



# **FIRE MANAGEMENT NOTES**

FALL 1978 Volume 39, Number 4

U.S. DEPARTMENT OF AGRICULTURE • FOREST SERVICE





# FIRE MANAGEMENT NOTES

*An international quarterly periodical devoted to forest fire management*

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## The Cover

Many urban people are moving to rural areas for temporary or permanent residency. The cover indicates what can happen if fire prevention is not effective. Our lead article explains one type of cooperative effort in reaching an increasing rural population.



### Please



### prevent forest fires!

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Subscriptions may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. The subscription rate is \$4.00 per year domestic or \$5.00 per year foreign. Postage stamps cannot be accepted in payment.

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**John R. McGuire, Chief, Forest Service**

**Henry W. DeBruin, Director, Aviation and Fire Management**

**David W. Dahl, Managing Editor**

# Central Oregon Fire Prevention Cooperative

John Jackson

Cooperation between all government agencies is essential for an effective wildland fire prevention program. In Oregon, a model for this type of needed cooperation can be seen in the Central Oregon Fire Prevention Cooperative.

## First Meeting

In November 1977, prevention personnel from the central Oregon area, Oregon State Forestry Department, met with staff personnel from the State Forester's office in Salem and the USDA Forest Service's Regional Office in Portland. At that meeting an interagency fire prevention cooperative was established. Membership included State Forestry Department, Forest Service, USDI Bureau of Land Management, and city and rural fire department personnel. The first action of this group was to attend the Advanced Fire Prevention Course in Marana, Arizona, in January 1978.

## "Kick off" Project

During the course of the Marana session, the members of the Team established June 1978 as a target date to have a cooperative effort in motion.

One of the early problems that surfaced was a general confusion on

the part of the public regarding fire protection boundaries, conflicting regulations, agency overlap, etc. The team felt that this confusion hampered the average citizen's ability to contact the responsible area agency, and fostered some negative attitudes in general regarding fire prevention.

The team members also felt that a "kick-off" project was needed to pull the interagency concept together. The featured "tab", *Central Oregon Fire Protection Information* (Pages 4, 5, and 6) was the project chosen to meet these two needs. It was funded through a grant from State and Private Forestry of the Forest Service's Regional office in Portland.

## Goal

The intent of this cooperative effort is to focus the combined prevention assets of all of the agencies into a year-round public information and education program concentrating on the high risk problems that occur within each season of the year. This means, in the Northwest, concentrating wintertime efforts toward the problems encountered by urban/structural/rural members. With this approach we hope to make the activities of the group truly year-round and truly interagency.

## Prerequisite For Success

A prerequisite for this type of operation to work is an upper level management commitment by each of the agencies involved for man-hours

and, at least until it gets off the ground, in-kind services to support the organization. We feel fortunate that we have had strong support in this regard.

## Future Projects

In the spring of 1979, we will initiate an interagency team teaching effort in the public schools to stem the increasing number of children-caused fires in the area.

At the present time, central Oregon is seeing an extensive urban expansion into wildland areas. The "recreational subdivision", with its unique hazard-risk situation, is a somewhat new protection problem to this part of the State. We are initiating a pilot program in the spring, with one subdivision, to develop aesthetically acceptable ways of dealing with fuels management.

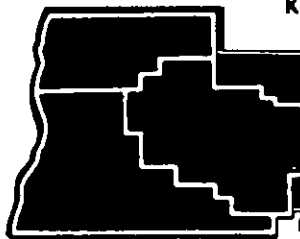
Looking ahead, we hope to make better use of news media opportunities to "get the word out" to the public. With the fairly rapid population increase in the area from outside the State, this is going to be an ongoing need.

We feel that the co-op is really just getting started, but that we will soon have a framework established to handle new problems as they surface and carry new programs as they are developed to meet these new needs.

Continued on next page

*John Jackson is prevention, safety, and training assistant, Oregon State Department of Forestry, Prineville, Oregon*

Keep this insert for accurate fire prevention information.



# Central Oregon Fire Protection Information

Published by the Central Oregon Fire Prevention Cooperative

Recent population growth in Central Oregon has made it necessary for all fire service agencies to place increased emphasis on fire prevention and suppression. A critical part of this effort includes providing for an increased public awareness of the situation. This publication is designed to provide as much information as possible on fire protection district boundaries, various regulations that apply within the different districts and general information on land ownership available for recreation activities.

The goal of the Central Oregon Fire Prevention Coop is to develop a strong fire prevention program for Central Oregon by combining the prevention assets of all of the fire service agencies.

The Prevention Coop is made up of all fire service agencies in Crook, Deschutes and Jefferson Counties. An Executive Committee, made up of one representative from each of the wildland fire agencies and a representative of the city and rural departments, works with the day to day coordination of fire prevention activities and special projects such as this publication.

In addition, an Advisory Committee from each county is being formed to provide a communications link between the public and this prevention effort. The Advisory Committee will be comprised of representatives of many of the economic and governmental groups of the tri-county area. If you have any ideas you feel would be of value, please contact your local fire chief, or local fire prevention coordinator from any of the following agencies: Deschutes National Forest, Ochoco National Forest, Oregon State Forestry, Bureau of Land Management.



## Reporting Fires & Burning Permit Issuance

### State Forestry Department:

This organization is charged with protection of forest lands not otherwise protected by another agency. As a result there are areas of overlap with several of the rural departments where forest lands are involved. In these cases of overlap the rurals protect the structures and related agricultural lands while the State Forestry protects the forest lands during the designated fire season (normally May through October). During the rest of the year, home owners in areas outside of city and rural fire protection districts have essentially no fire protection coverage for their homes.

### United States Forest Service:

The Forest Service conducts all land management activities on U.S.F.S. lands. Local Ranger District offices have information available on these activities. See map on following pages for identification of Deschutes and Ochoco National Forest Lands.

### Bureau of Land Management:

The BLM is responsible for all management activities on BLM lands. Fire protection on some BLM lands is provided by other agencies. An example of this may be seen in the LaPine area where protection is provided by the State Forestry. Other management activities are still conducted by the BLM. See map on following pages.

### City & Rural Fire Departments:

Structural and rural fires should be reported to appropriate fire departments on a year-round basis (see maps on following pages). Regulations may vary between fire districts. Contact your local city or rural department for details.

## Wildland Fire Information Summary:

### Oregon State Forestry Departments:

West Central District-Prineville & Sisters  
Walker Range FPA-Gilchrist

1. REPORT FIRES TO:  
447-5658 Prineville  
549-2731 Sisters  
433-2451 Gilchrist  
For information call the above numbers during normal working hours.
2. Burning permits may be obtained by calling one of the above numbers — see map on following pages to determine which one to call. Inspection of burning site required prior to permit being issued.
2. Walker Range FPA functions as a district of the State Forestry Dept. in matters dealing with fire control.

### Ochoco National Forest:

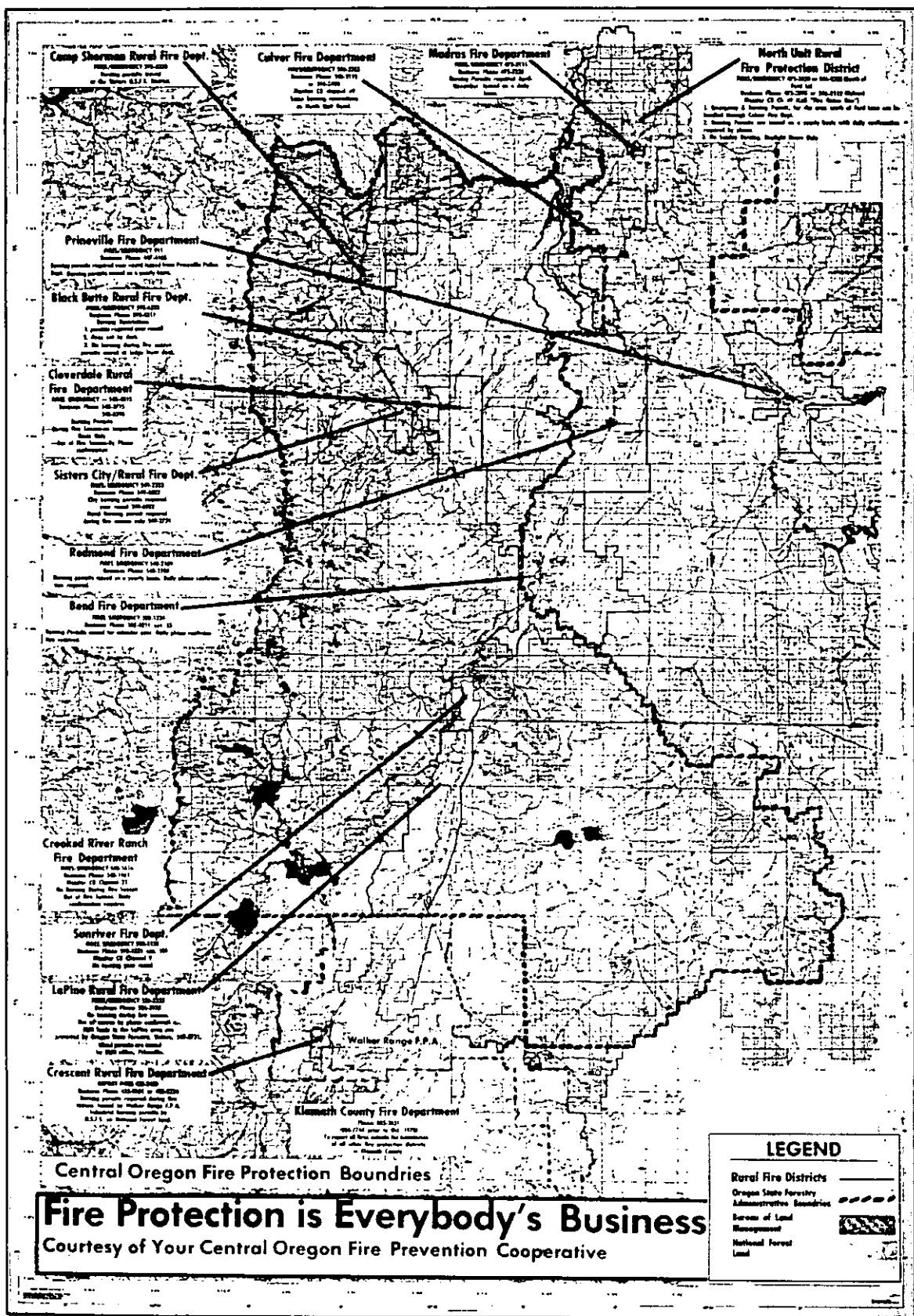
1. REPORT FOREST FIRES — 447-6845, Prineville. For recorded fire weather and industrial fire precautionary class schedules, call 447-3383, Prineville. For other information (recreation, hunting, etc.) during regularly scheduled working hours, call: Supervisor's Office 447-6247  
Big Summit R.D. 447-3845  
Paulina R.D. 447-3183  
Prineville R.D. 447-3825  
Snow Mountain R.D. 573-7292  
Crooked River N.G. 447-4120
2. Campfire permits are not required.
3. Woodcutters and pole cutters are required to obtain permits from one of the offices listed above.

### Deschutes National Forest:

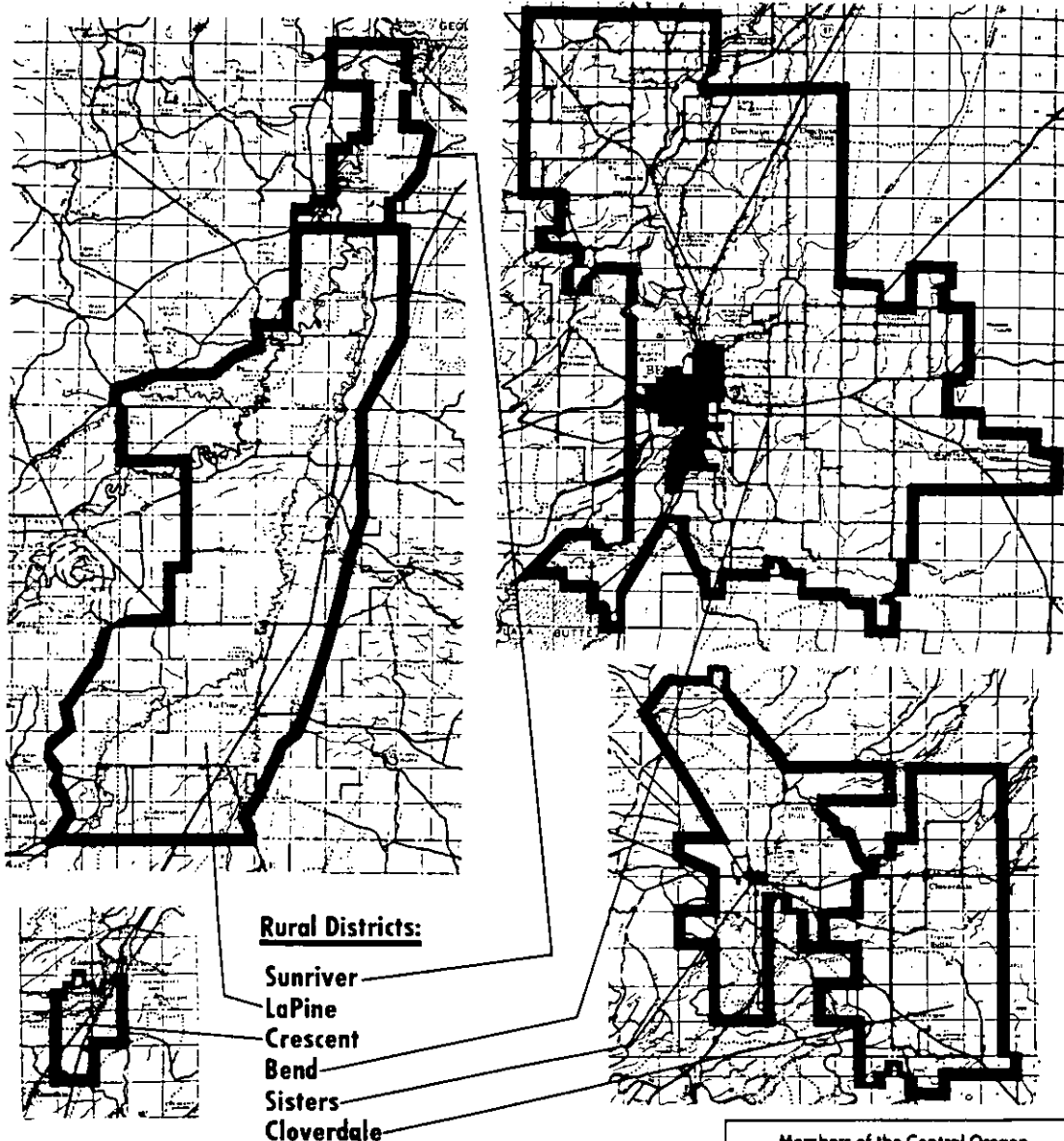
1. REPORT FOREST FIRES — 382-5211, Bend. For recorded fire weather, industrial fire precautions class and recreational information, call 389-3357, Bend.  
For other information call:  
382-6922 Bend  
433-2234 Crescent  
549-2111 Sisters
2. Campfire permits are not required.
3. The Deschutes National Forest does not issue burning permits for non-National Forest land with the exception of those private lands in the Metolius-Camp Sherman area which are issued by the Sisters Ranger District.
4. Woodcutters are required to obtain woodcutting permits from one of the offices listed below:  
Bend and Fort Rock Ranger Districts  
3rd and Rovers St., Bend  
Crescent Ranger Station, Crescent  
Sisters Ranger Station, Sisters.

### Bureau of Land Management

- Prineville District:
1. REPORT FIRES TO: 447-6467, Prineville. For recorded information on weather and current fire conditions, call 234-2324, Prineville. For other information call 447-4115, Prineville.
  2. BLM does not issue burning permits for non-public lands with the exception of those private lands in the Pauline-Snow Mountain area receiving BLM fire protection.
  3. Campfire permits are not required on BLM lands.
  4. Woodcutters are required to obtain woodcutting permits from the Prineville District office. No permits are issued between June 1 and October 31.



# RURAL FIRE DISTRICT BOUNDARIES



## General Summary of the Wildland Fire Regulations

The following list of fire regulations apply generally to all wildland areas without regard to which agency provides the fire protection.

The following acts are prohibited:

1. Carelessly or negligently throwing or placing any burning, glowing or ignited substance in any other substance which may cause a fire into any place which might start a fire.
2. Firing any waste fuel or incendiary ammunition.
3. Cutting timber, brush, dead, brush or grass to burn except as authorized by permit.
4. Leaving a fire without completely extinguishing it.
5. Allowing a fire to escape from control.

control

6. Building, attending, maintaining or using a campfire without removing all flammable material from around the campfire adequate to prevent its escape.
7. Possessing, discharging or using any kind of fireworks or other pyrotechnic device except emergency highway hazard flares.
8. Smoking, except inside a building or vehicle or when seated in an area of total fire control.

(2) feet in diameter that is barren or cleared of all flammable materials (capples during designated fire season only).

9. Operating or using any internal or external combustion engine on any timber, brush, or grass covered land, including trails traversing such land, without a spark arrester, maintained in effective working order (capples during designated fire season only).
10. Going or being upon an area of

logging slash when such areas are subject to a complete shut down of industrial operations because of serious fire weather conditions.

11. Building, maintaining, attending or using a fire or campfire unless equipped with a run (2) pound gas or shovel at least 36 inches long, and a water container with at least a one gallon capacity, or a two and one half (2 1/2) gallon ABC fire extinguisher.

Other Closures or Restriction May be Imposed as Fire Danger Dictates.

## Members of the Central Oregon Fire Prevention Cooperative

Bend Fire Dept.  
Black Butte Rural Fire Dept.  
Camp Sherman Rural Fire Dept.  
Cloverdale Rural Fire Dept.  
Crescent River Ranch Fire Dept.  
Crescent Rural Fire Dept.  
Culver Fire Dept.  
LaPine Rural Fire Dept.  
Madras Fire Dept.  
North Unit Rural Fire Protection District  
Prineville Fire Dept.  
Redwood Fire Dept.  
Sisters Fire Dept.  
Sunriver Fire Dept.  
Bureau of Land Management-Prineville District  
Deschutes National Forest  
Ochoco National Forest  
Oregon State Forestry-West Central District  
Walker Range Forest Protective Association

# The Concept of "Spatial Risk" and its Application to Fire Prevention

Clint Phillips and Brad Nickey

Fires caused by people have long been a concern of wildland fire protection agencies. Agency managers need a method of planning and evaluating fire prevention programs to deal effectively with this ignition source. Managers need to know:

1. Where and in what numbers are human-caused fires expected to occur in the future?
2. How do these fires relate to the resource values protected?
3. What human activity is expected to cause those fires?
4. What are the estimated effects of fire prevention in changing those expectations?

## Analytical Concept

An analytical concept, spatial risk, that may help answer the above questions, has been borrowed from other applications. Spatial risk is a measure of the probability of something—in this case a wildfire (or wildfires)—occurring on a designated area of land during a specific time period.

An alternate concept can be used: "expected fire occurrence." It is a measure of the average occurrence of a wildfire (or wildfires) on a designated area of land during a specific

time period. It is mathematically related to spatial risk and is derived from the same data. In this article the terms "expected incidence" and "average incidence" will be used interchangeably, although the terms are technically somewhat different.

## Principle of Using Spatial Risk

Here is the general principle applying spatial risk to wildland fire prevention programs. Let us suppose that one or more wildfires caused by people start within a specific area of land having a particular set of environmental characteristics that are significant to the starting of those fires. Then, wherever else that same set of environmental characteristics exists, the same number of wildfires of this kind should logically occur in the future.

If the same number of fires does not actually occur in the other locations, then the reason for the difference may be attributed to fire prevention effort or to unknown factors. The trick, of course, is to eliminate as much as possible all the "unknown factors" so that the difference in fire incidence can be attributed wholly to fire prevention.

## Development of Spatial Risk

*Step 1:* Spatial risk requires gathering data on the number of human-caused wildfires for specific planning units and periods of time. The planning unit can be any shape or size. The period of time is also arbitrary. Where the concept is being

tested cooperatively in San Bernardino County, Calif., by both the Forest Service and the California Department of Forestry, the "planning unit" is a legal section or a quarter-section; the "period of time" is the most recent 5 years.

*Step 2:* For each planning unit, data are also gathered about those environmental factors that are known or are suspected to have a strong relationship to fire incidence, e.g., different standards of roads and trails, population densities and distribution, campgrounds, railroads, powerlines, fuel models, streams, etc.

*Step 3:* The data are run through a procedure of complex multivariate analysis. This process uses a computer program called THAID, which is a recent offspring of AID (Automatic Interaction Detection) developed by the Institute of Social Research, University of Michigan. THAID was developed to assist analysts in their search for an appropriate model to explain the most significant characteristics of the phenomena they are investigating. In our case the procedure provides an explanatory model consisting of those environmental factors (and their interactions) that best explain the level of fire occurrence within the planning unit.

*Step 4:* The next step of analysis uses the explanatory model developed in Step 3 to determine the expected future fire incidence of other planning units, based upon the specific environmental factors as-

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Brad Nickey is a research scientist at the Riverside Forest Fire Laboratory, Pacific Southwest Forest and Range Experiment Station, located at Riverside, Calif.

Continued on next page

## "SPATIAL RISK"

From page 7

sociated with the units. For example, let us assume that the explanatory model finds legal sections having certain measures of environmental factors B, E, S, and T and also having a history of 4.5 human-caused fires per year, on the average. We should expect in the future the same annual incidence of 4.5 fires, on the average, in all other legal sections having an equal measure of environmental factors B, E, S, and T.

Step 5: The final step in the proc-

ess is to prepare PLAID maps that display the expected future fire incidence for all sections. (PLAID is an acronym for *Projected Location After Inventory Decomposition*. It describes the overlay maps that visually display spatial risk. The "Inventory Decomposition" refers to the analytical procedure used to derive the explanatory model in Step 3.)

Expected fire incidence is grouped into five or six broad classes of annual incidence per section, such as 0-.5, .6-1.0, 1.1-2.0, and 2.1-4.0 fires per year, etc. Each class is represented on the map by some kind of

symbol, such as vertical lines, horizontal lines, cross-hatching, etc. (fig. 1). Each section is given the symbol that represents the class of expected fire incidence it fits. The final product is a map from which it is relatively easy to note different levels of expected fire incidence. With the sections presenting a varying pattern of horizontal lines, vertical lines, diagonal lines, etc., the map has a "plaid" appearance, just coincidental to the acronym!

Continued on page 19

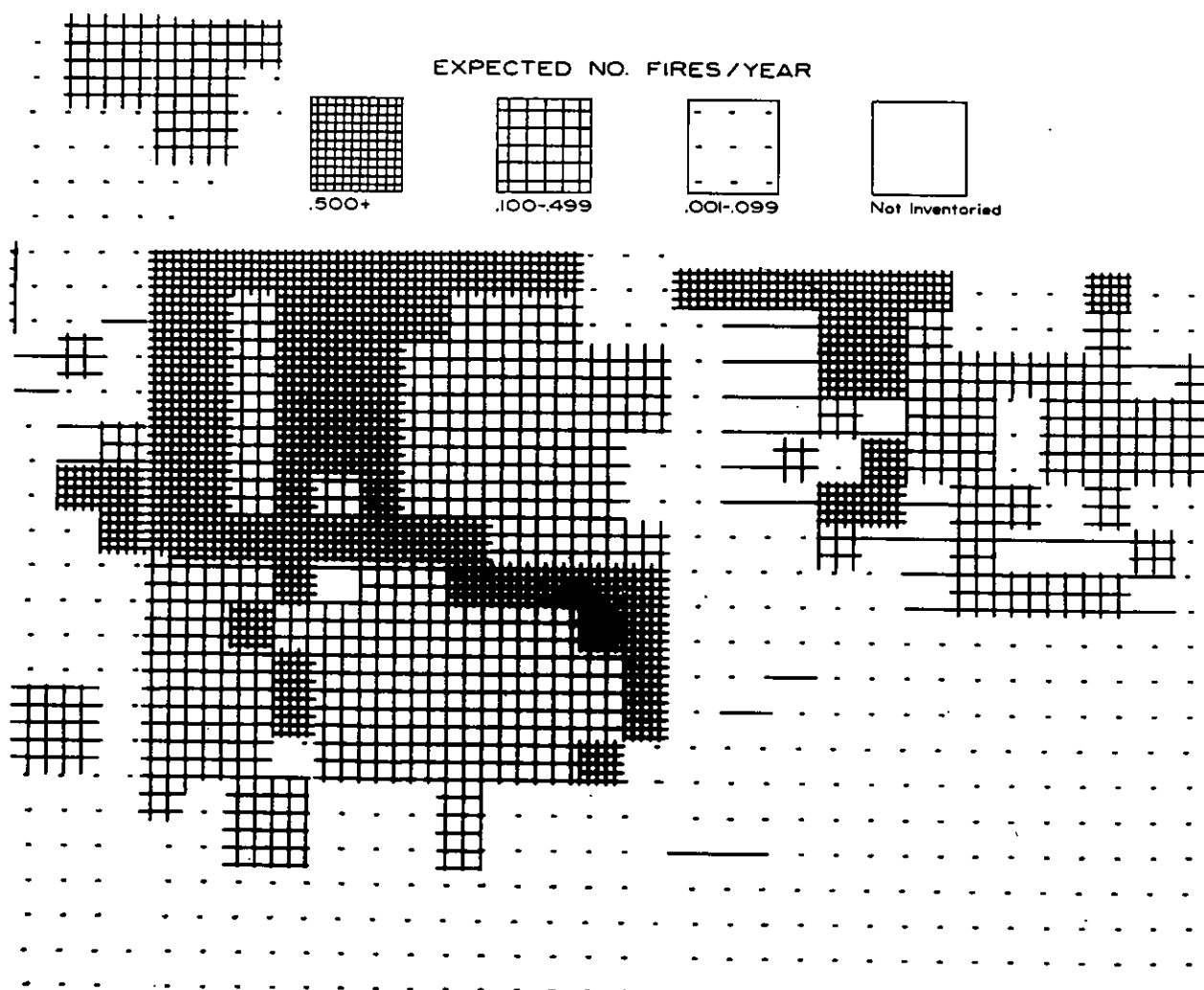


Figure 1.—PLAID map of expected children-caused fires in Battalions 2 and 3, San Bernardino Ranger Unit, California Department of Forestry.



# An Approach To Hazard Classification

R. Gordon Schmidt

Over the years numerous systems have been developed for estimating fire danger and assessing the resources necessary for adequate fire protection. Development over the last half century included:

- In 1914, one of the first attempts to classify fuels was undertaken for California forest cover types. This system assigned numerical values of 100 to grass, 23 to brush, and 11 to timber in an attempt to assess the acres burned per hour in each of these cover types (Dubois 1914).
- In 1929, a relative hazard rating was developed for northern California cover types based on rate of area spread. This effort coupled actual fire behavior and fuel conditions together to yield estimated hazard values (Show and Kotok 1929).
- In 1936, the adjective rating system for the Northern Region was produced. Four adjectives—low, moderate, high, and extreme—were used to rate fuel beds for “resistance to control” and “rate of spread.” Areas were rated on weather conditions of the average-worst day. The rules for establishing adjective ratings were based largely on the fuel appraiser’s past experience. This was the first attempt to look solely at fuels without regard to cover type. The system gained national acceptance and is currently still in use in all Regions to one degree or another (Hornby 1936).
- With the advent of the National

Fire Danger Rating System (NFDRS) came the fuel modeling approach to classifying fuels. The fuel modeling approach established the numerical data necessary to describe the fuel complex used in solving Rothermel’s mathematical model for determining fire spread (Rothermel 1972). This approach was applied to large areas for the purposes of estimating fire danger in protection units.

In general, these systems are based largely on subjective estimates of the fuel conditions for the area.

While these approaches attempted to integrate fuel, weather, and topography they did so subjectively, except for the NFDRS. No system has been developed to specifically aid the fuel manager in planning.

## The Concept

A long list of fire physics researchers have developed portions of an integrated approach to determining fire behavior. Rothermel (1972) developed the most current model for predicting fire spread. Rothermel’s model is the basis for most of our current fire management tools, such as the NFDRS (Deeming *et al* 1972) and the fire behavior nomograms (Al-

bini 1976).

The integrator of the three fire behavior influences—fuel, weather, and topography—is the fire itself. The fire determines what part each fire behavior factor plays in the behavior of the fire.

The integrated approach requires description of the three fire behavior influences—fuel, weather, and topography. Fuel can be described through an inventory. Weather elements can be defined at a fixed planning level, such as the 90th percentile, using weather records. Topographic influences can be determined from topographic maps or actual measurements.

As an example of this approach, consider the first photo (fig. 1) in the Photo Series for Quantifying Forest Residues in the Coastal Douglas Fir-Hemlock Type (Maxwell and Ward 1976). The fuel data necessary for solving Rothermel’s spread model are shown in table 1.

Consider this fuel complex to be in the Bull Run Watershed on the Mt. Hood National Forest in Oregon.

Our planning level for weather is

Continued on next page

Table 1  
Fuel Data

Timelag Class	Surface Area-To-Volume Ratio (1/ft)	Loading (Tons/acre)
1 hour	1500	0.20
10 hour	109	2.00
100 hour	30	1.50
1000 hour	8	3.60
Fuel Bed Depth: 0.2 feet		

*Gordon Schmidt is fire management officer on the Columbia Gorge Ranger District, Mt. Hood National Forest, Portland, Ore.*



Figure 1—Douglas-fir, Size Class: 4, Clearcut.

## AN APPROACH

*From page 9*

the 97th percentile level. That is that level below which 97 percent of the weather values were less severe. These weather data are shown in table 2. Fuel moistures are listed here as they are a direct reflection of weather.

For purposes of the example we

will place the fuel complex on a 47 percent slope.

Once the data have been defined, they can be integrated using Rothermel's spread model. The model is much too "bulky" to solve by hand. Several different computer programs are available to integrate the data. The AFFIRMS program has a link called "firecasting" that can be used. Also, the TI-59 calculator can be used with a preprogrammed chip for the spread model.

Table 2  
Weather Data

1-hour fuel moisture	4.5%
10-hour fuel moisture	5.5%
100-hour fuel moisture	11.0%
1,000-hour fuel moisture	20.0%
Midflame wind speed	8.0 mph

The output from the model consists of several parameters, one of which is Byram's (1959) fireline intensity. Fireline intensity is the heat energy release rate per linear foot of flaming fire, expressed in Btu/foot/second.

The data in our example produced a fireline intensity of 1.9 Btu/ft/sec and a forward rate of spread of 1.1 feet per minute.

Many researchers have correlated fire control problems with Byram's intensity. With this large body of research available, interpretations of Byram's intensity are simple and relatively accurate. For example, a Byram's intensity level of less than 100 Btu/ft/sec indicates a fire that is easily controlled by direct attack with hand tools. Intensities of 100–500 Btu/ft/sec require somewhat more

sophisticated control methods such as bulldozers and aerial retardant. Fires producing more than 500 Btu/ft/sec are on the verge of uncontrollability (USDA Forest Service 1978).

Using these three general categories, and site-specific information on fuel, weather, and topography, sites can be classified based on their potential fire controllability. These three broad categories are called Hazard Levels (table 3).

Our example is clearly classified at Hazard Level I.

## Limitations

The Bull Run Watershed on the Mt. Hood National Forest is currently classified in this manner. Some uses of the analysis are:

1. Identification of unacceptable fuel complexes that can cause problems should a fire occur (Hazard Level III).
2. Establishment of priority for fuel treatment. The highest Hazard Level is treated first.
3. Certification of fuel treatment objective attainment. As an example, a clearcut is treated to Hazard Level I.
4. Commonality in communications concerning fuel hazards. The Photo Series for Quantifying Forest Residues in the Coastal Douglas Fir-Hemlock Type (Maxwell and Ward 1976) has been appraised with this system, which gives photographs of the Hazard Levels (Schmidt 1978).
5. Use of site specific data in other areas of resource management such as wildlife habitat.

All the limitations and assumptions incorporated in Rothermel's spread model (1972) exhibit themselves in this system; they are:

1. Fuel uniformity, both vertical and horizontal, is assumed. This assumption is largely violated in natural fuels, but Rothermel's (1978) concept for appraising nonuniform fuels will aid in overcoming this limitation.
2. Steady-state combustion

occurs—little or no fluctuation in fire intensity occurs.

3. Erratic fire behavior is not considered within the model. Long-range spotting, fire whirls, and crowning are outside the scope of the model and are not predicted by it. Some inferences in relation to the probability of these events occurring may be made from Rothermel's model output (USDA Forest Service 1978).

Other limitations include:

1. The system is best used as a comparative tool to weigh one area against another. The predicted level of Byram's intensity may not accurately represent the actual intensity if the area burns.
2. This system is not designed to be a real-time fire behavior system. If a fire occurs on an area, a Fire Behavior Officer is necessary and this system is of little use.

Research needed to help make this system more accurate includes determining the level of fuel inventory intensity necessary and further work on correlating Byram's intensity with the resistance to control element of Hornby's system.

## Conclusion

It appears as though the objective Hazard Level approach to classifying fuels is applicable nationwide. This system could offer a logical replacement for Hornby's adjective rating system.

## Literature Cited

Table 3  
Hazard Levels

Level	Byram's Intensities	Controllability
I	100 Btu/ft/sec	Direct attack by hand
II	100-500 Btu/ft/sec	Bulldozers, aerial retardants
III	500+ Btu/ft/sec	Uncontrollable

Albini, Frank A.

1976. Estimated wildfire behavior and effects. U.S. Dep. Agric. For. Serv. Intermt. For. Range Exp. Stn. Gen. Tech. Rep. INT-30.

Byram, George M.

1959. Combustion of forest fuels. In: Forest fire control and use. K. P. Davis, 1959, McGraw Hill, New York, Chapter 3, p. 61-69.

Deeming, J. E., J. W. Lancaster, M. A. Fosberg, R. W. Furman, and M. J. Schroeder.

1972. National fire danger rating system. U. S. Dep. Agric. For. Serv. Rocky Mt. For. Range Exp. Stn. Res. Pap., RM-84.

Dubois, C.

1914. Systematic fire protection in California forests. U.S. Dep. Agric. For. Serv., Wash., D.C. 68 p.

Hornby, L. G.

1936. Fire control planning in the northern Rocky Mountain region. U.S. Dep. Agric. For. Serv., North Rocky Mt. For. Range Exp. Stn., Prog. Rep. 1, 188 p.

Maxwell, Wayne G., and Franklin R. Ward.

1976. Photo series for quantifying residues in the coastal Douglas fir-hemlock type. U.S. Dep. Agric. For. Serv., Pac. Northwest For. Range Exp. Stn. Gen. Tech. Rep., PNW-52.

Rothermel, R. C.

1972. A mathematical model for predicting fire spread in wildland fuels. U.S. Dep. Agric. For. Serv., Intermt. For. Range Exp. Stn., Res. Pap. INT-115.

1978. A concept for appraising fire in nonuniform fuels. U.S. Dep.

Continued on page 19

# Determining Arrival Times of Fire Resources By Computer

Romain M. Mees and Ira B. Pearman

Portable computer terminals connected to a central computer are now widely used by many land management agencies. In California, the fire management staff of the Cleveland National Forest is using an interactive terminal and a computer program called TRAVEL to determine travel times for both air and ground suppression forces to selected locations within existing initial attack response areas.

In determining preplanned response areas, travel time by fire suppression resources dispatched to a fire, topography, past fire frequency and size, and current fuel conditions are frequently used. The size and shape of these areas depend heavily on the initial attack time required to travel to the far corners of each response area.

Arrival times provided by the TRAVEL program can be used to redefine the size and shape of existing response areas and the order in which suppression forces are dispatched within each area.

## TRAVEL Program

Two data files, describing the road

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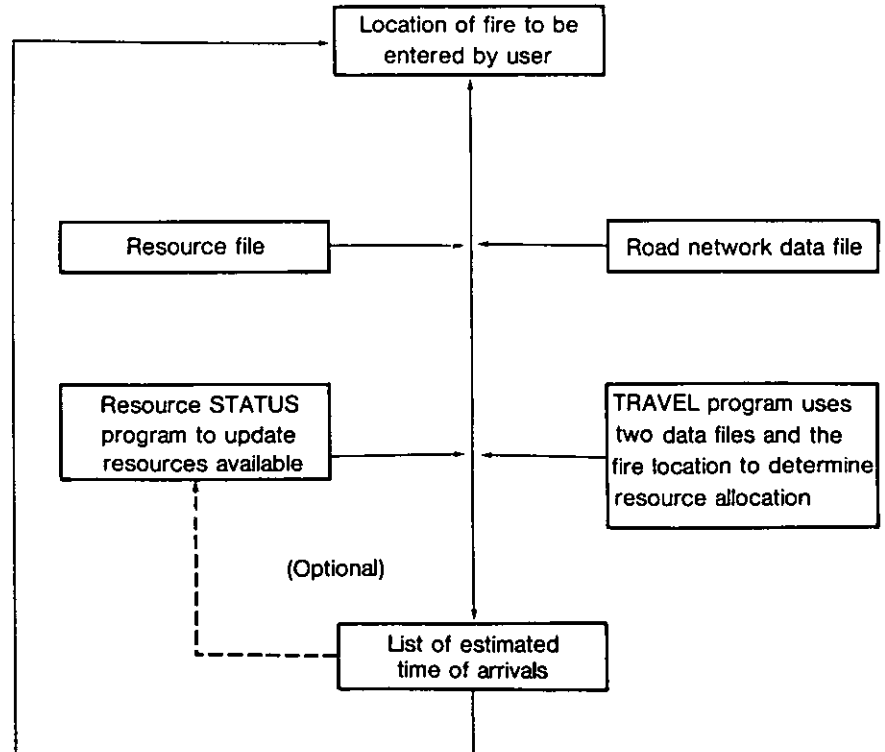
*Ira Pearman is forest dispatcher, Cleveland National Forest, San Diego, Calif.*

system used by the planning unit and the suppression resources available, must be kept at the central computer site. The program and data files were developed and maintained by the Pacific Southwest Forest and Range Experiment Station, Riverside Fire Laboratory. The road network data must be up-to-date to provide current road travel times. Definitions and

data specifications are the same as for the road network described in FOCUS (USDA 1977). All suppression forces must be identified by name, location, getaway time, status, and other attributes.

To obtain a listing of resources and their arrival times at a particular location, the dispatcher specifies the location of the fire in (a) longitude

Figure 1--The TRAVEL program provides for allocation of resources to a fire. The STATUS program provides for an update of the resources.



and (b) latitude coordinates, (c) the maximum initial attack time he wishes to consider, and (d) the off-road travel (walk) speed to approach the fire on foot. The accuracy of arrival times computed by the program depends on the travel times and node locations provided by the user.

The listing of initial attack resources consists of all units (existing and proposed) dispatchable from home base to the fire within the specified 30-minute time limit. Column 1 lists the arrival time (minutes), including getaway (delay) time, actual time on the road or in the air, and off-road travel time computed at an average walk speed, subject to local terrain conditions. Column 2 lists the computed bearings from the aircraft or helicopter base location to the fire (a zero is given to all ground units). Column 9 lists the delay or getaway time originally entered for each unit by the dispatcher into the resource data file. The other columns are used to further identify the ground or air units by name (3), location (8), capacity in gallons (6), and number of persons on the unit (5).

## Results

The TRAVEL program requires road network data described in terms of node locations and travel times between nodes. The user must acquire a data file for the description of the suppression forces.

The resulting travel time computations can be used to:

1. Assist in the development of preplanned response areas. Because of local road constraints, it can be determined if suppression forces located nearest to a fire and historically selected as the first initial attack (response) units are always the units with the earlier possible arrival times at the fire site. The expected time differential between aircraft and ground force arrival for many areas on the forest can also be evaluated. These findings often lead to a realignment and reevaluation of preplanned areas.
2. Assist in 24-hour dispatch during the fire season. The TRAVEL program can be used during the fire season to develop arrival times for those units not dispatched under preplanned allocations but needed for further suppression and support.
3. Assist in fire suppression training. Air and ground force arrival times computed by the program can be used to develop real life fire situations during the use of a fire simulator for training purposes.

## STATUS Program

The resource information comes from the resource file and can be updated using the STATUS computer

program.

The TRAVEL program can be run concurrently with the STATUS program (fig. 1). The STATUS program allows the dispatcher to update the status of any suppression unit in the resource data file. Items such as current location of the suppression force, number of people, special attributes and equipment, getaway time, and crew boss name, can be entered and updated.

The combination of the TRAVEL and STATUS programs enables the dispatcher to determine what forces to send to a given area, when they should arrive, and which can best be used as secondary or backup forces.

The TRAVEL program has contributed to more efficient dispatching on the Cleveland National Forest. With occasional updates in the Forest's road network, it should provide many years of service under varying conditions and suppression requirements.

## Literature Cited

- U.S. Department of Agriculture,  
Forest Service.  
1977. User's manual for FOCUS  
(Fire Operational Characteristics  
Using Simulation). U.S. Dep.  
Agric. For. Serv., Pac.  
Southwest For. Range Exp. Stn.,  
For. Fire Lab., Riverside, Calif.



## EXAMPLE

The following list of suppression units, available at the fire site within 30 minutes, results from entering these data: longitude, 117° 537', latitude, 33° 879', maximum initial attack time, 30 minutes; off-road walk speed, 3 miles per hour.

(1) TIME	(2) BEARING	(3) NAME	(4) UNIT	(5) PEOPLE	(6) SIZE	(7) TYPE	(8) BASE NO.	(9) DELAY-T
4	0	Corona FS	1	5	300	12	2GD	2
5	0	Corona CDF	1	4	500	22	1GD1	5
5	0	Corona CDF	2	4	500	22	1GD2	5
10	0	Corona Moved FS	1	5	300	12	62GD	2
18	276	Ryan	2	0	800	7	70AR	10
18	276	Ryan	3	0	800	7	71AR	10
19	143	Ont	1	0	2000	7	72AR	15
19	311	El Cariso	1	2	13	5	73HT	7
20	0	Temescal FS	1	5	500	12	6GD	2
22	276	Ryan	1	0	1400	7	69AR	12

# Helicopter Use In Forest Fire Suppression; 3 Decades

Ralph G. Johnston

"Help!" the voice on the radio screamed, "I'm trapped, the fire's all around me!" The year, 1947; the fire, the Bryant Fire on the Angeles National Forest in southern California. The situation: a radio operator running an emergency radio relay station on a remote ridgetop was in the path of a blowup. Five minutes after his call, he was safely off the mountain. The helicopter had made its forest fire debut in the United States.

Over 30 years ago, on August 5, 1947, the helicopter was first utilized on a forest fire in the United States, not only for rescue but for logistical missions.

Weary firefighters have often dreamed of some method or vehicle to ride over tree tops and across canyons and mountain peaks to attack small isolated fires.

This dream started to develop into a reality when, in 1922, an Auto-Gyro was utilized for a reconnaissance flight over the Los Padres National Forest in California. This flight is considered the first use of a rotary-wing aircraft in forestry-type missions.

Other noteworthy achievements of helicopter fire suppression use prior to 1947 in North America include:

- The first recorded use of a helicopter for fire management in North America occurred June 26, 1946, on the Sudberry District, Ontario Department of Lands and Forests, Province of Ontario, Canada. The helicopter was a Bell 47-B, donated

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through the cooperation of Larry Bell of Bell Aircraft, who was interested in expanding the useful roles of helicopters.

- The second recorded use occurred in Alaska on July 12, 1946, on an Alaska Fire Service fire. A Sikorsky R-5A was used (for reconnaissance purposes only) on a fire near Fairbanks.

- The third recorded use was on the Red Rock Fire, Angeles National Forest, Castaic, Calif. September 9-10, 1946. A Sikorsky R-5 helicopter from March Field was utilized for scouting, mapping, and dropping freight. It did not land on the fire.

- Testing of Sikorsky R-5A and R-5D helicopters was conducted by USDA Forest Service (USDA FS) and

U.S. Army Air Force, in mountainous areas during 1945.

### The First Decade

August 5, 1977, marks the 30th anniversary of the first, fully-operational, extended use of a rotary-wing aircraft on a forest fire in the United States and possibly in the world. The unique capabilities of a Bell 47-B helicopter were fully realized and demonstrated on this fire. This helicopter, flew hundreds of firefighters and 1,000 pounds of freight; evacuated sick, injured, and trapped firefighters; flew reconnaissance/scouting missions; and "hover jumped" firefighters for purposes of helispot construction.

Operating in temperatures up to 107 degrees F and in pressures encountered at 5,400 ft. altitude, it demonstrated that, although the helicopter was very limited in payload capability, it had a place as a logistical vehicle in the fire organization.

In 1949, the first helicopter training film was developed to aid in instructing firefighters on safety around the aircraft and on principles of helispot location and construction.

During 1954, a special project referred to as "Operation Fire Stop" was initiated by a host of Federal, State, county, Military, and private organizations who pooled their efforts to develop new tools, methods, and techniques to help meet the California forest fire problem. One phase of this project was experiments with both large and small helicopters to perform such tactical operations as laying fire hose and delivering firefighters and water and pumping equipment (helipumps) without landing.

These experiments lead to the selection of a four-man crew that was assigned specifically to a contracted Bell 47-D model helicopter at Chilao, Angeles National Forest. This crew was designated as a helishot crew (later changed to helitack crew) to continue field testing of helijumping, dropping water, and laying fire hose from the air.

The first decade of helicopter fire use was primarily logistical or support operations with the light Bell 47 piston engine model helicopters. By 1957, the experiments and tests for laying hose, dropping water, sling-ing, helipumpers, dropping para-cargo and helijumping were completed and ready for operational use. A Bell 47-G-2 helicopter was contracted and a USDA FS five-man crew was assigned to the helicopter. This helitack crew was the first operational crew using the necessary equipment and accessories. They developed and refined many procedures and techniques still being used today.

The hose tray—helitank—helipumpers—para-cargo hardware family of accessories was developed and tested by Herb Shield of the Arcadia Equipment Development Center, Arcadia, California (now the San Dimas Equipment Development Center, San Dimas, California).

### The Second Decade

The hardware available and in use today by the fire services, not only in the United States but in many parts of the world is the refinement of the original concept by Herb Shield. Numerous demonstrations took place in 1957 for the news media, interested public, private groups, and top-level management personnel of various Government agencies. In the process of learning to use this hardware, failures naturally occurred; however, successful use of these concepts outweighed the failures.

Also in 1957, the late Roland Barton, Chief Pilot of Los Angeles (L.A.) County Fire Department, started pioneering a helicopter fire-fighting program that today is one of the finest of its kind in the world. Seven light piston engine helicopters used on the 1957 Gale Fire in the Angeles National Forest, moved over 3,000 firefighters during a 10-day period.

In 1958 there was increased use of light helicopters on fires and selected use of large, commercial and military

helicopters (S-55, S-58, and H-21) on fires.

This year also marked the introduction of the Alouette II helicopters for fire suppression use. This light turbine helicopter was the first having good payload capability for higher altitude fire suppression missions in the Western United States.

Another significant first was accomplished in 1958 on the Morris Fire, Angeles National Forest in California, with the laying of 10,000 feet of fire hose from two light Bell 47G-2 helicopters (one a USFS Contract and the other belonging to the L.A. County Fire Department). Helitack crews from both agencies served as ground crews for loading trays. This accomplishment represents possibly the longest and fastest laying of fire hose on record.

Development of standardized lesson plans on helicopter safety, helispot location and construction, and helijumping were developed by James Murphy of the Pacific Southwest Forest and Range Experiment Station. In 1958, Murphy trained over 300 California firefighters in helicopter use.

More and larger helicopters were used on fires in 1959, including ten light- and medium-sized helicopters on the Woodwardia Fire, Angeles National Forest. This represented one of the largest helicopter operations in forest fire use to that date. Over 3,000 firefighters, 56,000 gallons of water or retardant, and 45 tons of freight were moved or dropped. The first helicopter training film was also developed that year.

During 1961, helicopters of all sizes were utilized by fire agencies in large fleets, and used on fires in numerous areas of the United States. Also during 1961-62, a fixed mounted 100-gallon drop tank for light helicopters was used for dropping water and retardants on fires. The Canadians developed a helicopter bucket "hover fill" system that was utilized by several fire agencies in the United States. Buckets of

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500-gallon capacity were used with larger helicopters.

During 1961, the Bell 47G-3B, which provided higher altitude capability, was introduced to the fire services, and the Hiller 12E provided increased speed for fire suppression activities.

During 1962-63, increased numbers of helicopters were placed on formal contracts and based on strategic locations in forest areas in the United States by various fire agencies.

In 1964, 19 helicopters were utilized on the Coyote Fire, Los Padres National Forest in California. Fourteen helitack crews from the USDA FS and National Park Service U.S. Department of the Interior assisted in managing this operation. During a 12-day period they flew 1,172 hours, moving over 8,900 firefighters and 250,000 lbs. of freight, dropping 28,000 gallons of water and retardants, laying 18 miles of telephone line (from a helicopter telephone wire layer) to provide communication to various fire camps, and conducted 13 helijumps for hot spotting and helispot construction.

In 1964, a Bell 204-B, medium-sized turbine helicopter was first used in a fire suppression system. Placed under a formal contract, this aircraft proved to be an outstanding aerial vehicle for moving large crews of firefighters and thousands of pounds of freight. Dropping of water, retardants, and cargo; helijumping; and the first experimental use of parachuting and rappelling firefighters were tested with this aircraft.

Large fleets of helicopters were utilized on a Bureau of Land Management (BLM) Fire in north-central Nevada this year.

During 1965, a "Helitack Training guide" was developed to assist users in the methods and management of helicopters engaged in fire suppression activities.

In 1966 and 1967, fleets of up to 20 helicopters were assigned to individual fires in the western United States and Canada. A NPS fire in West Glacier, Montana, during 1967 utilized seven U.S. Air Force Huey F Models and three commercial light machines. Moving thousands of firefighters and tons of freight, new records were again set in men and freight moved on a forest fire.

The introduction of the light turbine Hughes 500, Hiller FH-1100, and Bell 206A helicopters increased speed and strength of attack for many fire agencies.

This second decade of use can be categorized as the era of use of increased numbers and size of aircraft, and the introduction of turbine-powered aircraft for logistical missions.

Development of training packages and intensified training efforts by all

agencies were implemented; many agencies reported that one of the key factors attributing to speed of attack and low burned acreage had been the efficient use of helicopters and helitack crews during this decade.

### The Third Decade

The third decade, starting in 1968, saw the continued increase in use of light and medium turbine helicopters for fire suppression by the fire services. This year marked the development, testing, and use of a 350-gallon external fixed helitank for the Bell 204-B, medium-sized helicopter. This tank, developed by the USDA FS with the cooperation of the L.A. County Fire Department, turned out to be the finest tank so far developed for dropping and cascading water and retardants from helicopters.





In 1968, Oregon and Washington began utilizing Kaman H-43A model helicopters with buckets for fire suppression. Another helicopter management training film was produced to assist in training the user of helicopters in fire operations. The Bureau of Land Management (U.S. Dep. of the Interior), in Alaska used over 50 helicopters (for tactical and logistical missions) on the Swanson River Fire. This represented the largest number of helicopters assigned to one fire in the history of helicopter firefighting.

During 1970, managers of numerous class C (10 acres) and larger fires in north-central Washington used over 50 light, medium, and heavy helicopters to provide support for combating this conflagration.

In 1971, Federal fire agencies reported that over 1,500 forest and range fires were attacked and successfully controlled by the use of helicopters.

In 1973, a multitude of project forest fires in western Montana and northern Idaho triggered the need for another fleet of over 50 helicopters. On the Caribou fire, in northern Montana a Boeing/Vertol 107-11 was utilized as a helitanker with an 800-gallon bucket. By hover-filling from a small lake near the head of the fire, the helicopter was able to drop over 9,500 gallons of water per hour. This was instrumental in controlling the head of the fire.

The seven-passenger French-made Alouette III helicopters were placed either on formal contract or rental agreement by many fire agencies in the United States in 1974.

During 1975, an increased number of medium-sized helicopters (Bell 205A-1, S-55T, etc.) were utilized by fire agencies on rental agreement, lease, contract, or owned. Light- (Boeing/Boelkow 105-C) and medium- (Bell 212) sized twin engine helicopters were also added to the fleet of firefighting helicopters.

1976 and 1977 saw the increased use of light and medium twin turbine helicopters. It is estimated that over

300 helicopters were flown over 40,000 hours a year at a cost of over \$36,318,000, by the fire services in the United States (Federal, State, county, and cities).

The combination of increased payload and altitude performance coupled with speed was the most significant development during this decade. These improvements provided the fire services with the capability to move thousands of firefighters and tons of freight, drop 100 to 2,000 gallons of water or retardant from buckets or fixed tanks, perfect the techniques of rappelling or parachuting firefighters, and opened up the possibility of helicopter night-flying.

This chronology might lead one to the conclusion that the course of helicopter acceptance and use by the fire services was one of smooth sailing. Such was not the case. Many discouragements confronted the first users. Only a handful of personnel initially believed in the helicopter/helitank concept during its infancy and daringly voiced their belief by implementing helicopter use for fire suppression. However, they faced skepticism from their co-workers.

From the firefighter's viewpoint, the helicopter has become a familiar multiple-use firefighting aircraft. Its value and effectiveness are beyond question, as this remarkable vehicle is as necessary in modern day fire suppression as hand tool crews, smokejumpers, tractors, and ground and air tankers. It has increased tactical and logistical mobility by supplementing traditional ground-bound systems, for both initial attack and project fires.

To utilize this capability efficiently, helicopters must be integrated into the fire organization and closely managed by trained personnel. The success of efficient use also depends upon:

- Matching helicopter performance capabilities to mission's requirements.
- Requiring highly skilled pilots with the ability to perform the assigned mission.

- A landing system (helispots, helistops, heliports) strategically located in relation to the problem area.
- The availability and use of aircraft-rated external hardware and accessories.
- Profiting from our mistakes and improving on what we already know.
- Avoiding technology outstripping the fire service's ability to manage it.

In conclusion, I would be remiss if I did not mention the pioneering efforts by many contract helicopter pilots, contractors, agency administrators, pilots, fire control officers at all levels, helitack foreman, crewmen, equipment developers, and fire researchers. Aside from the various Federal Government agencies, many States, counties, and cities stretching from Hawaii to Maine have utilized and pioneered helicopter use for fire suppression mission.

The objectives for the helicopter's use, both present and future, remain the same—to conduct an operation, efficiently considering safety, tactics, logistics, and economics.

## Literature Cited

- California Division of Forestry.  
1963. Fire control experiments—a story of helitack operation in northwest California., Calif. Div. For., 10 p.
- Davis, James B.  
1963. Dropping fire retardants by helicopter: tests of three new helitanks. Pac. Southwest For. Range Exp. Stn., Berkeley, Calif., U.S. Dep. Agric. For. Serv. Res. Note PSW-27, 16 p.
- Dektar, Cliff.  
1962. Helicopter air attack drops. Los Ang. Cty. Fire Dep., Los Angeles, Calif. 2 p.
- Funk, Ira C., and F. W. Millan.  
1948. Test operations of Bell model helicopter: model 47-B in mountainous area. U.S. Dep. Agric. For. Serv., Arcadia Fire Control Equip. Dev. Cent., Equip. Dev. Rep. No. 12, 13 p.
- Johnston, Ralph, G.

Continued on next page

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From page 18

1964. Bell 204B helicopter evaluation report. U.S. Dep. Agric. For. Serv., Redding, Calif. 35 p.
1971. Helitack training guide. U.S. Dept. Agric. For. Serv., 170 p.
- Johnston, Ralph G., and Richard Erickson
1973. Interagency helicopter management training guide. U.S. Dep. Agric. For. Serv. 15 P.
- Johnston, Ralph G., and James Murphy. 1965. Helitack guide, U.S. Dep. Agric. For. Serv., Reg. 5, 155 p.
- Murphy, James
1958. Ground operations for helicopters. U.S. Dep. Agric. For. Serv., Fire Control Notes 19(2): 74-78.
1958. Helitack crews pay off in California. U.S. Dep. Agric. For. Serv., Fire Control Notes 19(2): 94-96.
1958. Training the helitack crew. U.S. Dep. Agric. For. Serv., Fire Control Notes 19(2): 91-93.
1959. Safety rules for helitack. U.S. Dep. Agric. For. Serv., Pac. Southwest For. Range Exp. Stn. Coop. Rep., 77 p.
1959. Helispot location and construction. U.S. Dep. Agric. For. Serv., Pac. Southwest For. Range Exp. Stn., Misc. Pap. 31, 18 p.
1959. The helijump—the research and development of the helicopter hover jump technique. U.S. Dep. Agric. For. Serv., Pac. Southwest For. Range Exp. Stn., Misc. Pap. 33, 22 p.
- Shield, Herbert J., J.C. Kidwell, and R.N. Turk.
1961. Flight performance of Hiller model 12E/61. U.S. Dep. Agric. For. Serv., Arcadia Equip. Dev. Cent., 17 p.
- Shield, Herbert J.
- Helicopter flight data are easy to use. U.S. Dep. Agric. For. Serv., Arcadia Equip. Dev. Cent. Rep., 5 p.
1959. Helicopter accessories for forest fire control. U.S. Dep. Agric. For. Serv., Missoula, Mont. Equip. Dev. Cent., 33 p.
1959. Installation and use of helicopter hose tray. U.S. Dep. Agric. For. Serv., Arcadia Equip. Dev. Cent., 6 p.



## "SPATIAL RISK"

From page 7

### Application To Fire Prevention

How can spatial risk be applied to fire prevention? A study of spatial risk PLAID maps could lead to at least two conclusions:

1. If the *actual* fire incidence is different between two areas having the same set of significant environmental characteristics (and therefore the same *expected* fire incidence) and we have done our homework correctly, selecting and analyzing the environmental data associated with fire incidence, then the difference should be explainable in terms of fire prevention effort in the two areas.
2. When the analysis shows that there are sections where *actual* fire incidence was less than *expected* and we *know* that it was *not* attributable to fire prevention effort, then maybe we need to step up fire prevention in those areas before incidence begins to increase, as expected. The actual occurrence of a fire incident in the section is dependent on the "chance" or the mathematical probability of the event; sooner or later the incident will occur if the present environmental conditions persist.

In the application of spatial risk in San Bernardino County, the fire data have been broken down further by *cause* of fire. A separate spatial risk PLAID map has been made for each of the most important causes of fires (incendiary, equipment, playing with fire, smoking, and all other), as well as for D and larger fires. A map is made, for example, for incendiary-caused fires. The map indicates (through symbols) those sections where incendiary-caused fires have *actually* occurred or where they are *expected* to occur in the future in particular numbers because of a particular set of environmental factors.

Spatial risk will provide clues as to where and how to apply efforts of fire prevention. An alternative might be to change one or more of the environmental factors that are predictors of high fire incidence: A program of fuel reduction might be initiated; a particular road or trail might be closed to entry on certain days; a greenbelt might be established; or fishing no longer be permitted in a reservoir. The environmental factors change and, accordingly, so should the expected fire incidence.

If you have had difficulty determining where and how you can most effectively expend your efforts in fire prevention or wondering how to evaluate the effectiveness of your present program of fire prevention, give spatial risk a try. You may like it.



### AN APPROACH

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Agric. For. Serv., Intermt. For. Range Exp. Stn., Manuscript on file. Missoula, Mont.

Schmidt, R. Gordon.

1978. Hazard appraisal-photo services for the Bull Run management unit. U.S. Dep. Agric. For. Serv., Pac. Northwest Mt. Hood Natl. For., Portland, Oreg.

Show, S. B., and E. I. Kotok.

1929. Cover types and fire control in the national forests of Northern California. U.S. Dep. Agric. For. Serv., Tech. Bull. 1495. 87 p.

U.S. Department of Agriculture.

1978. Fire behavior officer's field reference. U.S. Dep. Agric. For. Serv., Natl. Fire Train. Cent., Marana, Ariz.



## Slide Tape Available

The Intermountain Region, USDA Forest Service, has a new slide-tape program on "Planning for Initial Attack." Copies or more information may be obtained from the Director, Cooperative Forestry and Fire, USDA Forest Service, 324 25th St., Ogden, UT 84401.

## Recent Fire Publications

Albini, F. A., and J. K. Brown.

1978. Predicting slash depth for fire modeling. U.S. Dep. Agric. For. Serv. Intermt. For. Range Exp. Stn., Ogden, Utah. U.S. Dep. Agric. For. Serv. Res. Pap. INT-206, 22 p.

Howard, James O.

1978. A technique for predicting logging residue volumes in the douglas-fir region. U.S. Dep. Agric. For. Serv., Pac. Northwest Exp. Stn., Res. Pap. PNW-235, 14 p.

McNab, W. Henry, M. Boyd Edward, Jr., and Walter A. Hough.

1978. Estimating fuel weights in slash pine-palmetto stands. Soc. Amer. For., For. Sci. 24:345-358.

Moore, Bud.

1978. The big burn, edited by Stanley Cohen and Donald Miller. Pict. Hist. Publ. Co., Missoula, Mont. 65 p.

U.S. Department of Agriculture, Forest Service.

1978. Effects of fire on fauna. U.S. Dep. Agric. For. Serv., Gen. Tech. Rep. WO-6, 41 p.



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