Forecasting Wildland Fire Behavior: Aids, Guides, and Knowledge-Based Protocols

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Can wildland fire behavior really be predicted? That depends on how accurate you expect the prediction to be. The minute-by-minute movement of a fire will probably never be predictable—certainly not from weather conditions forecasted many hours before the fire. Nevertheless, practice and experienced judgment in assessing the fire environment, coupled with a systematic method of calculating fire behavior, yield surprisingly good results (Rothermel 1983).

This is the third and final special issue of *Fire Management Today* in a series of issues devoted to the subject of wildland fire behavior. The first two issues contained 36 articles dealing with wildland fire behavior case studies and analyses published in *Fire Management Today* and its predecessors between 1937 and 2000. These two issues contained lead articles on various aspects of those subjects (Alexander and Thomas 2003a, 2003b). Not included in these two issues are two recent articles on fire behavior published in *Fire Management Today* (Brown 2002; Cornwall 2003).

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By systematically reflecting upon our fire behavior forecasts and the tools that helped us prepare them, we become the masters of fire behavior models and not their servants.

This issue is devoted to aids, guides, and knowledge-based protocols involved in predicting wildland fire behavior for safe and effective fire suppression (Alexander 2000). It includes 21 articles published from 1947 to 1998. A recent article by Weick (2002) that emphasizes the importance of human factors in the field of fire behavior forecasting could have easily been included.

The Practice of Predicting Wildland Fire Behavior

More than 50 years ago, Barrows (1951) outlined the basic concepts of predicting or forecasting wildland fire behavior that are still very valid today (see the excerpt on pages 6–7). As figure 1 shows, the process of judging fire behavior can be divided into five simple steps:

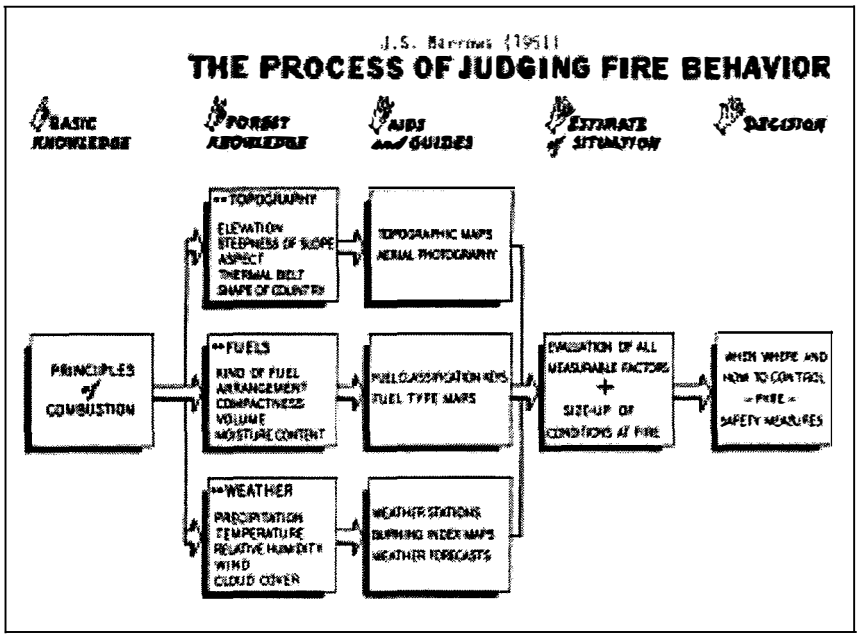

Figure 1—*Judging fire behavior requires systematic analysis of many factors (from Barrows 1951).*

1. *Basic knowledge.* The foundation for judging probable fire behavior must rest on basic knowledge of the principles of combustion: What is necessary for combustion to occur? What causes the rate of combustion to increase or decrease? How may combustion be reduced or stopped?
2. *Forest knowledge.* Three basic factors in a forest area—weather, topography, and fuels—are important indicators of fire behavior.
3. *Aids and guides.* Several aids and guides are available to assist in evaluating weather, topography, and fuels.
4. *Estimate of situation.* The probabilities for various patterns of fire behavior are systematically explored through an estimate of the situation based upon the combined effects of weather, fuels, and topography.
5. *Decision.* The end product of the fire behavior analysis is a decision outlining when, where, and how to control the fire and spelling out any special safety measures required.

For this third and final issue in the series dealing with wildland fire behavior, we chose articles from past issues that reflect the various elements involved in Barrows' (1951) process of judging or predicting wildland fire behavior.

Comparisons of Fire Behavior Predictions and Forecasts Needed

After 50 years, the only item we would add to Barrows' (1951) outline is the need for the fire behavior analyst (FBAN) and others engaged in wildland fire management to pause for a moment to compare, in a rigorous and systematic fashion, the FBAN's or their own fire behavior predictions to actual fire behavior. This is the only way one can truly meet Barrows' (1951) advice to "evaluate the combined effects of all significant factors influencing fire behavior."

We recommend that fire behavior analysts adopt the framework of the After Action Review, as described on the Wildland Fire Lessons Learned Center Website.

Conscious reflection, not as an afterthought but as a normal routine in the day-to-day business of fire behavior forecasting, involves a highly professional method of questioning whether our fire behavior aids, guides, and protocols are working. By systematically reflecting upon our fire behavior forecasts and the tools that helped us prepare them, we become the masters of fire behavior models and not their servants.

To paraphrase Dr. Karl Weick (2003)—coauthor of *Managing the Unexpected: Assuring High Performance in an Age of Complexity* (Weick and Sutcliffe 2001)*—becoming a *mindful* FBAN is a constant struggle for alertness, and to be alert means to "constantly and diligently seek instances where your model didn't work and identify indicators you missed that signaled expectations weren't being filled...."

We recommend that FBANs and others adopt the framework of the After Action Review, as described on the Wildland Fire Lessons Learned Center Website (<http://www.wildfirelessons.net/AftrIncdntRpt.htm>), by putting their fire behavior forecasts through a reflective scrutiny based on four basic questions:

1. What did your fire behavior forecast say would happen?
2. What actually happened?
3. Why did the fire behavior aid, guide, or protocol predict accurately (or inaccurately)?
4. Finally (and most importantly), if you had to make this forecast again, what would you do differently? How would you change the way you used the aid, guide, protocol, or model/system in this different approach?

Judging the quality of a fire behavior prediction or forecast solely on the outcome can be hazardous. By chance, good predictions or forecasts can sometimes have bad outcomes and bad predictions or forecasts can result in good outcomes (fig. 2). From a practical standpoint, overpredictions can be easily readjusted without serious, lasting consequences, whereas underpredictions can be disastrous (table 1) from the standpoint of human safety (i.e., for the public and for fire-

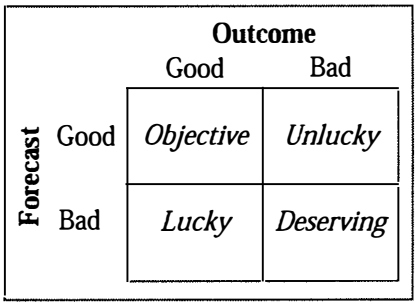

Figure 2—*The 2-by-2 fire behavior prediction or forecast matrix (based on Saveland and Wade 1991) shows that even good forecasts can have unlucky outcomes.*

* See D. Iverson, "Book Review: Managing the Unexpected" *(Fire Management Today* 62(4) [Fall 2002]: 36–37); and J. Williams, "Next Steps in Wildland Fire Management" *(Fire Management Today* 62(4) [Fall 2002]: 31–35).

On the Place of Fire Behavior in Wildland Fire Management*

Although forestry dates back hundreds of years, organized forest fire research has been underway less than 30 years. During much of this time the major efforts have been devoted to studies of fire behavior or closely allied fields. As a result, much has been learned about how fires act, in spite of the relatively short period of organized effort. Knowledge stemming from any research projects, plus the experience gained from the control of thousands of fires, provide a good foundation for a general understanding of the complex subject.

The main purpose of this publication is to summarize the most important aspects of fire behavior as we now know them. The author recognizes that there are still many unknowns in the behavior of forest and range fires. These unknowns will be the targets of future research. In the meantime it is important that the best available information on fire behavior be placed in the hands of the men who must carry on the vital task of fire control ...

Knowledge of fire behavior is an essential requirement for firefighters. Successful fire control operations depend, first of all, upon the ability of the protection forces to judge where and when fires will start and how they will behave once ignition takes place. Every member of the firefighting team from ranger to smokechaser must be able to make reliable estimates of the behavior of fires burning under a wide variety of conditions. These estimates must be good enough to provide the basis for decisions which will lead to fast, efficient, and safe firefighting.

Fire Behavior and Suppression Methods

The character and difficulty of the suppression job on every fire depends largely upon the behavior of the fire. The speed, strength, and type of attack are governed by the location of the fire and its reaction to the surrounding environment. Each change in environment may change fire behavior and in turn call for some adjustment in firefighting strategy and techniques. The ability of the man handling the suppression job to evaluate the behavior pattern largely determines the efficiency and economy of the entire firefighting operation.

A primary purpose of evaluating the behavior of every fire is to reduce or prevent unexpected "blowups and runs." A careful check on everything that will affect the behavior of a fire reduces the chances for the "unexpected." When a skilled size-up has been made in advance, the unexpected may become expected and a potential blow or run may often be anticipated soon enough to be prevented. Effective fire control requires that suppression plans and action be carried out in accordance with continuing estimates and forecasts of what the fire is going to do. Analysis of fire behavior is a basic requirement in firefighting applicable equally to the one-man smokechaser or the big fire where hundreds of men are in action.

Fire Behavior and Safety

An important reason for understanding fire behavior is to provide safety for the firefighters. Every fire behavior situation calls for specific safety measures. Experience gained from fighting thousands of fires has shown that the suppression job may be accomplished with a reasonable degree of safety. To achieve safety it is highly important that all firefighters have a general knowledge and the leaders of the firefighting forces have a high degree of knowledge of fire behavior.

The most dangerous individual in a suppression organization is usually the man who is afraid of fire. Fear is largely a result of ignorance. Many risks can be eliminated from firefighting if each man knows what to expect the fire to do. The average firefighter need not be an expert on

*From Barrows (1951) handbook *Fire Behavior in Northern Rocky Mountain Forests.*

all phases of fire behavior, but he should have a working knowledge of ignition, combustion, and rate of spread of fires burning in forest fuels. Equipped with such basic fire behavior "know-how" the individual firefighter can approach his job without fear and with confidence that he can perform required duties in a safe and efficient manner.

Fire Behavior and the Forest Manager

In the northern Rocky Mountains fires influence many phases of the forest management job. The behavior of fires is an important factor in the growth, harvesting, and regeneration of forest crops. How often fires occur and how hot they burn affect both the quality and quantity of products harvested from the forest. The forest manager may influence fire behavior by the nature of his operations, especially in timber cutting. When a forest is opened up by thinning or harvesting operations, lower humidities, high temperatures, and higher wind velocities are created within the stands. Fire behavior is thereby affected. Sometimes the debris remaining after logging constitutes a fuel condition which greatly increases the chance for fires to ignite and burn intensely. For these reasons it is important for forest managers to know fire behavior and to be able to evaluate the influence of forest management operations on it.

Judging Fire Behavior

Many complex factors influence the ignition, rate of spread, and general behavior of fires. Some of these factors can be measured more or less precisely with instruments. Others do not lend themselves to exact measurements and therefore must be evaluated in general terms. The combined effects of all factors, whether measured precisely or not, determine the behavior of a fire. No single factor, such as wind, steepness of slope, or kind of fuel, will provide the answer to questions of when and where fires will start and how fast they will spread. Likewise, no single instrument or meter will answer these fundamental questions. Therefore it is necessary for the fire control man to develop a system aided by instruments and other guides where available, which will help him evaluate the combined effects of all significant factors influencing fire behavior.

Keen observation is a fundamental requirement for judging fire behavior. Many visible signs are present in the forest to assist the fire control man in arriving at reliable decisions. These include such things as the color of the grass and other annual vegetation, the position of a fire on a slope, the time of day, and the amount of sunshine filtering through the forest canopy. One of the purposes of this handbook is to analyze the importance and the meaning of the most significant of the many factors that may be observed and to present a method of evaluating their combined effects.

Fire Safety Measures

A thorough understanding of fire behavior is essential to the promotion of safety in firefighting operations. Accidents often occur when so-called "unexpected fire behavior" develops. To avoid these "unexpected events," the first and most important safety measure on every fire, regardless of size, is to make the estimate of the fire behavior situation.... Fires behave according to certain laws. Runaway fires do not just happen. When keen observations and evaluations are made of weather, topography, and fuels, there are very slim chances for firefighters to be surprised suddenly by an unexpected blowup.

Every fire behavior situation calls for special safety measures. In most cases the best safety measure is aggressive and intelligent firefighting aimed at abating the danger spot.

Keen observation and interpretation of weather, topography, and fuels lead to a good understanding of fire behavior and to safe, efficient firefighting.

fighters). Underpredictions can also render chosen operational strategy and tactics useless (Cheney 1981).

In addition to evaluating the outcome of a forecast, it is wise to look at the fire behavior prediction process itself. Russo and Schoemaker (1989) examine common pitfalls for decisionmakers that are equally valid for FBANs and others making fire behavior predictions or forecasts. Decision trap 10 (see the sidebar) is a failure to audit the decisionmaking process—a failure to understand that one's decisionmaking leaves one constantly open to the other nine decision traps.

Other Related Articles and Information

It's worth noting that *Fire Management Today* and its predecessors have also published a variety of other fire behavior and fire behavior-related articles in the past 67 years (Bunton 2000a, 2000b). Many are shown in the list of additional references beginning on page 10.

Because copies of many of these articles are difficult to obtain, even through library sources, they are being scanned and will be made available through the World Wide Web. Many are now available for downloading from the *Fire Management Today* Website (<http://www.fs.fed.us/fire/fmt/index.html>). The same Website has an author index posted for volumes 1–59 of *Fire Management Today* and its predecessors.

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Judging the quality of a fire behavior prediction or forecast solely on the outcome can be hazardous.

References

Alexander, M.E. 2000. Fire behavior as a factor in forest and rural fire suppression. For. Res. Bull. 197, For. Rural Fire Sci. Techn. Ser. Rep. 5. Rotorua and Wellington, NZ: Forest Research in assoc. with New Fire Service Commission and National Rural Fire Authority.

Alexander, M.E.; Thomas, D.A. 2003a. Wildland fire behavior case studies and analyses: Value, approaches, and practical uses. Fire Management Today. 63(3): 4–8.

Alexander, M.E.; Thomas, D.A. 2003b. Wildland fire behavior case studies and analyses: Other examples, methods, reporting standards, and some practical advice. Fire Management Today. 63(4): 4–12.

Table 1—*The scope of quantitative wildland fire behavior prediction (adapted from Rothermel 1974, 1980).*

Fire situation	*Intended use*	*Resolution*		*Relative usefulness/ value*	*Ease of prediction accuracy*	*Impact of inaccurate prediction*
		Timeframe	*Area*			
Possible	Training	Long-term	Not applicable	Moderate	Extremely to very easy	Minor or minimal
	Long-range planning (e.g., preparedness system development)	Yearly/ seasonal	State/ province/ territory	Good	Easy to moderately Easy	Significant
Potential	Short-term planning (e.g., daily fire assessment)	Daily/ weekly	Forest/ district	Very good	Moderately difficult to difficult	Serious
Actual	Near real-time (e.g., automated dispatch, project fires, escaped fire situation analysis)	Minutes to hours	Stand- or site-specific	Excellent	Very to extremely difficult	Critical

The Ten Most Dangerous Decision Traps*

1. *Plunging in:* Beginning to gather information and reach conclusions without first taking a few minutes to think about the crux of the issue you're facing or to think through how you believe decisions like this one should be made.
2. *Frame blindness:* Setting out to solve the wrong problem because, with little thought, you have created a mental framework for your decision that causes you to overlook the best options or lose sight of important objectives.
3. *Lack of frame control:* Failing to consciously define the problem in more ways than one or being unduly influenced by the frames of others.
4. *Overconfidence in your judgment:* Failing to collect key factual information because you are too sure of your assumptions and opinions.
5. *Shortsighted shortcuts:* Relying inappropriately on "rules of thumb," such as implicitly trusting the most readily available information or anchoring too much on convenient facts.
6. *Shooting from the hip:* Believing you can keep straight in your head all the information you've discovered, and therefore "winging it" rather than following a systematic procedure when making the final choice.
7. *Group failure:* Assuming that with many smart people involved, good choices will follow automatically, and therefore failing to manage the group decisionmaking process.
8. *Fooling yourself about feedback:* Failing to interpret the evidence from past outcomes for what it really says, either because you are protecting your ego or because you are tricked by hindsight.
9. *Not keeping track:* Assuming that experience will make its lessons available automatically, and therefore failing to keep systematic records to track the results of your decisions and failing to analyze these results in ways that reveal their key lessons.
10. *Failure to audit your decision process:* Failing to create an organized approach to understanding your own decisionmaking, so that you remain constantly exposed to all the above mistakes.

* Based on Russo and Schoemaker (1989).

Russo and Schoemaker (1989) examine common pitfalls for decisionmakers that are equally valid for FBANs and others making fire behavior predictions or forecasts.

Barrows, J.S. 1951. Fire behavior in northern Rocky Mountain forests. Stn. Pap. No. 29. Missoula, MT: USDA Forest Service, Northern Rocky Mountain Forest and Range Experiment Station.

Brown, H. 2002. Thirtymile Fire: Fire behavior and management response. Fire Management Today. 62(3): 23–30.

Bunton, D.R. 2000a. Creating an index that mirrors our past. Fire Management Today. 60(1): 27–31.

Bunton, D.R. 2000b. Subject index—Volumes 31–59. Fire Management Today. 60(1): 32–94.

Cheney, N.P. 1981. Fire behaviour. In Gill, A.M.; Groves, R.H.; Noble, I.R., eds. Fire and the Australian Biota. Canberra, Australia: Australian Academy of Sciences: 151–175.

Cornwall, M. 2003. Dome Peak Fire: Witnessing the extreme. Fire Management Today. 63(1): 16–18.

Rothermel, R.C. 1974. Concepts in fire modeling. Paper prepared for Advanced Fire Management Training Course, National Fire Training Center, 1974 November 11–22, Marana, AZ.

Rothermel, R.C. 1980. Fire behavior systems for fire management. In: Martin, R.E. and others, eds. Proceedings of the Sixth Conference on Fire and Forest Meteorology. Washington, DC: 58–64.

Rothermel, R.C. 1983. How to predict the spread and intensity of forest and range fires. Gen. Tech. Rep. INT–143. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station.

Russo, J.E.; Schoemaker, P.J.H. 1989. Decision traps: Ten barriers to brilliant decision-making and how to overcome them. New York, NY: Simon and Schuster Incorporated.

Saveland, J.M.; Wade, D.D. 1991. Fire management ramifications of Hurricane Hugo. In: Andrews, P.L.; Potts, D.F., eds. Proceedings of the 11th Conference on Fire and Forest Meteorology; 1991 April 16–19; Missoula, MT. SAF Publ. 91–04. Bethesda, MD: Society of American Foresters: 124–131.

Weick, K.E. 2002. Human factors in fire behavior analysis: Reconstructing the Dude Fire. Fire Management Today. 62(4): 8–15.

Weick, K.E. 2003. Managing the unexpected: A look at the big ideas. Paper presented at the Georgia Tech's DuPree College of Management and Leadership Center, Carter Presidential Center; 2003 March 25; Atlanta, GA.

Weick, K.E.; Sutcliffe, K.M. 2001. Managing the unexpected: Assuring high performance in an age of complexity. San Francisco, CA: Jossey-Bass. ■

Additional References on Wildland Fire Behavior*

Fire Behavior Officer/Fire Behavior Analyst

Bushey, C.L.; Mutch, R.W. 1990. Fire behavior service center for extreme wildfire activity. Fire Management Notes. 51(4): 34–42.

Chandler, C.C.; Countryman, C.M. 1959. Use of fire behavior specialists can pay off. Fire Control Notes. 20(4): 130–132.

Countryman, C.M.; Chandler, C.C. 1963. The fire behavior team approach in fire control. Fire Control Notes. 24(3): 56–60.

Dell, J.D. 1966. The fire-behavior team in action—The Coyote Fire. Fire Control Notes. 27(1): 8–10, 15.

Knutson, K.K. 1962. The place of the fire behavior officer in the fire suppression organization. Fire Control Notes. 23: 81–82.

Weick, K.E. 2002. Human factors in fire behavior analysis: Reconstructing the Dude Fire. Fire Management Today. 62(4): 8–15.

Training

Alexander, M.E. 2002. The staff ride approach to wildland fire behavior and firefighter safety awareness training: A commentary. Fire Management Today. 62(4): 25–30.

Andrews, P.L.; Sackett, S.S. 1989. Fire observation exercises—A valuable part of fire behavior training. Fire Management Notes. 50(1): 49–52.

Carlton, D.W. 1991. Fire behavior training—A look at some upcoming changes. Fire Management Notes. 52(2): 15–19.

Cochran, A.R. 1957. A training course in fire safety and fire suppression techniques. Fire Control Notes. 18(1): 33–38.

Editor. 1958. Safe practices under blowup conditions—A training outline for the fire crew boss. Fire Control Notes. 19(1): 3–7.

Euler, D.H. 1946. The sand box as a fire-control training tool. Fire Control Notes. 7(1): 37–39.

Giffen, C.A. 1956. Fire control practices: A training course. Fire Control Notes. 17(3): 26–29.

Keller, P. 2002. What's a staff ride? Fire Management Today. 62(4): 6–7.

Keller, P. 2002. Walk back into tragedy: A quantum leap forward. Fire Management Today. 62(4): 16–21.

Moore, W.R. 1959. Training in the ten standard fire fighting orders. Fire Control Notes. 20(2): 58–60.

Mutch, R.W. 2002. Why don't we just leave the fireline? Fire Management Today. 62(4): 22–24.

Thomas, D.; Cook, W. 2002. Dude Fire staff ride. Fire Management Today 62(4): 4–5.

Thorburn, W.R.; MacMillan, A.; Alexander, M.E.; Nimchuk, N.; Frederick, K.W.; Van Nest, T.A. 2003. "Principles of Fire Behavior": A CD-ROM-based interactive multimedia training course. Fire Management Today. 63(2): 43–44.

Research

Alexander, M.E.; Andrews, P.L. 1989. Wildland fire occurrence and behavior analysis in the year 2000 and beyond. Fire Management Notes. 50(4): 35–37.

Alexander, M.E.; De Groot, W.J.; Hirsch, K.G.; Lanoville, R.A. 1989. Use of posters for interpreting fire behavior and danger research. Fire Management Notes. 59(2): 41–44.

Alexander, M.E.; Maffey, M.E. 1992–93. Predicting fire behavior in Canada's aspen forests. Fire Management Notes. 53–54(1): 10–13.

Alexander, M.E.; Yancik, R.F. 1977. The effect of precommercial thinning on fire potential in a lodgepole pine stand. Fire Management Notes. 38(3): 7–9, 20.

Banks, W.G.; Frayer, H.C. 1966. Rate of forest fire spread and resistance to control in the fuel types of the Eastern Region. Fire Control Notes. 27(2): 10–13.

Barry, E.F. 1942. How about the esprit de corps. Fire Control Notes. 6(3): 124–125.**

Byram, G.M.; Martin, R.E. 1962. Fire whirls in the laboratory. Fire Control Notes. 23(1): 13–17.

Countryman, C.M. 1956. Old-growth conversion also converts fire climate. Fire Control Notes. 17(4): 15–19.

Countryman, C.M. 1973. The fire environment concept. Fire Management. 34(2): 17.

Curry, J.R. 1936. Fire behavior studies on the Shasta Experimental Forest. Fire Control Notes. 1(1): 12–13.

Davis, L.S.; Martin, R.E. 1961. Time-temperature relationships of test head fires and backfires. Fire Control Notes. 22(1): 20–21.

Davis, W.S. 1949. The rate of spread–fuel density relationship. Fire Control Notes. 10(2): 8–9.

Gisborne, H.T. 1942. Review of problems and accomplishments in fire control and fire research. Fire Control Notes. 6(2): 47–63.

Greenlee, D.; Greenlee, J. 2002. Changes in fire hazard as a result of the Cerro Grande Fire. Fire Management Today. 62(1): 15–21.

Jemison, G.M. 1939. Determination of the rate of spread of fire in the Southern Appalachians. Fire Control Notes. 3(1): 4–7.

Johnson, V.J. 1982. The dilemma of flame length and intensity. Fire Management Notes. 43(4): 3–7.

Luke, R.H.; McArthur, A.G. 1963. Fire behavior studies in Australia. Fire Control Notes. 24(4): 87–92.

Sackett, S.S.; DeCoste, J.H. 1967. A new mobile fire laboratory. Fire Control Notes. 28(4): 7–9.

Stocks, B.J. 1977. Fire behavior research in Ontario. Fire Management Notes. 38(2): 9–11, 19.

Traylor, R.E. 1961. Correlation of weather to fire spread in grass and brush fuels on the Snake River plains in southern Idaho. Fire Control Notes. 22(4): 118–119.

Computerized Aids and Decision Support Systems

Andrews, P.L. 1986. Methods for predicting fire behavior—You do have a choice. Fire Management Notes. 47(2): 6–10.

Andrews, P.L.; Bevins, C.D. 1999. BEHAVE fire modeling system: Redesign and expansion. Fire Management Notes. 59(2): 16–19.

Andrews, P.L.; Chase, C.H. 1990. Update of the BEHAVE fire behavior prediction system. Fire Management Notes. 51(1): 22–25.

Eubanks, R.L.; Bradshaw, R.L; Andrews, P.L. 1986. Current status of BEHAVE system. Fire Management Notes. 47(2): 29–31.

Finn, M. 2001. British Columbia Forest Service adds new software for wildland firefighting. Fire Management Today. 61(2): 43–44.

Finney, M.A.; Andrews, P.L. 1999. FARSITE—A program for fire growth simulation. Fire Management Notes. 59(2): 13–15.

Rothermel, R.C. 1983. BEHAVE and you can predict fire behavior. Fire Management Notes. 44(4): 11–15.

Scott, J.H. 1999. NEXUS: a system for assessing crown fire hazard. Fire Management Notes. 59(2): 20–24.

Van Gelder, R.J. 1976. A fire potential assessment model for brush and grass fuels. Fire Management Notes. 37(3): 14–16.

Hand-Held Computer Technology

Bradshaw, R.L.; Dean, W.A. 1980. Adding print capability to your TI-59 fire behavior CROM. Fire Management Notes. 41(4): 7–8.

* Articles on or related to fire behavior from issues of *Fire Management Today* and its predecessors *(Fire Control Notes, Fire Management, and Fire Management Notes)* from 1936 to 2003 that were not reprinted or referenced elsewhere in this three-part series of special issues *(Fire Management* Today volumes 63[3], 63[4], and 64[1]).

**See C.F. Olsen, "Analysis of the Honey Fire" *(Fire Management Today* 63(3) [Summer 2003]: 29–41).

Burgan, R.E.; Susott, R.A. 1986. HP-71 replaces TI-59 for fire calculations in the field. Fire Management Notes. 47(2): 11-13.
Burgan, R.E.; Susott, R.A. 1988. Correcting an error in the HP-71B fire behavior CROM. Fire Management Notes. 49(2): 31-32.
Cohen, J.D.; Burgan, R.E. 1979. Hand-held calculator for fire danger/fire behavior. Fire Management Notes. 40(1): 8-9.

Research Instrumentation

Clark, B.; Steuter, A.A.; Britton, C.M. 1981. An inexpensive anemometer frame. Fire Management Notes. 42(3): 13-14.
Dibble, D.L. 1960. Fire climate survey trailer. Fire Control Notes. 21(4): 116-120.
Little, E.C. 1973. Costs $10—Foolproof timer measures rate of fire spread. Fire Management. 34(4): 10-12.
McMahon, C.K.; Adkins, C.W.; Rodgers, S.L. 1986. A video image analysis system for measuring fire behavior. Fire Management Notes. 47(1): 10-15.
Schaefer, V.J. 1959. Use of the 60-second print camera for stereophotography of project fires and related activities. Fire Control Notes. 20: 89-90.

Supporting Tools and Equipment

Anderson, K. 2001. NIFC FIRE RAWS unit survives burnover. Fire Management Today. 61(2): 39-42.
Clark, B.; Roberts, F. 1982. A belt weather kit accessory for measuring woody fuel moisture. Fire Management Notes. 43(3): 25-26.
Dell, J.D.; Hull, M.K. 1966. A fire-behavior team field unit. Fire Control Notes. 27(3): 6-7.
Division of Forest Fire Research, Intermountain Forest and Range Experiment Station. 1959. Belt weather kit. Fire Control Notes. 20(4): 122-123.
Ellis, G.R. 1965. A combination pocket meter for windspeed and duration. Fire Control Notes. 26(2): 5.
Fischer, W.C. 1978. New portable weather instrument shelter performs well. Fire Management Notes. 39(3): 15-18.
Maxwell, F.; McCutchan, M.; Roberts, C.F. 1974. Automation of fire weather observations. Fire Management. 35(3): 22-25.
Palmer, T.Y.; Pace, G.D. 1974. Microwave oven dries fuels fast. Fire Management. 35(2): 22-23.
Sackett, S.S. 1980. An instrument for rapid, accurate determination of fuel moisture content. Fire Management Notes. 41(2): 17-18.
Warren, J.R. 1980. Remote automatic weather stations (RAWS). Fire Management Notes. 41(2): 15-16.
Warren, J.R. 1986. Very portable remote automatic weather stations. Fire Management Notes. 47(4): 5-7.

Fuels and Fuel Sampling

Altobellis, A.T.; Cooper, R.W. 1963. Moisture content of gallberry and palmetto during a dry period. Fire Control Notes. 24(1): 10.
Blank, R.W.; Simard, A.J.; Eenigenburg, J.E. 1985. A tester for measuring the moisture content of dead fine fuels. Fire Management Notes. 46(2): 8-12.
Bruce, D. 1951. Fuel weights on the Osceola National Forest. Fire Control Notes. 12(3): 20-23.
Buck, C.C. 1951. Flammability of chaparral depends on how it grows. Fire Control Notes. 12(4): 27.
Countryman, C.M. 1974. Moisture in living fuels affects fire behavior. Fire Management. 35(2): 10-14.
Dieterich, J.H. 1963. Litter fuels in red pine plantations. Fire Control Notes. 24(4): 103-106.
Miller, R.K.; Schwandt, D.L. 1979. Slash fuel weights in red pine plantations. Fire Management Notes. 40(1): 6-7.
Potts, D.F.; Ryan, K.C.; Loveless Jr., R.S. 1984. A procedure for estimating duff depth. Fire Management Notes. 45(2): 13-15.
Scott, J.H.; Reinhardt, E.D. 2002. Estimating canopy fuels in conifer forests. Fire Management Today. 62(4): 45-50.
Weise, D.R.; Saveland, J.M. 1996. Monitoring live fuel moisture—A task force report. Fire Management Notes. 56(3): 13-14.

Guidelines and Decision Aids

Alexander, M.E.; Stam, J.C. 2003. Safety alert for wildland firefighters: Fuel conditions in spruce-beetle-killed forests of Alaska. Fire Management Today. 63(2): 25.
Anderson, H.E. 1984. Calculating fire size and perimeter growth. Fire Management Notes. 45(3): 25-30.
Cargill, G.E. 1970. Table speeds fire spread estimates. Fire Control Notes. 31(2): 15-16.
Greenlee, J.; Greenlee, D. 2003. Trigger points and the rules of disengagement. 63(1): 10-13.
Melton, M. 1989. The Keetch/Byram Drought Index: A guide to fire conditions and suppression problems. Fire Management Notes. 50(4): 30-34.
Melton, M. 1996. Keetch-Byram Drought Index revisited: Prescribed fire applications. Fire Management Notes. 56(4): 7-11.
Mitchell, J.A. 1936. Rule of thumb for determining rate of spread. Fire Control Notes. 1(7): 395-396.
Pirsko, A.R. 1961. Alinement chart for perimeter increase of fires. Fire Control Notes. 22(1): 1-4.

Fire Weather and Fire Weather Forecasting

Countryman, C.M. 1972. This humidity business: What it is all about and how it is used in fire control. Fire Control Notes. 33(2): 10-11.
Cramer, O.P. 1950. Use your weather records to interpret fire-weather forecasts. Fire Control Notes. 11(4): 41-43.
Cuoco, C.J. 1992-93. Prescribed burns? Share information with fire weather forecasters and involve them in the planning. Fire Management Notes. 53-54(3): 10-13.
Fite, F.M. 1953. Fire weather forecasts. Fire Control Notes. 14(1): 18-20.
Fujioka, F.M. 1997. High resolution fire weather models. Fire Management Notes. 57(2): 22-25.
Graham, H.E. 1964. A portable fire-weather forecast unit for use on back-country fires. Fire Control Notes. 25(3): 11.
LaMois, L.M. 1961. Weather and forest fires. Fire Control Notes. 22(1): 22-24.
O'Dell, C.A.; Hammer, L.C. 1979. Fire weather meteorological support units. Fire Management Notes. 40(2): 3-5.
Potter, B.E. 1997. Making sense of fire weather. Fire Management Notes. 57(2): 26-27.
Rodney, E.A. 1964. Forest fires and fire weather conditions in the Asheville, N.C., fire weather district—Spring season, 1963. Fire Control Notes. 25(3): 7-9, 15.
Schroeder, M.J. 1950. The Hudson Bay High and the spring fire season in the Lake States. Fire Control Notes. 11(1): 1-8.
Svorcek, A.J. 1965. 50 years of fire weather service. Fire Control Notes. 26(2): 8-9.
Watkins, C.H. 1961. The Oregon state mobile fire weather unit. Fire Control Notes. 22(3): 89-92.

Long-Duration Projections

Lukens, D.; Krebs, J. 1986. Long-term fire behavior projections. Fire Management Notes. 47(4): 22-23.
Mohr, F.; Both, B. 1986. Confinement—A suppression response for the future? Fire Management Notes. 56(2): 17-22.
Mohr, F.; Lukens, D.; Terry, D. 1987. Managing confinement suppression response on the Middle Ridge and Little Granite Fires, August 1986. Fire Management Notes. 48(3): 23-25.