16-oz copper or of 30-age steel or iron, protected against corrosion, or shingle-pattern roofings, either without underlay or with underlay of rosin-sized paper.
				Zinc sheets or shingle roofings with an underlay Type 30 or two layers of Type 15 asphalt-saturated asbestos felt.
Cement Asbestos Shingles	Exceeding 4	Laid to provide two or more thicknesses over one layer of Type 15 asphalt-saturated asbestos felt.	Laid to provide one or more thicknesses over one layer of Type 15 asphalt-saturated asbestos felt.	

APPENDIX D. Typical Prepared Roof Coverings

Description	Minimum Incline In. to Ft.	CLASS A	CLASS B	CLASS C
Brick Concrete Tile Slate		Brick, 2½ in. thick. Reinforced portland cement. 1 in. thick. Concrete or clay floor or deck tile. 1 in. thick. Flat or French-type clay or concrete tile, 3/8 in. thick with 1½ in. or more end lap and head lock, spacing body of tile ½ in. or more above roof sheathing, with underlay of one layer of Type 15 asphalt-saturated asbestos felt or one layer of Type 30 or two layers of Type 15 asphalt-saturated organic felt. Clay or concrete roof tile, Spanish or Mission pattern, 7/16 in. thick, 3-in. end lap, same underlay as above. Slate, 3/16 in. thick, laid American method.		

APPENDIX D. Typical Prepared Roof Coverings

Description	Minimum Incline In. to Ft.	CLASS A	CLASS B	CLASS C
Asphalt-Asbestos Felt Sheet Coverings	Not Exceeding 12	Factory-assembled sheets of 4-ply asphalt and asbestos material.	Factory-assembled sheets of 3-play asphalt and asbestos material or sheet coverings of single thickness with a grit surface.	Single thickness smooth surfaced.
Asphalt-Asbestos Felt Shingle Coverings	Exceeding 4		Aspnalt-asbestos felt grit surfaced.	
Organic-Felt (previously referred to as rag felt) Shingle Covering, with special coating.	Sufficient to permit drainage	Grit surfaced, two or more thicknesses.	Grit surfaced, two or more thicknesses.	
Organic-Felt (previously referred to as rag felt) Shingle Coverings	Sufficient to permit drainage	Grit surfaced, two or more thicknesses.	Grit surfaced, two or more thicknesses.	Grit surfaced shingles, one or more thicknesses.
Asphalt Glass Fiber Mat Shingle Coverings	Sufficient to permit drainage	Grit surfaced, two or more thicknesses.	Grit surfaced, two or more thicknesses.	Grit surfaced shingles, one or more thicknesses.
Asphalt Glass Mat Sheet Covering	Sufficient to permit drainage			Grit surfaced.
Fire-retardant treated red cedar wood shingles and shakes	Sufficient to permit drainage			Treated shingles or shakes, one or more thicknesses; shakes require at least one layer of Type 15 felt underlayment.

APENDIX E. Built-up Roof Coverings

Description	Minimum Incline In. to Ft.	CLASS A	CLASS B	CLASS C
Asphalt organic-felt, bonded with asphalt and surfaced with 400 lbs of roofing gravel or crushed stone, or 300 lbs of crushed slag per 100 sq ft of roof surface, on coating of hot mopping asphalt.	3	4 (plain) or 5 (perforated) layers of Type 15 felt. 1 layer of Type 30 felt and 2 layers of Type 15 felt. 1 layer of Type 15 felt and 2 layers of Type 15 or 30 cap or base sheets. 3 layers of Type 15 or 30 cap or base sheets. 3 layers of Type 15 felt. Limited to non-combustible decks.	4 layers of perforated Type 15 felt. 3 layers of Type 15 felt. 2 layers of Type 15 or 30 cap or base sheets.	
Tar-asbestos or organic-felt bonded with tar and surfaced with 400 lbs. of roofing gravel or crushed stone, or 300 lbs of crushed slag per 100 sq ft of roof surface on a coating of hot mopping tar.	3	4 layers of 14-lb asbestos-felt or Type 15 organic-felt. 3 layers of 14-lb asbestos-felt or Type 15 organic-felt.	3 layers of Type 14-lb asbestos-felt or Type 15 organic-felt.	
Steep tar organic-felt	5	4 layers of Type 15 tar-saturated organic felt, bonded with steep coal-tar pitch, surfaced with 275 lbs 5/8-in crushed slag per 100 sq ft of roof surface on steep coal-tar pitch.		
Asphalt organic-felt, plain or perforated, bonded and surfaced with a cold application coating.	12			3 layers of Type 15 felt. 1 layer of Type 30 felt and 1 layer of Type 15 felt. 2 layers of Type 15 or 30 cap or base sheets. 2 layers of Type 15 felt and 1 layer of Type 15 or 30 cap or base sheets.