Fire Management today

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Wildland Fire Behavior Case Studies and Analyses: Part 1

United States Department of Agriculture
Forest Service

DEDICATION

This special issue of *Fire Management Today* is dedicated to the memory of Paul M. Gleason (1946–2003).

His passion for wildland firefighter safety and his deep professional interest in wildland fire behavior will be sorely missed.

Martin E. Alexander and David A. Thomas
Issue Coordinators

Editor's note: This issue of *Fire Management Today* reprints articles from early editions of the journal, some of them decades old. Although the articles appear in today's format, the text is reprinted largely verbatim and therefore reflects the style and usage of the time. We made minor wording changes for clarity, added intertitles and metric conversions where needed, and occasionally broke up paragraphs or broke out sidebars to improve readability. All illustrations are taken from the original articles.

Erratum
In the Spring 2003 issue of *Fire Management Today,* the table of contents showed an incorrect title for Stephen J. Pyne's article (volume 63[2], page 17). The correct title is "Firestop II."

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On the Cover:

Historical photo from USDA Forest Service files showing the Wheeler Fire in 1948 "working down Bear Canyon toward Wheeler Gorge Camp" on the Los Padres National Forest, CA. Photo: Forest Service Photograph Collection, USDA Forest Service, Washington Office, Washington, DC (no. 451594; F.E. Dunham, 1948).

The FIRE 21 symbol (shown below and on the cover) stands for the safe and effective use of wildland fire, now and throughout the 21st century. Its shape represents the fire triangle (oxygen, heat, and fuel). The three outer red triangles represent the basic functions of wildland fire organizations (planning, operations, and aviation management), and the three critical aspects of wildland fire management (prevention, suppression, and prescription). The black interior represents land affected by fire; the emerging green points symbolize the growth, restoration, and sustainability associated with fire-adapted ecosystems. The flame represents fire itself as an ever-present force in nature. For more information on FIRE 21 and the science, research, and innovative thinking behind it, contact Mike Apicello, National Interagency Fire Center, 208-387-5460.

FIRE 21

Firefighter and public safety is our first priority.

Contents

Short Features

Wildland Fire Behavior Case Studies and Analyses: Value, Approaches, and Practical Uses

M.E. Alexander and D.A. Thomas

Since 1936, the Washington Office of the USDA Forest Service has published a periodical devoted to articles dealing with a very wide range of fire management topics. The name of this journal has changed through the years, from *Fire Control Notes*, to *Fire Management*, to *Fire Management Notes*, and finally to *Fire Management Today*.* A good many of the 243 issues that have been published in the past 67 years have included a fire-behavior-related article. With the passage of time, however, many of these articles have become "buried," found only by the most intrepid researchers on the shelves of major libraries.

In an effort to unbury the past and to increase both institutional memory and organizational learning within the wildland fire community, the authors approached the editorial staff of *Fire Management Today* with the idea of republishing a selection of these past fire-behavior-related articles. We are pleased that they took us up on our suggestion.

Marty Alexander is a senior fire behavior research officer with the Canadian Forest Service at the Northern Forestry Centre, Edmonton, Alberta; and Dave Thomas is the regional fuels specialist for the USDA Forest Service, Intermountain Region, Ogden, UT.

* For more on the history of *Fire Management Today*, see Hutch Brown, "How Did *Fire Control Notes* Become *Fire Management Today*?" *Fire Management Today* 60(1) [Winter 2000]: 8–14.

In an effort to unbury the past and to increase both institutional memory and organizational learning within the wildland fire community, we are reprinting past articles on fire behavior.

This special issue of *Fire Management Today* begins a series of three consecutive issues with articles related to fire behavior. This issue contains the first of two installments of articles involving fire behavior case studies and analyses of wildfires; examples pertaining to prescribed fires are not included (e.g., Custer and Thorsen 1996). The 19 case studies and analyses in this issue are presented in chronological order, from 1937 to 1967. The third issue in this series will be devoted to aids, guides, and knowledge-based protocols involved in forecasting wildland fire behavior for safe and effective fire suppression.

General Value of Case Studies

The importance of documented case studies or histories of wildland fires has been repeatedly emphasized by both fire managers and fire researchers (e.g., Byram 1960; Thomas 1994; Turner and others 1961). As long-time Forest Service wildland fire researcher/administrator Craig Chandler (1976) has noted, "Time and time again case histories have proven their value as training aids and as sources of research data." The authors strongly support this notion and have endeavored to reflect it in our individual work areas in fire research and fire management, respectively (Alexander and Lanoville 1987; Thomas 1991).

The idea of relying on wildfires as a possible source of data is especially pertinent to empirically based schemes for quantitative fire behavior prediction that rely on this kind of information in whole or in part (e.g., Alexander 1985; Forestry Canada Fire Danger Group 1992; Rothermel 1991). This fact is especially significant at the extreme end of the fire intensity scale, where experimental fires are exceedingly difficult to arrange (Alexander and Quintilio 1990; Cheney and others 1998).

Information gleaned from wildland fire behavior case studies has also proved of value in testing and evaluating various fire models, theories, decision aids and support systems, and management guidelines (e.g., Anderson 1983; Haines and others 1986; Nelson 1993; Pearce and Alexander 1994). For example, Lindenmuth and Davis (1973) used an observation of the initial run of the Battle Fire, a 28,400-acre

(11,500-ha) fire that occurred May 14–20, 1972, on the Prescott National Forest, AZ, to assess the performance of their empirically based model for predicting fire spread in Arizona's oak chaparral fuel type.

Approaches to Case Studies

There are many examples in North America and elsewhere where fire researchers and fire managers have attempted to observe and document the behavior of free-burning fires, using various types of data collection methods and monitoring equipment, on an ad hoc or a more formal basis (e.g., Barney and others 1978; Barrows 1961; Billing 1986; Schaefer 1957; Traylor 1961*). These efforts extend back many years (Gisborne 1929) and continue into the 21st century (e.g., Burrows and others 2000).

Fire behavior researchers are rarely in the right place at the right time to observe and document the behavior of forest and range fires. While there have, of course, been some exceptions (e.g., Sneeuwjagt 1974; Stocks and Flannigan 1987), including escapes from outdoor experimental fires (Alexander and others 1991; Stocks 1987), for the most part fire operations personnel tend to be in the best position to make and record key observations. Probably the most concerted and systematic effort by fire researchers to observe and record actual fire behavior was made by the Forest Service's Southern Forest Fire Laboratory in Macon, GA, from the late 1950s to early 1970s (DeCoste and Sackett 1966; Sackett and DeCoste 1967). This was no doubt due in large part to George Byram's (1960) influence.

Some limited documentation has also been undertaken by fire managers and fire researchers serving as fire behavior officers or specialists/analysts on various wildland fire incidents (e.g., Johnson 1964; McCaw, Maher, and Gillen 1992; Norum 1982; Thomas 1991). Fire researchers have also been involved in many "after-the-fact" investigations (e.g., Butler and Reynolds 1997; Fogarty and others 1996; McCaw, Simpson, and Maher 1992). Van Wagner (1971) has pointed out that "some valuable reference data can be collected by being in the right place at the right time. It is, in fact, quite feasible to obtain good data by visiting the scene of a … fire shortly after it has occurred, while its history is still fresh both on the ground and in the mind of the fire boss."

Byram (1954) made extensive use of the case study method of individual fires in his research into blowup fire behavior. As he notes, "Some of the observations and details of behavior are written down in fire reports, but most of the information is still in the memories of men who worked on the fires. Fire behavior may, therefore, be difficult to reconstruct at times, especially on fires which occurred a number of years ago. Usually, however, a surprising amount of detail can be obtained by talking with men who were on the fires and by going over the fire area with them."

A final possibility is the hindsight analysis of major wildland fire incidents in the light of present-day knowledge and tools using existing historical information to establish the fire's chronology and general behavior. The reports of Haines and Sando (1969), Stocks and Walker (1973), Street and Alexander (1980), and Rothermel (1993) are good examples of this approach to case studies.

Pragmatic Value of Case Studies

A practical fire manager, always interested in the control of wildfires and the ignition of prescribed fires, might ask: What is the use of historical fire behavior case studies? How can old documents help fire management personnel become better managers of forest and range fires, in all their forms? Beyond the recreation of a "good read," what utility do these articles offer? How can old essays become relevant for a 21st-century firefighter?

The old articles will only seem dated if we fail to make use of them. There are two primary reasons to thoroughly study these fire behavior case studies:

- To learn from them and thereby lessen the chance of making the same mistake again; and
- To prepare ourselves not to be surprised to the point of distraction by a fire's surprising behavior in a particular fuel type under a given weather condition.

Not making the same mistake twice and being prepared to be surprised will go a long way toward creating a highly reliable firefighting organization where safety truly matters.

Unless we actively learn from past wildland fires, then the only way we can gain additional fire behavior knowledge is to actually experi-

* A summary of this work can be found in R.E. Traylor, "Correlation of Weather to Fire Spread in Grass and Brush Fuels on the Snake River Plains in Southern Idaho," *Fire Control Notes* 22(4) [Fall 1961]: 118–119.

ence a fire's behavior or to model the fire's behavior on a computer at our desk. Even the most active fire behavior analyst (FBAN) rarely gets enough near-real-time opportunities to predict the spread and intensity in every fuel complex or to complete a prediction enough times to become good at it (Thomas 1994). The best learning scenario for a practicing fire behaviorist is a combination of all three learning techniques: actively using case studies, getting field experience, and practicing computer modeling. Each is a distinct mode of learning and adaptation; when combined, they become a powerful model for continuous learning.

Case study knowledge, coupled with experienced judgment and fire behavior modeling, is also considered an effective operational technique or procedure for appraising fire potential (Brown 1978). Burrows (1984) maintains that most wildland firefighters base their expectations of how a fire will behave largely on experience and, to a lesser extent, on fire behavior guides. If this is indeed the case, then it is worth reiterating the points made by Forest Service fire research pioneer Harry T. Gisborne (1948) about experienced judgment: "For what is experienced judgment except opinion based on knowledge acquired by experience? If you have fought forest fires in every different fuel type, under all possible kinds of weather, and if you have remembered exactly what happened in each of these combinations, your experienced judgment is probably very good. But if you have not fought all sizes of fires in all kinds of fuel types under all kinds of weather then your experience does not include knowledge of all the conditions." Presumably then, case studies can help supplement and thereby strengthen (but never replace) a person's experience level.

> "Time and time again case histories have proven their value as training aids and as sources of research data."
> *–Craig Chandler (1976)*

Safety Value of Case Studies

As we read through this chronological selection of articles, especially the accounts of forest fires where firefighters lost their lives or there were near-misses or unforeseen blowups, we can ask ourselves and our crews whether we have fully grasped the major "lessons learned" from these past fire behavior events. Excellent methods of using past fire behavior knowledge from case studies to increase wildland firefighter safety in the future are the staff ride (Alexander 2002; Thomas and Cook 2002),* the sand box exercise (Euler 1946), yearly fire refreshers (e.g., the 2001 USDI Bureau of Land Management Fireline Safety Refresher videos), and weekly tailgate safety meetings.

For example, one of these articles could be handed out each week to members of an organized fire crew. The crew would be given time to read and ponder the article. Then, in a group setting, with the fire foreman (i.e., hotshot superintendent, smokejumper-in-charge, local fire management officer, etc.) acting as facilitator, the crew could be led through a series of questions that the article has inspired. For example:

- Is there something that we can apply to our current situation?
- Have we learned all that this old fire has to teach us?
- Could the same situation occur today?
- What are we going to do differently after reading this case study?

This process, if faithfully followed throughout a fire season, would increase both mindfulness and resilience (Weick and Sutcliffe 2001), the two hallmarks of individuals and their organizations determined to do everything they can to control and use wildland fire safely.

Both authors have used case studies to lead training sessions in the classroom. One of us (Thomas) has also used the technique in the field at the site of past fires. In June 1994, a group of FBANs on a visit to the site of the 1949 Mann Gulch Fire were asked, using existing historical case study information as a starting point for a fire behavior prediction, if they could have prevented the firefighter fatalities that occurred on this infamous fire. Using the available historical fire information, a similar question was asked of a large group of fire management personnel on a staff ride of the 1990 Dude Fire (Thomas and Cook 2002). In both of these examples, many of the students said that these "training" sessions were some of the best they had ever attended. Using case studies or histories, an "old" fire's fire behavior came alive.

* For more on the staff ride technique, see the various articles on the Dude Fire Staff Ride in *Fire Management Today* 62(4) [Fall 2001].

> "A surprising amount of detail can be obtained by talking with men who were on the fires and by going over the fire area with them."
> *–George Byram (1954)*

Another benefit of having these articles available again is for their use within fuel specialist reports used in environmental assessments. Fuel specialists are increasingly called upon to justify why an interdisciplinary team recommended one fire hazard abatement technique over another. These case histories, especially the descriptions of fire behavior in a given fuel type (e.g., Helms 1979), could be cited in those reports (or hyperlinked to a main database), saving much analysis time. The fuels specialist would not have to explain how a fire might burn in a given fuel type, for she or he would have a published account to cite or hyperlink to.

Learning Contribution

A learning organization has been defined as one that is "skilled at creating, acquiring, interpreting, transferring, and retaining knowledge, and at purposefully modifying its behavior to reflect new knowledge insights" (Garvin 2000). Fire behavior case studies go a long way toward preparing a foundation for organizational learning; in so doing, they follow the true spirit of learning implied in this definition. Simply put, our fire management culture, now dominated by a learning pattern of trial and error, would become a learning culture, one in which a systematic study of the past through the use of case studies would become a routine procedure.

This special issue of *Fire Management Today* devoted to fire behavior, and the two others that will follow, are in keeping with the ideals and sentiment expressed by Roy Headley (1936) in the very first issue of *Fire Control Notes*. Headley, who cofounded the journal as the head of the Forest Service's Division of Fire Control (the predecessor of today's Fire and Aviation Management), called for integrating and sharing "the experience, thinking, and experiments" of the many people engaged in wildland fire management. To this end, Headley envisioned *Fire Control Notes* as "a common meeting ground, a clearing-house of developments." In this sense, *Fire Management Today*, by republishing the past (and thereby reviving it for the future), has rediscovered its own unique niche.

Acknowledgments

The authors offer their sincerest heartfelt appreciation to Hutch Brown, Madelyn Dillon, and Carol LoSapio, editors of *Fire Management Today*, for their significant contributions to this special issue, and to April Baily, the journal's general manager, for supporting the concept of these special issues on wildland fire behavior. Their dedication and outstanding editorial abilities have brought "life" to many of the articles contained in this issue that have long been forgotten.

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Blackwater Fire on the Shoshone*

USDA Forest Service, Division of Fire Control

Preliminary reports in hand as this issue goes to press show that initial action on this lightning fire was alert, prompt and vigorous—quite remarkably so, considering that the Shoshone National Forest is rated as a low-danger forest, and doesn't even have lookout stations. The country was high and steep—just below timber line. In spots the lodgepole pine and fir were dense and limby—the familiar patches of rather scrubby jungle found on the better sites at high elevations. There were steep slopes covered with dense but not jungly stands—just the setting for wind-driven crown fires of intense heat. Pictures of the area show bare ridge tops and open places here and there. Fuel on the ground seems to have been quite light—as would be normal under such conditions. One would guess that the fuel experts would rate the area at "Low rate of spread" and "Low resistance to control." But when the "heavy" wind started sweeping this way and that on Saturday, August 21, fifteen men lost their lives. Six of these died from their burns after the blow-up.

When the heavy wind started sweeping this way and that on Saturday, August 21, fifteen men lost their lives.

Large Loss of Life

The danger from such accidents probably is statistically less than the danger from automobile accidents, which is so familiar we largely ignore it. But such fire accidents do happen and impress us all the more because of their infrequency. This is the largest loss of life from a single National Forest fire since 1910. It is the irony of fate that it had to occur on a National Forest which, so far as can be determined from the records here, has had only one other large fire during its whole history. The latest reports on size of this fire put it at 1,100 acres (445 ha).

To the men who died in this disaster, all fire control men everywhere pay tribute. To the bereaved families they extend the deepest sympathy. To the survivors, and particularly the exceptionally large number of injured men, is extended appreciation and cordial concern from all those engaged in the high adventure of protecting American forests from devastation by fire.

District Ranger Post's statement (excerpted in the sidebar on page 10) is published as an authentic case record of the processes of judgment in such situations where a man must think first and think clearly about the safety of the men in his crew. His words will recall to all experienced men many days of harassed effort to get the line ahead and the fire mopped up before something happened—but always with a running accompaniment of a plan (sometimes unconscious) for the best way to safety for the crew if something went wrong.

His statement is also a technical case history of the handling of men in such crises. His record could be followed better with the aid of a map, but even without it much can be gleaned from the story.

Heroic Conduct

As a record of unassuming heroic conduct the statement needs no comment. It was dictated straightaway in the presence of D.P. Godwin, with no rehashing or editing except the correction of the spelling of one name and the insertion of the name of Bert Sullivan in one place. Post has some bad burns, and both hands and both sides of his face are heavily bandaged. He is out of danger, but will bear scars.

Junior Forester Tyrrell of Ranger Post's party died later from his burns. In speaking of him in his signed statement, Enrollee Alcario Serros says:

Then we saw that we didn't have no chance to go back, so Ranger Post told Mr. Tyrrell to take care of us, and he took us up to the rim rock. The fire started from the

The Division of Fire Control in the USDA Forest Service's national office was the precursor of the agency's Fire and Aviation Management Staff, Washington Office, Washington, DC.

* The article is reprinted from *Fire Control Notes* 1(5) [20 September 1937]: 305–306.

east, and then south, and then the west. It was the west fire that burned us. As the fire came closer to us we layed down on the rock ridge. Mr. Tyrrell layed on top of me. When the fire burned Mr. Tyrrell he ran and I ran, too, about 10 feet.

District Ranger Clayton, whose message Ranger Post received, died with six of his men. A seventh got out, but died from his burns. ■

When cut off from the safety sought above timber line (center background), Ranger Post and 40 men who followed his instructions survived by taking what shelter they could, first on the left (north) side, then the right side of the bare spot on the ridge (center foreground). Junior Forester Tyrrell died later from burns inflicted by the flames and heat that swept over them.

The Blowup Begins

The following eyewitness account describes the onset of the blowup on the Blackwater Fire on the afternoon of August 21, 1937. The blowup resulted from the passage of a dry cold front.*

Up until this time no wind was in evidence. Almost like a shot out of a gun, there was a heavy wind. It swept through the area in as near as I can determine in a northeasterly direction, this carried sparks over the constructed line and below us. I heard a fire roar to the northwest and it appeared to be a considerable distance away. I called to Tyrrell and told him that something was going wrong and that I was going to investigate. I ran for some distance to the northwest and climbed a rocky point and saw below me a spot fire of considerable size burning to the northeast and around a ridge to the north of us. My impression was that this fire should be immediately taken care of and possibly abandon work on our line in order to do it.

I turned to summon help for this job when there was decided change in the wind again and the spot fire was swept into the southwest directly into the line of men on line construction. In a few seconds numerous fires appeared below the line.... Almost at once it was clearly evident that further attempts at line construction in that area was out of the question. I sent out a call for all men to abandon their work and proceed to the ridge to the northeast. This was approximately three o'clock, P.M.

U.J. Post, District Forest Ranger
August 27, 1937

* Excerpt from "Statement by Ranger Urban J. Post," *Fire Control Notes* 1(5) [20 September 1937]: 308–315. Photos taken of the blowup can be found in E. Kauffman, "Death in Blackwater Canyon," American Forests 43(11) [November 1937]: 534–540.

The Factors and Circumstances That Led to the Blackwater Fire Tragedy*

A.A. Brown

Original editor's note: Included as a vital part of the full report on the Blackwater Fire was the report made by A.A. Brown after an exhaustive study of the fire behavior and the critical circumstances which converged to bring about the tragedy. Mr. Brown had been only recently transferred to Region 2 to head the fire control work of that Region, and he brought to the tasks involved in this disaster the sound knowledge and discernment springing from long and successful fire experience.

Four Critical Factors

While no proof is available, the nature and circumstances of the blow-up on August 21 seem to indicate that an undiscovered spot fire, probably from the night before, to the north of Clayton Gulch and over the small, sharp ridge in Clayton Creek (one-half mile [0.8 km] west and north of the point where the Clayton group was later found), was the first critical factor in making the trap in which the men were caught and burned to death on that day. Apparently this spot fire at first spread up the slope immediately above to the northeast. This is clearly indicated by the note Ranger Clayton sent to Ranger Post at the time the spot fire spread conspicuously just prior to the blow-up.

The second critical circumstance was the fact that the timber above the newly constructed line had not crowned out except for a small fringe along the south edge. The third critical circumstance was the fact that "spotting" from the fire of the previous day had given a ragged edge to the burning area on the steep downhill side, with small spots below the general front. As a result the fire fighters found it expedient to connect the fire line below the hottest spots, leaving considerable unburned surface fuel inside the line at the lowest point.

> The nature and circumstances of the blow-up on August 21 indicate that there were four critical factors involved.

The fourth critical element was the nature of the forest fuel in this drainage. It consisted of a very dense stagnated stand of Douglas fir with a varying mixture—5 to 15 per cent—of spruce and of alpine fir. A dense overhead canopy existed, with dead branches nearly to the ground, with many small, brushy, dead or nearly dead suppressed trees as an understory, a considerable volume of sound dead branches, logs and suppressed trees on the ground, and with varying amounts of moss throughout the canopy and on all the dead branches. In addition, slopes of 20 to 60 per cent prevailed.

These four factors set the stage for what happened.

Strong Wind

The relative humidity at 1 p.m. on August 21 was 6 per cent, with a temperature of 90 ºF (32 ºC) at the fire danger station at the Wapiti Civilian Conservation Corps (CCC) camp, two and one-half miles (4 km) away at 2,000 feet (610 m) lower elevation. At approximately 3:30 p.m., with these critical circumstances prevailing, a strong gusty wind of apparently at least 30 miles' velocity per hour (48 km/h) came up from the southwest. About 3:45 p.m. it swerved and became a west wind. (These times are based on the circumstantial evidence of other events of the fire.)

The duration of this strong velocity is uncertain because of the strong convectional winds set up almost at once by the crowning. It is reasonable to suppose that the change in direction may have been largely a convectional effect. At the start, timber began to crown above the line and the whole fire there began to pick up in intensity and to throw new spots below the line, as might be expected. Possibly this

When this article was originally published, A.A. Brown was head of Fire Control for the USDA Forest Service, Rocky Mountain Region.

* The article is reprinted from *Fire Control Notes* 1(6) [December 6, 1937]: 384–387.

exerted a strong convectional pull on the spot fire below, which had also begun to crown.

At any rate, the course of the drive from the spot fire changed to the east and started directly up the drainage. The two crown fires then rapidly closed together with the cyclonic effect of such a circumstance, which reached its climax at 4:20 p.m. As a result, the major portion of the head of the Clayton Creek drainage from the spot fire up to Double Mountain was swept clean in a final crown fire conflagration which was completed by approximately 5 p.m.

In this conflagration 9 deaths occurred directly. Six additional men were so badly burned that death ensued, and 36 additional men suffered injuries from which they are recovering.

Firefighter Movements*

Just before the crowning started, the distribution of men on the newly constructed line in Clayton Creek had been as follows: Five men of the National Park Service crew on mop-up were operating as far as the first small park, about 5 chains (330 feet [101 m]) northeast of the ridge. Beyond them for 30 chains (1,980 feet [603 m]) were 6 men of the BPR crew, who had been actively pushing the new line construction from this point on, and who had got as far as Clayton Gulch, plus a few men who had been dropped off from Post's crew. Beyond them were Ranger Post, with Foremen Tyrrell and Saban and sub-foreman Hale, with about 40 men who had taken up the new line at Clayton Gulch and had completed 16 chains (1,056 feet [322 m]) at the time the blow-up occurred.

> The two crown fires then rapidly closed together with the cyclonic effect of such a circumstance, sweeping clean the major portion of the head of the Clayton Creek drainage.

Clayton, who had been placed in charge as sector boss of the new construction, was following the fresh crew in and checking up on conditions as he went. Apparently he was checking particularly on spot fires. The BPR crew were giving most of their attention to spot fires at two points below the 30 chains (1,980 feet [603 m]) of line they had constructed. They were about 20 chains (1,320 feet [402 m]) in from Trail Ridge, except for Pierce, one of their members who had been left alone on hot line at a point about 10 chains (660 feet [201 m]) in, where several logs were on fire close to the fire trench. Two men were left to help him as Post's crew came past and about 6 men were left with Saban and Clayton to work on spot fires.

By the time this distribution was completed, about 3:45 p.m., Post, Clayton, and Fifield, probably simultaneously, saw evidence of an uncontrolled spot fire. Fifield, according to his statement, was on the rock point of Trail Ridge at the time and thought at first that it was the spot near the bottom of the first gulch which had previously been found and trenched, but discovered instead that it was in line with it, but over the small ridge just to the north. He at once gave thought to Wolcott's crew, who were in this vicinity, but found them coming out on account of the crowning there. Wolcott immediately went on up Trail Ridge and also called out the men from the fire trail north of Trail Ridge. Pierce, who had been near the highest point of the fire trail before it dipped down into Clayton Gulch, had already come out to the first small park with the two CCC boys helping him because of a flash of crowning just below him, which apparently crossed the fire line but died down again at the little park. He attempted to get the attention of the rest of the BPR crew, but, receiving no answer, decided they were withdrawing the other way.

About 6 other CCC boys were also assembled at the park, and all came out together at Wolcott's alarm call. The heavy crowning apparently occurred shortly afterward (about 4 p.m.). Post's attention was attracted to the spot fire when it started crowning toward the northeast up the slope on the north side of Clayton Creek. His first thought was to take his crew to it, but the wind changed and the fire started up the gulch before he could take any action to that end. Accordingly he started moving his crew from its path as best he could, as described in his statement.

Death Trap

Clayton's movements are not so clear in detail. It is evident from the note he dispatched to Post that the spot fire had attracted his attention, apparently from on the spur ridge just south of the gulch, where he was later trapped. Up to the time this fire started directly up the gulch it was a threat to the

*See the maps on page 14 (from the article by D.P. Godwin referenced in the sidebar on page 13).

> With the direction of the fire's path directly up the gulch, it probably acted as a furnace draft and became a death trap.

line above which [it] must be stopped, but probably did not appear to be dangerous to life. Clayton saw it was the focal point if the line were to be held, and that more men than the 7 with him would be required.

It does not seem likely that he waited on the ridge above Clayton Gulch the 20 minutes or more that seems to have elapsed from the first active spreading of the spot fire below until the general blow-up occurred. Probably he started down toward it, either with his group or alone. If alone, he probably left instructions for his group to await his investigation of potentialities below. Or, if he took his group, he probably left one or more men at the spring in the gulch to await reinforcements from Post. In either case, the natural route of travel toward the spot fire would be down the gulch toward it. Once off the ridge the full potentialities of the fire below would not have been immediately as evident to him as it was to Post above. Presumably, as soon as he saw what was about to happen, he turned back to get the men at the spring. In doing so he had to go back up the slope ahead of the fire and probably got to his men just at the time that every avenue of escape was cut off. Had the fire been going across topography the bare gulch might have served satisfactorily as a refuge. With the direction of its path directly up the gulch, it probably acted as a furnace draft and became a death trap.

Reconstructed Tragedy

In conclusion, the reconstructed tragedy depended on each of the four factors first discussed which contributed to the behavior of the fire, plus the distribution and movement of the men at the time. The high wind and burning conditions alone, without the spot fire, would have created a dangerous situation, and would have no doubt forced abandonment of the newly constructed fire line, but without loss of life, since distances to safety were not great. Exactly the same strategy employed would likely have succeeded without incident a few hours earlier, or perhaps even at that time of day if no sudden change in wind velocity or direction had occurred.

Had the spot fire not been in line with one already controlled, or had not been hidden by the sharp little ridge in the bottom of Clayton Creek, it would have had earlier attention from the Park crew from Trail Ridge, and again the situation would have been changed.

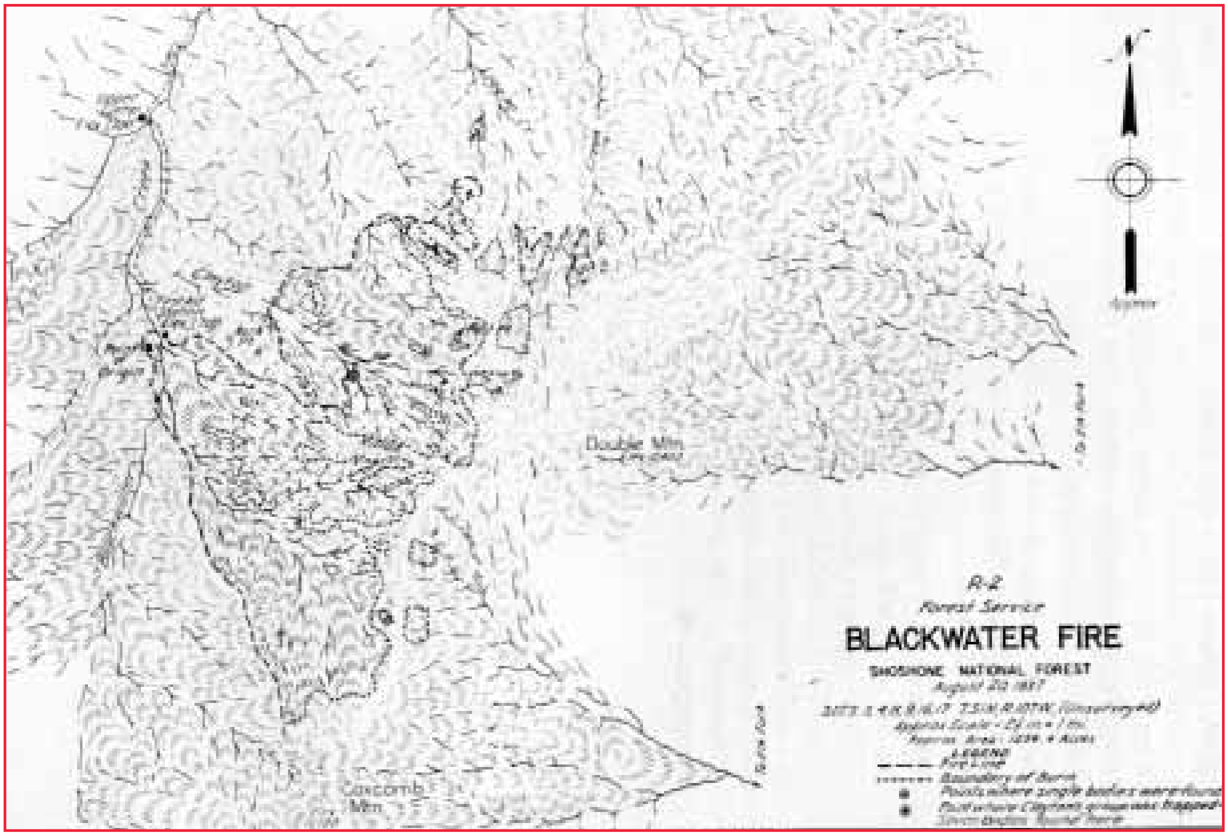
More time on the part of either Clayton or Post to fully scout out the potentialities of the fire ahead of the crews might have prevented the tragedy.

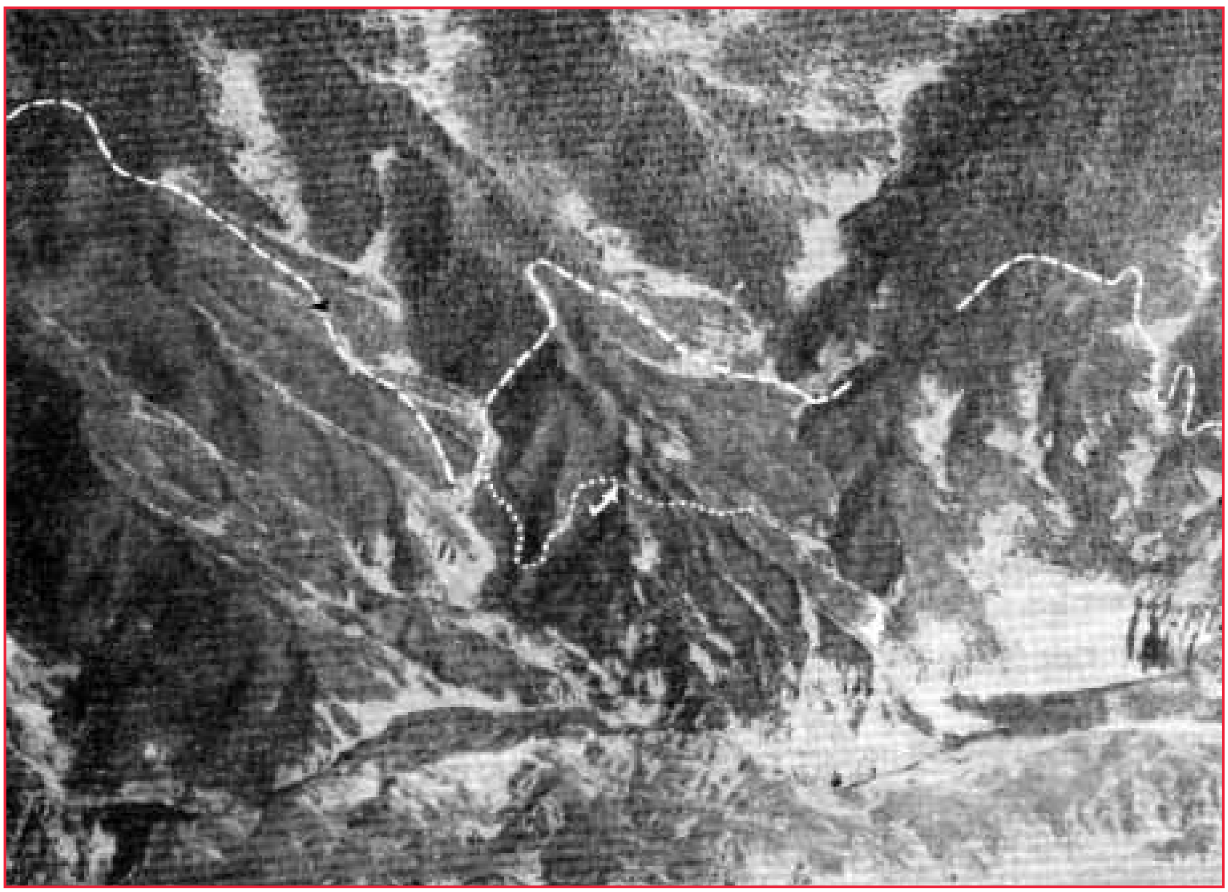
Earlier arrival of the new crew, even by as little as a half hour, would have resulted in completing the new line and would have concentrated the attention of all supervising officers and man-power on all threats to holding it. This would have resulted in a different distribution of the crews and probably slight danger. Many other premises may also be drawn, but the matter of timing of action of the fire vs. movement of men gave the distinctive and fatal combination. ■

Other Articles on the Blackwater Fire

Godwin, D.P. 1937. The handling of the Blackwater Fire. Fire Control Notes. 1(6) [6 December 1937]: 373–383.

Brauneis, K. 2002. 1937 Blackwater Fire investigation: Boost for smokejumpers? Fire Management Today. 62(2): 24–26.





Aerial view of Blackwater Fire, looking southeast directly up the head of Clayton Creek. Dashed line indicates the lost control line. Center arrow shows the gulch where Ranger Clayton and seven men were trapped. Arrow toward the upper left shows the open point on the ridge where Ranger Post took refuge with his crew.

Lessons From Larger Fires on National Forests, 1938*

Roy Headley

Editor's note: Roy Headley took the "lessons learned" from field reports on "larger fires" (fires covering more than 300 acres [121 ha]). In places, he added comments, indicated by brackets and the italicized notation "–Ed."

> Failure to study the action on larger fires invites weaknesses that will let big ones grow into bigger ones.

Among fire control men there is a real difference of opinion on the extent to which study should be concentrated on the larger fires as distinguished from all fires. Some believe that concentration of attention on large fires is dangerous and may result in neglect of the methods and principles which are of importance in keeping small fires from becoming larger.

The answer is probably a matter of proper balance. Both classes should be studied. Failure to review the action taken on even the smallest fires invites weaknesses that will let more little ones grow into big ones. But larger fires have characteristics peculiar to themselves. Management of the larger fire jobs is a rather distinct branch of control—and a backward branch. Failure to study the action on these larger fires invites weaknesses that will let big ones grow into bigger ones. These bigger ones hurt, too. Out of a total of 219,000 acres (88,000 ha) burned in 1938, 35,000 acres (14,000 ha) were lost in one fire. Seventy-five thousand acres (30,000 ha) were lost in the four largest fires.

Lessons Learned

Such an infinite variety of problems are involved in the management of large fire jobs that thoughtful men seldom fail to learn from each one something which should be guarded against in the future, something which should be done differently, some cherished belief which must be modified or abandoned. For 35 years I have been working on or observing suppression jobs, but I still learn something from every fire I reach.

Sometimes, alas, we "learn the same lesson over and over"—or do we? For example, I have learned throughout many years that there is some flaw in our management of larger fires which keeps us from getting a reasonable output of held line from a crew of a given size. Plenty of other people have learned the same thing. But, untrained as we are in the science and art of management, we have not found ways to act satisfactorily on what we have learned. Our learning has too often failed to lead to productive action.

The first essential in such matters is to grasp the need for change, the nature and importance of a problem, the chance to introduce something better. With that fact in mind, the outline for 1938 reports on larger fires requested a record of lessons learned by the man or men who had most to do with each fire. Some of the most suggestive answers received are quoted in this article. Perhaps these notes will help reduce the number of times lessons have to be "relearned" by different men—or by the same men.

Northern Region (R-1)

Absaroka—Chico fire—429 acres (174 ha). The fire got over the line because of incomplete mop-up and men being gathered in a bunch to get water. The foreman in charge was a young, inexperienced administrative guard who, in his zeal to be helpful, left his crew to help on another part of the line. Had he had more experience, he would have recognized that his crew lacked training and knowledge of fire fighting, and he would not have left them. This might also be traced to the fact that the sector was too long for efficient handling by the sector boss. The country was so steep that the man in charge could not cover his whole line often enough.

When this article was originally published, Roy Headley headed the Division of Fire Control, USDA Forest Service, Washington, DC.

* The article is an abridged version of sequential articles published in *Fire Control Notes* 3(3) [Summer 1939]: 6–17 and 3(4) [Fall 1939]: 30–45.

> For 35 years I have been working on or observing suppression jobs, but I still learn something from every fire I reach.

Kaniksu—Goose Creek fire—544 acres (220 ha). An organization principle was violated in that authority on the ground was divided between two heads and coordination was not effected. Two men, either qualified to handle the entire fire, were on the job. Each assumed the other to be in charge. Each aggressively worked on opposite sides of the fire, expecting the other fellow to see that balance was maintained.

The men planning the attack were confronted by a fire burning very fast and throwing spot fires ahead. Fire was in a heavy, dry, white-pine slash area which had been logged during the summer and was pushed by a 20-mile (32-km/h) wind. It was figured that the fire would travel in a northeasterly direction, which it did to a certain extent, but not as fast as was anticipated. Consequently, more men were figured for the northeast side than actually needed. If our foresight had been as good as our backsight, more men would have been placed on the west side where there were barely enough men.

Kootenai—Rocky Creek fire—380 acres (154 ha). The old story that an undetected spot fire blew up and caused this to be an extra-period fire holds true here.

In an analysis of the action on this fire by the supervisor, administrative assistant, two rangers, and an alternate and dispatcher who were on this fire, it was agreed that the 25 men who were searching for spot fires were sufficient under the conditions that existed at the time of this fire. However, a spot fire got away, and caused the second run; therefore, the number of men or the organization of them must have been at fault.

Bulldozers were used to construct approximately three-quarters of a mile (1.2 km) of line on this fire. The main criticism was on account of some of the burning fuel having been covered with duff and dirt which added hours to the time required to do the mop-up job.

The time of arrival, the rate of spread, and the size and value of the rapid-spread area determined the action to take. I believe a bulldozer line under not too difficult topographic conditions can be constructed in less time than any other machine we have on hand. The cost of mop-up is, of course, a problem, but corral is the fist job. Because of the value of bulldozers, and the possibility of breakdowns, I recommend an extra machine on a fire-line construction job.

California Region (R-5)

Angeles—San Antonio fire—3,270 acres (1,323 ha). We were slow in completing lines on some sectors, because of using crews too large—20 men per experienced crew leader. We should have (for this particular fire, and it is true in most fall fires that spread with erratic lines and many spots) used *small* crews, 5 men to each trained fire fighter, and made sectors small enough to provide closer supervision and more effective performance.

Splendid cooperation with the United States Weather Bureau in their special fire-weather forecasts during the entire fire season, and specifically during the progress of this fire, made possible a more accurate planning program for fire personnel needs and strategy to be employed (particularly on backfire work).

Records show and this fire confirms: Our late fall fires are a problem we have not met in southern California. In the absence of early rains, in September and October we get Santa Anna conditions, extremely low humidity and high wind velocities up to 50 miles per hour (80 km/h). These conditions sometimes last a few days—sometimes 3 weeks. Practically all serious fires in southern California for the last 10 years have started under these conditions, indicating we have pointed our efforts to the normal season conditions and gained much ground, but now we must point to these abnormal fall conditions and plan to meet them by:

1. Study more intensively, the behavior of these late fall fires.
2. Provide a 24-hour patrol and lookout service. This was a night fire—as have been two or three others.
3. Make more intensive use of closures regardless of private property interests.
4. Shorten elapsed time between discovery and first action by movement of equipment and men so as to concentrate in high hazard areas and high occurrence zones.
5. Intensify use of secondary lookout points.
6. Have night suppression crew on duty, dressed and ready to go.

In summary: Put *additional heat* on every control effort we normally practice for regular summer season.

> The large area and rapid spread of this fire was due entirely to the dense and continuous stand of "cheat grass."

Klamath—Red Cap fire—16,196 acres (6,554 ha). The suppression action on this fire was characterized by insufficient manpower and overhead in the first five burning periods, then a sudden build-up of men in a belated attempt to conform to the Forester's policy of immediate control. This sudden build-up led to placing more men in the field than could be adequately serviced—with consequent loss of efficiency. For example, on divisions 1 and 2, zone B, it took 400 men (including camp workers, etc.) 4 days to build and backfire 404 chains (26,664 feet [8,127 m]) of line. Theoretically, 400 men should have built the line in 1 day, which would have been in accordance with the Forester's policy; but actually, they lost 50 percent efficiency because of lack of food and bedding; and it is estimated that about half of the remaining effort was dissipated in too wide line construction, so 100 men fully serviced and adequately supervised could have accomplished the same job in the same time.

The Weather Bureau fire-weather field station forecasts were used throughout the fire. The assurance of this station that certain favorable conditions would continue made it possible to plan and construct a line into the head of the Red Cap Canyon, thereby saving about 4,000 acres (1,600 ha) that had appeared to be doomed.

The marvelous "do or die, stick to the bitter end" spirit of the short-term force was magnificent. It was with a feeling of deepest regret that with the first big rain storm on October 1 I was forced to dismiss them with the expressed hope that they could find enough to do through the winter to come back mentally and physically fit to tackle another season.

San Bernardino—Arrowhead fire—12,362 acres (5,003 ha). The Arrowhead fire originally started in a cabin on the crest of the San Bernardino Mountain range. After very thorough investigation as to the cause of the fire, it is believed that it was due to faulty flue construction. The defect was believed to have been where the thimble fastened to the brick chimney.

Extreme fire weather conditions existed at the beginning of this fire and continued throughout. A high wind was blowing at gale force, 45 to 50 miles per hour (72–80 km/h), and the humidity was very low, about 7 percent.

The cabin in which the fire started had wooden, untreated shingles, also others that burned near this one. Due to the high winds the burning shingles were probably the greater cause of the many spot fires.

The rate of spread of this fire was extremely great during the first few hours. Approximately 8,000 acres (3,200 ha) burned during the first 7 hours or over 1,000 acres per hour (400 ha/h).

Because of the high rate of spread it is doubtful that any means of preparedness in presuppression would have reduced the size of this particular fire. However, it was thought that we were deficient in the number of tank trucks available at the beginning of the fire and during the fire. A tank truck at Arrowhead ranger station would be very desirable and had there been one there it would have arrived on the fire about 7 minutes after the fire was reported instead of 36 minutes as was the case. Even though there had been a tank truck at Arrowhead ranger station, it is doubtful that it would have made any difference in this fire. But as a presuppression lesson we can see the importance of having favorable distribution of tank trucks.

All line constructed and lost was uncompleted line. All backfire work that was done was held although it slopped over in places. Orchard torches were used. No acreage was burned through backfiring which would not have been lost by the fire anyway.

Sequoia—Fish Hatchery fire—500 acres (200 ha). Investigation shows that regardless of any suppression action taken after the crews arrived on the fire, it could not have been controlled while still small. This fire was simply moving too fast after it got up a headway. It is barely possible that had we been able to put about 50 men on this fire at the time the first crews arrived, the fire could have been held to a small acreage. However, there was no failure in first attack action, as the first crew traveling 10 miles (16 km), arrived 17 min-

> Records show and this fire confirms: Our Santa Ana fires are a problem we have not met in southern California.

utes after the origin of the fire. We feel, therefore, that the only way this fire could have been prevented from becoming large would have been for the district ranger to have taken such action earlier in the season as would have prevented the fire from starting. This might have been possible had he specifically designated a dumping ground for the use of the Kern Country Juvenile Camp and had this ground thoroughly fire-proofed at the stated of the season.

The fire was in very rough country where night work was difficult. District Ranger Stathem now believes that it would have been better business to have reduced his night crews in size, concentrating most of his manpower on the line during daylight hours.

The lower fire line was built paralleling an oiled road and in some places within 800 feet (240 m) of this road. The reason for this was that it was believed at the time that it was necessary to do this to protect a high-voltage transmission line that was between the fire line and the road. Looking back on this, it is easily seen, however, that there was an opportunity to drop back to the road and hold the fire and also protect the transmission line with a much smaller crew, inasmuch as the line would have been easier to hold on the road.

Shasta—Salt Creek fire—1,690 acres (684 ha). The most important lesson that I learned from this fire was that it burned more rapidly at night, especially downhill, than I had thought possible, and as a consequence, the fire made an advance beyond the point where it was estimated it would be held.

Shasta—Big Lake fire—745 acres (301 ha). The most important thing I learned on this fire was that in slash type cover one should never try to attack the head of a fire if it reaches an area of more than 3 acres (1.2 ha). To attack the rear first and pinch it in on both sides, putting the heaviest attack on the side toward which the wind is blowing.

Shasta—Mount Hedron fire—8,300 acres (3,400 ha). This fire originated in a grass sage–juniper fuel type in gently rolling country at a time when the wind was blowing approximately 20 miles per hour (32 km/h). The fire was attacked by 20 men and 2 tank trucks within 11 minutes of its origin, and at that time it was about 3 acres (1.2 ha) in size and spreading rapidly. Cooperators were immediately called upon for help, but by the time they arrived the fire was completely out of control and was heading north before a strong tail win.

The action of the fire indicated that it probably would have been a 300-acre (120-ha) fire even though there had been a full camper of CCC enrollees at Leaf which was only 8 miles (12 km) away. It seemed to be one of those fires that had to make its run.

Trinity—Glennison Fire—370 acres (150 ha). This fire reached the size it did as a direct result of crowning through the unburned canopy on the day following control. Past records will show that this is a common occurrence on fires in the Canyon Creek areas, and a special effort had been made to mop up the entire fire before the burning period of the day following control.

In spite of the efforts of 65 men with backpack pumps and a power pumper, the fire flared up from inside and crowned out in the unburned canopy of live oak.

If there is any lesson to be learned from this experience, I believe it is the necessity of having enough men with water equipment to cover the entire fire before the beginning of the next burning period. This is a rather difficult and costly procedure, especially when control is not achieved before daylight. The flare up on this fire began at 12 noon, which did not allow much time to cover the entire fire. Also, it is not advisable to send men into the burn before it has had time to cool sufficiently to allow them to work safely.

Control of this fire the day following was achieved by following the above procedure to a large extent. However, weather conditions were more favorable until the late afternoon, which allowed more time to mop up.

In summarizing the above, perhaps the most important point is to achieve control as early as possible the first night so that the fire will cool down before daylight, and allow more time for mop up.

Trinity—Little Bear Wallow Fir—2,200 acres (890 ha). Civilian Conservation Corps (CCC) enrollees are ineffective on a fire when not thoroughly trained in fire suppression, and they must be accustomed to hard hiking in rugged country and able to do effective work after arriving at the fire. In the case of this fire, the initial attack was made by an experienced guard and two green enrollees. The boys, who were transferred here with a New York company a day or so previously, were soft, untrained, and not accustomed to hiking, and not only slowed down the guard's travel time to the fire, but were useless after arriving there.

North Pacific Region (R-6)

Siskiyou—Cedar Camp (Chetco) Fire—34,627 acres (14,014 ha). Something must be done to stop incendiary fires from being started to keep large fires burning. On the division in which I worked, it is a positive fact that one fire was set, and I am relatively sure that others were set in the same area. Take the local man's advice as to fire behavior and wind drafts if he is reliable. Reliable local men are indispensable as scouts, especially in unfamiliar country.

Siskiyou—Nome Fire—5,800 acres (2,300 ha). Planes proved to be an excellent means of supplying fire camps both from the standpoint of speed and economy. Camps were serviced that otherwise would have had to be supplied by man pack, as was done for several days when planes were grounded, which required 8 hours of hard packing by good men to get 40 pounds of supplies into camp.

Planes will not eliminate the use of horses. During the time that this fire was burning the smoke became so dense the planes were grounded for several days, which clearly brought out the fact that pack stock must be relied upon at times.

> An important principle is that the front of a fast running fire is often untouchable. But a lull always comes. The job is to be sure to grab it for keeps during that first lull.

More use should be made of the indirect method of control on fires of this size and in this type of topography. There is always the human aversion to burned area that is continually cropping up on fires of this kind.* Men work too close to the fire, thus sacrificing time and labor. More satisfactory results can be obtained by dropping back and taking advantage of natural breaks in topography.

A stream, unless it is large and clear of brush, makes a poor fire line. The variable winds up and down streams, the possibility of rolling logs and falling snags, and the rapid spread of a fire up the sloe once it crosses a stream, makes it exceedingly dangerous to use.

Fremont—Bonanza Fire—9,155 acres (3,705 ha). The large area and rapid spread of this fire was due entirely to the dense and continuous stand of "cheat grass" (*Bromus tectorum*) with very little timber overstory. Consequently, the usual "forest" fire standards are not fully applicable. However, the following was learned about this particular country.

1. Must keep roads cleared as fire breaks.
2. Must construct additional cross roads.
3. Must make definite plans for suppression (outline prepared).
4. Overhead, in general, needs more "mop up" training.
5. CCC enrollees must be shown "how" by fire foremen and straw bosses.
6. On very large fires it is better to use machinery for trench construction at the sacrifice of some acreage than to depend on hand work too close to the fires.

Investigation of the cause of breakover on August 26 showed that while a good trench and clean burn had been obtained on the extreme southeast corner of the fire, and mop up had been carried back of the line an adequate distance for ordinary circumstances, the crowning of a small green pine tree on a low ridge about 300 feet (90 m) inside the line threw sparks into the thick cheat grass and juniper timber which quickly crowned and spread under the brisk breeze. Men working in the vicinity of the break took action almost immediately, but were unable to cope with the heat of the crowning junipers and did not have time to use the indirect method.

Rocky Mountain Region (R-2)

Roosevelt—Jenny Lind Fire—664 acres (269 ha). I believe the most

* Editor's note: American Indians routinely used fire for natural resource management, a practice that some European settlers adapted to their needs. But by the 1930s, the culture of fire control was so deeply ingrained that "aversion to burned area" seemed quintessentially "human."

To summarize, it is apparent that extreme effort should be made to satisfy the requirements of the Forester's policy as to control in the early burning stages.

important point to be noted is the great difficulty of insuring adequate initial action on a very aggressive fire in its initial stages. [Three miners, 100 feet (30 m) away, saw fire and attacked it 5 minutes after it started. District ranger with one man arrived at fire 35 minutes after it started. But larger crews did not reach fire in time to prevent 39- to 54-mile (63–87 km) wind from starting fire on its first run. Probably most important lesson to be learned is that on a forest not provided with regular detection and other facilities common to western fire forests, a fire starting in slash in a gale of wind could be and was stopped at 664 acres (269 ha).–*Ed*]

Almost uniformly there was too much tendency to bury burning material along the fireline in such a way that it only prolonged the burning and the mop-up period. The correct use of dirt has been so much emphasized that there are few if any of the foremen ignorant of the undesirability of partially burying heavy material; but there seemed to be great difficulty in getting thus particular fault corrected.

A common fault which was perhaps the most serious was that of inclosing ragged fire perimeter inside a line without taking any measures to clean burn. This needs to be given a great deal of emphasis on all forests.

Southwestern Region (R-3)

Gila—Lookout Ridge Fire—575 acres (233 ha). Class 6 burning conditions prevailed and were not recognized. The fuels were very dry and the wind was strong. The lesson learned here is that a fire danger station would have furnished a definite check on burning conditions, and this could then have been promptly followed by proper strengthening of the guard force to meet class 6 or emergency conditions. [This forest is now supplied with a fully equipped station. Danger stations and danger ratings are designed to avoid just this sort of failure to recognize changes in fire danger.–*Ed*]

Poor line location due primarily to trying to hold fire to a minimum acreage with subsequent loss of excess acreage was an important factor. This is merely a matter of training in suppression. [Yes, but training in judgment, which is the most difficult and most backward field of training.–*Ed*]

Gila—Iron Creek Fire—2,318 acres (938 ha). Here again class 6 burning conditions existed unrecognized. Too much line was lost by working too close to the fire. [Understand that this fire and this weakness were used by the region for training by the case method. –*Ed.*] Width of fire lines must be governed by (a) fuel on ground; (b) steepness of slope; (c) wind velocity. In the past, fire lines have been entirely too narrow for safety in handling backfiring in windy weather. [Importance of training in judgment again emphasized. More common error is to make fire lines wider than need be for backfiring.–*Ed*]

Intermountain Region (R-4)

Wasatch—Shepherd Creek Fire—960 acres (388 ha). Particularly significant is that the fire, carried by a high wind, spread over 700 acres (280 ha) within 2 hours after it started. It traveled so fast that the fire truck, plow unit, and men could not keep pace. Forty men were on the fire within 20 minutes after it started, and, with our fire truck which suppressed a mile (3.2 km) of fire edge, and the plow unit that made over 3,000 feet (900 m) of fire line, it was impossible to cope with the high rate of fire spread. [But the wind dropped and the fire died down, after which the crews had a chance and did not muff it. An important principle is that the front of a fast running fire is often untouchable. But a lull always comes. The job is to be sure to grab it for keeps during that first lull. –*Ed.*]

Southern Region (R-8)

Conecuh—"Big Fire"—576 acres (233 ha). In the attack on this fire, as in most other fires on the Conecuh, (wire-grass type of ground cover), everything depended upon the success or failure of the tank truck. From the time of attack with this truck until the water supply was exhausted (15 minutes) 19 chains (1,056 feet [321 m]) of line were built. A reorganization has been made to provide for replenishment of the supply of water for the tank truck.

A whirlwind picked up burning material from as far as 100 yards (90 m) inside the line and dropped it outside in the rough, resulting immediately in a break-over of large proportions. On at least two occasions whirlwinds hit the fire line while suppression was being carried on with tank trucks, resulting in loss of sort lengths of line and excessive use of water. Variability of wind direction and prevalence of whirlwinds are factors not ordinarily considered in danger rating.

Evidence indicates there was time to have cut a line and backfired across the head. This would have speeded up control and promised better chance of holding to a smaller acreage.

Conecuh—Bradley Fire—792 acres (321 ha). There is a definite need for a mobile tractor-plow suppression unit, capable of rapidly plowing a line from which backfiring, could be done. This type of equipment appears to offer the only practicable means for stopping the head of the occasional bad fire short of natural breaks.

The relative humidity on the day of the fire (December 3) did not reach a point that could be called low. This shows that relative humidity, in itself, cannot be relied upon as an indicator of fire danger.

Ocala—Pleasant Flat Fire—2,161 acres (875 ha). The ground of the timber type through which this fire burned is generally covered with water during periods of normal weather, but dries out several times a year so that it becomes inflammable. Since it is not very accessible by tank trucks, the construction of permanent meandering 8-foot (2.4-m) firebreaks on the higher ground within the type will prove very helpful in suppression of any future fires which may occur.

The most important lesson that I learned from this fire was that it burned more rapidly at night, especially downhill, than I had thought possible.

Summarizing, I would say that the most important thing this fire showed was the inability of the ranger to make efficient use of the manpower and equipment that was available at the time of the fire. The matters of new and better equipment are secondary. [The ranger may take comfort from the fact that many others, including big shots in fire control, suffer from the same inability—but this should not deter him from seeking to be mentally prepared for efficient management of the next fire. *–Ed.*]

Kisatchie—Slash fire—407 acres (165 ha). Two hundred and ten acres (85 ha) of the fire had only recently been planted to slash pine. The slash pine of course was totally destroyed. The rough was composed of wire grass, broomsedge, and a fairly heavy carpet of hardwood leaves. The rough was of 5 years' accumulation, and can be considered heavy for longleaf type.

Investigation revealed that the fire was handled very well by the lookout men and the dispatcher. The discovery, report, and getaway times are excellent. However, the decision of the superintendent to send only 6 men with the junior foreman in a pickup to check on the fire was sadly at fault. The day was not an extremely bad one; however, a fresh south wind was blowing and any fire located within a quarter or a half mile (0.4–0.8 km) south of the boundary certainly should have merited both the fire truck (tank truck and Panama pump) and a full 16-man crew with the standard fire-fighting tool box. If the junior foreman had had a full 16-man crew and fire truck he would have unquestionably held the fire with only an acre (0.4 ha) or so of national forest land burned.

DeSoto—Saucier Fire—635 acres (257 ha). The weather conditions made the hazard extreme. There had been no rain for 3 days. The relative humidity was 33 at noon. Wind velocity varied from 8 to 16 miles per hour (13–26 km/h) during the fire. The ground cover was broomsedge grass. The flames had a range of 40 to 60 feet (12–18 m), crowning at times and spotting ahead.

Instructions were to backfire from a fire lane on the west side. This firebreak had been constructed 2 years ago and had not been maintained since this time. As a result, it was grown over and offered no effective barrier from which to backfire. The extreme weather conditions made it improbable that even if the firebreak had been recently maintained, the crew would have been able to hold their backfire on this narrow line.

> A whirlwind picked up burning material from as far as 100 yards inside the line and dropped it outside in the rough, resulting immediately in a break-over of large proportions.

DeSoto—Hell Hole Creek Fire—509 acres (206 ha). This fire emphasized how immediate and continued work on the flanks of a large fire can keep the acreage to a minimum and prevent new heads from forming when the wind shifts. Crews worked the flanks continually so that when the head was finally stopped the entire fire was corralled within a very few minutes.

The head of this fire presented a wall of flames 20 feet high (6 m), with a range of 30 to 40 feet (9–12 m). It was burning in a 5-year rough. Several of the fire fighters had narrow escapes while attempting to stop the head. Two different pump men were forced to abandon their pumps in order to outrun the fire.

This fire, as well as other large ones on the DeSoto, shows that in extreme weather conditions a great deal depends on the dispatcher's judgment in placing crews, not only for the head but for work on the flanks. The speed at which these fires travel offers little opportunity to correct tactical mistakes on the fire line.

North Central Region (R-7)

Gardner—Tower Fire—489 acres (198 ha). This was one of a series of 25 fires burning on the district on this date. The fire danger was class 6 and the wind velocity was 20 miles per hour (32 km/h). The fire spread rapidly in highly inflammable leaf and grass fuel.

Topography was rugged with steep slopes, which accelerated the rate of spread. Winds shifted frequently and small whirlwinds occurred along the fire front. As a result the fire had a number of heads, with one traveling along the top of each main ridge. The fire advanced in a solid sheet of flame, leaping 6 feet (2 m) high in most places, and the men could not get near the fire because of the intense heat. Spot fires, jumping in many cases over 100 feet (30 m) ahead of the main fire, were common. There was 2 to 3 years accumulation of leaves on the area.

When Assistant Ranger Barry arrived, he took charge of the fire immediately. He made a quick size-up of the situation, determined that direct attack was ineffective [It had already failed. –*Ed.*], and directed the crews to drop back several hundred feet from the fire edge to construct line. The technique used, which consisted of raking a line and backfiring from it, was considered satisfactory under the circumstances. This dropping back was essential because whirlwind conditions caused fires to spot 100 to 200 feet (30–60) ahead of the main fire.

Knowing the conditions as are known now, fire management could have been improved by backfiring from the truck trail and keeping the fire from crossing it. However, the use of this technique would have required at least 25 additional men as there were separate heads traveling toward the road.

The general belief that all fires in Missouri hardwoods can be handled by direct or parallel methods is false. On certain days, conditions are such that the only practical method is to drop back to natural or cultural barriers, such as the road in this case, and sacrifice some burned acreage in order to insure control.

A more extensive use of water should be resorted to on such days. On this fire three men could not control a 5-foot (1.5-m) spot fire by use of rakes. A marine pump would have saved the first line built on this fire. ■

Lessons From Larger Fires on National Forests, 1939*

Roy Headley

Editor's note: Roy Headley took the "lessons learned" from field reports on "larger fires" (fires covering more than 300 acres [121 ha]) in the Eastern, Southern, and North-Central Regions. He indicated the source following each report. His own summaries and comments are indicated by brackets and the italicized notation "–Ed."

> The Chestnut Ridge fire showed that weather conditions may rapidly change during early spring, and that the field organization must be kept on its toes.

Eastern Region (R-9)

George Washington—Chestnut Ridge Fire—872 acres (353 ha). This fire on March 9, under very serious burning conditions, was probably caused by children living in the vicinity. The fire caught the preparedness organization of the district napping. Towers were not manned. Weather stations and district fire truck not in operation, and the district ranger not in touch with his dispatcher. Failure to recognize emergency conditions and to build organization on the basis of emergency conditions results in fires of this class.

Once organized the suppression action was satisfactory. However, because of lack of preparedness it required 3-1/2 hours to get the suppression organization to the fire. The result was a large fire, and the lessons learned by all concerned are that regardless of previous weather, conditions may change very rapidly during the early spring, and that the field organization must be kept on its toes. *–Unsigned forest report*

A complete failure of district ranger to recognize degree of fire danger and plan accordingly. Corrective action has been taken. The most valuable lesson in this case involves the continuous daily use of fire-weather stations to determine degree of danger following rain. Very rapid changes involving only a few hours from no danger to high danger are to be expected during March, April, and May. *–R.M. Evans, regional forester*

Southern Region (R-8)

De Soto, Leaf River District—Plantation No. 24 Fire—1,682 acres (681 ha). [When discovered 5 minutes after known time of origin, this incendiary grass fire was 3 acres (1.2 ha). Report and get-away took 5 minutes. Three miles (4.8 km) of auto travel, 10 minutes. When reached by the first crew of 17 men, 20 minutes after origin, the fire was 20 acres (9 ha). But it burned 1,682 acres (681 ha), including 870 acres (352 ha) of plantation, before it was corralled 10 hours and 25 minutes after origin. In one place, wind velocity is reported as 2 to 19 miles (3.2–31 km/h); in another, 25 to 38 miles (40-61 km/h). Five days since last rain of 0.28 inch (0.71 cm). Number of chains per man hour, 2.3 (152 feet [46.3 m]). Much confusion and disorganization on the line. Maximum number of men engaged, 65. *–Ed.*] The initial tactics used by the fire boss were correct for this fire, and had the heavy equipment functioned properly, the fire would have been held to less than 100 acres (40 ha).

De Soto, Leaf River District—Leaf No. 35 Fire—416 acres (168 ha). [Fire was 75 acres (30 ha) when discovered 2 hours and 17 minutes after guessed time of origin. It spread 25 acres (10 ha) during the 53 minutes required for report, get-away, and the travel. *–Ed.*]

Low visibility accounts for the size of fire when discovered. There were five sets and the purpose of the fire was to provide sheep range. The exposed ridge site and high winds made suppression difficult. A fire usually occurs in this location about the same time each year. Next year it is planned to patrol these areas closely in an effort to prevent the fire or catch the incendiary. *–V.B. McNaughton, fire assistant*

When this article was originally published, Roy Headley headed the Division of Fire Control, USDA Forest Service, Washington, DC.

* The article is an abridged version of an article published in *Fire Control Notes* 4(1) [Winter 1940]: 15–17.

The lesson from the Ludlow fire is to promptly investigate if there is any doubt in the mind of a dispatcher or towerman as to the location of a smoke.

De Soto, Biloxi Ranger District—University No. 28 Fire—1,238 acres (501 ha). [Another grass, stockman, incendiary fire but with only one set. This time the lookout man snapped in with discovery within 4 minutes after guessed time of origin, when the probable area was one-tenth acre (0.04 ha). But report took 42 minutes. In the 65 minutes required for report, get-away, and 9 miles (14 km) auto travel, the fire spread to 350 acres (140 ha). Wind velocity reported as 13 to 18 miles per hour (21–29 km/h) when fire was first reached and during biggest run. *–Ed.*]

De Soto, Biloxi Ranger District—Camp Branch No. 16 Fire—419 acres (170 ha). On this fire, if the one-half ton pick-up which was equipped with a Panama pump and 55 gallons (208 L) of water had not bogged down, a successful attack could undoubtedly have been made on the head. *–V.B. McNaughton, fire assistant*. [Illustrating why Region 8 is interested in four-wheel drive trucks. *–Ed.*]

The fire was not scouted and no one reached the head until it had burned into the forks of the creek about 1 mile (1.6 km) south of where the initial attack was made. This fire illustrates what happens when the initial action on fires in this country is wrong. The climatic conditions and fuel types favor an extremely rapid rate of spread on practically all of our fires, and it is imperative that we get a crew on the head of the fire as soon as possible.

For this reason we dispatch a small crew on a "hot shot" pick-up and follow this unit with a 20-man crew. The small crew, upon reaching the fire should go to the head and take whatever action is necessary to check it. As I see it, there are only two possible conditions present; either (1) they can hold the head by direct attack, or, (2) they can't. In the latter case, their only alternative is to backfire against the head and depend on the follow-up crew to handle the flanks.

Bienville—Ludlow Fire No. 20—1,056 acres (427 ha). [The report shows that the fire started one-half mile (0.8 km) outside the boundary. Discovered at 10 acres (4 ha), 1 hour and 14 minutes after guessed time of origin, and reported to dispatcher. But report time is 45 hours and 6 minutes. Hence, with 5 minutes get-away time and 1 hour and 5 minutes for 4 miles (6.4 km) travel on foot, a total of 46 hours and 16 minutes elapsed from discovery to arrival. The fire was 500 acres (200 ha) when reached. It did not enter the forest until the second day after it started. *–Ed.*]

It is known at this time that a crew should have been dispatched to the smoke shortly following discovery. It does not hold, however, that this procedure can be followed on all smokes, the number and places of occurrence making this prohibitive.

It is planned to adopt a policy of closer investigation of doubtful smokes on days of poor visibility when no crossing-out is possible, even at the risk of increasing the false-alarm cost. Better a false alarm than a 600-acre (240-ha) fire!

Every fire training meeting or conference stresses the need of exercising good judgment in all phases of fire control. It is a little unfortunate that this qualification must attend an individual's every action in fire control. Very often, certain action which has merited commendation because of its practical application in hundreds of previous cases, falls down in a particular case, and the cry "poor judgment" is raised and not altogether unjustifiably, as with this fire.

The lesson to be learned from the Ludlow fire is definitely this, in my opinion: "Where the slightest doubt exists in the mind of a dispatcher or towerman as to the location of a smoke, because of poor visibility or any other reason, prompt investigative action should take place. Although it was known that debris burning was being done in the affected area, too great a chance was taken on these particular hazardous days to let a smoke of this nature, never definitely located until the third day, go uninvestigated. Out of this lesson should come an unqualified policy of action on smokes which literally cry out: "I need investigating!" ■

Lessons of the McVey Fire, Black Hills National Forest*

A.A. Brown

Editor's note: Early issues of Fire Control Notes *often prefaced articles with substantive remarks by the journal's editors. A.A. Brown's article on the McVey Fire is a good example, with a preface long enough to stand on its own (see the sidebar).*

The heading under which this must be written, and its implied purpose, impose an automatic censorship on its contents. A lesson in fire control to be of interregional interest should introduce something new, or should at least give new emphasis to principles or to aspects of their application that have not yet been fully learned. Whether or not any experience qualifies on either of these two counts depends on the class of individual.

McVey Fire

A list of the lessons learned by the Civilian Conservation Corps (CCC) boys on the McVey fire would have a very different content from the list that would be most appropriate for their foremen. Similarly, some of the lessons learned by members of the supervisors' staffs of the Barney and Black Hills Forests would sound trite to a southern California fire fighter, although other features of the job might have considerable thought-provoking challenge to outsiders.

When this article was originally published, A.A. Brown was head of Fire Control for the USDA Forest Service, Rocky Mountain Region.

* The article is reprinted from *Fire Control Notes* 4(2) [Spring 1940]: 63–67.

Making a pretty complete kill on 22,000 acres of highly productive country, the McVey fire was easily the worst fire of the 1939 year.

The following comments represent an attempt to sort out experiences of the McVey fire from which lessons may be drawn that are of interest to officers concerned with fire-control strategy on big fires. For the most part they do not represent anything new in principles of fire control.

The McVey fire itself was a conflagration in flashy fuels, in rolling topography, with variable winds. This combination is designed to test the resources of any fire boss. Rates of forward spread on wide fronts up to 120 chains (7,920 feet [2,414 m]) per hour occurred. Direction of spread varied, and rate of increase in terms of acreage burned went as high as 2,900 acres (1,200 ha) per hour during the run of Tuesday, July 11. The cover type of the whole area was ponderosa pine, interspersed with small meadows. Over two-thirds of the area burned consisted of thinned stands of ponderosa pine, in which the thinning slash formed a continuous layer of fuel of varying density and stages of decay, dating from 1933.

Although this fire reached a total area of 22,000 acres (8,900 ha), it was controlled as a second-period fire with a total of 46 miles (74 km) of held line. Because of the blow-up on July 11, only 10 miles (16.1 km) of line were still held by 8 p.m. of that day. The additional 36 miles (58 km) were built in one work period, from 8 p.m. Tuesday night to 9:15 a.m. Wednesday. The rate at which the fire burned out was remarkable for a timber fire. Once the entire perimeter was controlled, the whole area went cold almost overnight. This seems to have been due, in a large part, to the absence of heavy dry material, to the burning out done on all fire lines, and to the extreme heat produced by the slash on the ground.

The lessons to be learned from this fire for the local organization have the usual and familiar character of lessons in fire strategy, in organization, in speed of attack, in methods of attack, and in fire prevention and preparedness. All of these have been discussed at some length, and most of them on which it was agreed that something definite and constructive could be done locally have been duly listed in the conclusions of the Board of Fire Review. For the most part, they will not be repeated here, but an attempt will be made to go back a little further in a consideration of the significance of facts brought out by fires such as this one.

Inadequate Theory

One of the first things that seems important to recognize is the inadequacy of existing fire-fighting methods to meet and overcome all kinds of fires. A 1-acre (0.4-ha) fire may be only a smoldering spot or it may already be as dynamic as a small tornado.

Most of our theory of fire-control tactics is based on a two-dimension idea, and the control of a fire is usually pictured as the solution of a problem in plane geometry. It

Editors' Preface to A.A. Brown Article

Making a pretty complete kill on 22,000 acres (8,900 ha) of highly productive country, where every cubic foot of timber that can be grown is needed to sustain the dependent communities, the McVey fire was easily the worst fire of the 1939 year. To find and follow through the clues leading to increasing mastery of such fires offers the sharpest possible challenge to fire-control students. Such losses are intolerable, but it will take more than our usual insight and methods of study to find out why they occur. When we find the answers, it will take more than our usual forms of training to get the essential principles of control so embedded in the minds of enough men that these principles will be applied in future crises.

Breaking the Rules

At 11 p.m., 9 hours after the arrival of the first 68 men on the fire, those in charge recognized for the first time that they "were up against a fire that wouldn't act according to rule." The fire had spread less than 250 acres (100 ha) in the previous 5 hours and had reached a total of approximately 1,600 acres (650 ha). Wind from 7 to 10 p.m. had been "nearly imperceptible." Completion of the control line in the early morning hours "appeared certain" long before the time required by the first work-period policy. But about 11 p.m. the wind freshened a little and the fire marched out through the unworked gap of "less than half a mile [0.8 km]" and started a spread which was not corralled until 34 hours later.

The surge of the fire at about 11 p.m. the first day was the result of recognizable causes or it was not. Can we discover why this and similar fires behave the way they did? Whether, like a rattler, they actually gave a warning which we might learn to recognize in future before it is too late?

Fire Perimeter Control

The data submitted by Staff Technician Skinner shows that at 6 p.m. on the first day, 5-1/2 hours after discovery and 4 hours and 40 minutes after arrival of the first cooperator crew, the fire had a perimeter of 10.2 miles (16.4 km) (including a 25-percent addition to a machine count of map miles). Of this total, 4.6 miles (7.4 km) were in the same location as when the fire was finally corralled_mostly on or close to roads, fields, and prairies; and 2.3 miles were held until 9 a.m. the next morning. The spread from 6 p.m. of the first day to 9 a.m. of the second day came, therefore, from not over 3.3 miles (5.3 km) of front as of 6 p.m. on the first day. The author's figure of 10 miles (16.1 km) to build as of 6 p.m. evidently considers expected spread after that time, but does not include the 6.9 miles (11.1 km) of line or edge as of 6 p.m. which was in the same place at 9 a.m. the next morning.

Output of held line up to the completion of the final control line was 0.1 chain (7 feet [2.1 m]) per man-hour_which again falls within our semistandard of 0.06 to 0.16 of a chain (4 to 11 feet [1.2–3.3 m]) per man-hour. No figure is available on lost line.

Spot Fire Problem

Spotting was naturally very bad. Can't we develop better ideas for dealing with spot fires? As a simple example, how can we get men to watch and comb the places where spot fires may start instead of watching the fire from which the sparks come? Sounds easy, doesn't it?

Before the first crew arrived, two post cutters working nearby saw and tried to stop this fire. They tailed and had difficulty in escaping. They were suspected of starting the fire, but it was later proved to be a hang-over lightning fire.

seems to me that this type of thinking has carried over too far into ideas of application on the job so that the experienced fire foreman himself comes nearer to a full realization of the potentialities of a given fire in the third dimension than does the so-called fire-control expert.

This of course, sums up to our inability to cope with crown fires. It is not a new subject but it has been rather studiously ignored in discussions of fire fighting. Certainly, this one factor looms large in the history of the McVey fire.

Nine hours after arrival on the fire, those in charge recognized for the first time that they "were up against a fire that wouldn't act according to rule."

Missed Opportunity

Assuming that nothing could be done during the height of the spread of this fire through the crowns, there were lulls during which it might have been controlled if certain things could have been done quickly enough. These "ifs" comprise debatable points from which some lessons may be drawn. During the first afternoon and evening, from 6 p.m. to 11 p.m., the fire dropped out of the crowns and stayed relatively quiet. There were 10 miles (16.1 km) of fire line to build, which it was expected would be complete by 2 a.m. As it turned out, this would have been completed, probably by midnight, but the blow-up at 11 p.m. with less than one-half mile (0.8 km) of line still to build resulted in losing nearly all that had been accomplished. A plan of attack designed to complete the job before 11 p.m. might have saved the day.

It has long been realized that it is unsafe to stake everything on the assumption that a fire will slow down at night. Yet fires do so so commonly that both the forester's and the regional policy are based on overnight action which is judged to be adequate on a big fire if sufficient manpower and facilities are mobilized to control a more or less static fire perimeter before 10 a.m. of the next day. On the McVey fire, forest officers allowed themselves a large safety margin, but as it turned out, not enough, since they did not foresee the critical necessity of a safe perimeter that could be held against all odds by 11 p.m. of the first night.

Regardless of how feasible such an accomplishment might have been on this particular fire, it, of course, presents a very real question in the case of future fires. Will it ever be possible to predict the behavior of an exceptional fire far enough in advance to insure the exceptional intensity of attack required? Ways in which Region 2 officers believe such foresight might be improved are: Through improved fire-danger ratings, improved fire-weather forecasting, and through better recognition of potentialities of local fuel hazards.

Unsound Strategy

The next lesson of critical import and perhaps the one of most constructive value of all is that of the strategy of control in an aggressive fire such as this. Although the main head or heads of the fire took one direction, then another, during its run, prevailing winds and past experience with such fires in this locality have revealed that the odds are four to one that the greatest conflagration threat will be to country to the east and northeast of the fire. This was well known, yet the timing of control effort was such that the most northerly and westerly extensions of the fire were the last to be controlled. As a result the blow-up here flanked all the hard-won control line to the east.

This was a question of judgment at the time and not as obvious a failure as it may sound in review. The worst fuels and the most aggressive head of the fire were given first attention, and the hardest part of the fight seemed already won when the fire made its new drive northward on its west flank. This extension set the stage for the final run eastward on a front of conflagration proportions. The west flank of the fire had already burned out to a wide expanse of noninflammable grassland which gave a strategic advantage. Had the progression of safe-control line been entirely from the grassland eastward along the north flank and from the completed south line northwestward along the east flank, the investment in fire-control line would have been better protected against loss and the same blow-up with the same amount of uncontrolled perimeter farther east at 11 p.m. would have been far less disastrous, in terms of both a narrower new head and less lost line.

> Forces were reorganized and a fresh attack was made—a sound strategy, but its execution failed from circumstances which may also carry some lessons.

This lesson in importance of sound strategy would not have become apparent at all had the fire remained quiet an hour longer or had the fresh crews scheduled for this sector been the first to arrive and start work instead of the last. Similarly, more manpower or increased efficiency in line construction, sufficient to complete all control line before 11 p.m., might have resulted in success with the timing used.

Failed Execution

After the fire had made its run northward another lull occurred between the hours of 2 and 7 a.m. of the morning following. Forces were reorganized and a fresh attack was made during this period which carried considerable promise of success in spite of a greatly increased perimeter. In this case little fault can be found with the strategy planned, but its execution failed from circumstances which may also carry some lessons.

The critical sector of the new line was being pushed rapidly from both ends by experienced fire foremen using the one-lick method and burning their line clean as they went. Follow-up crews were organized to guard the hot line and to control spot fires. The latter failed to accomplish this. No one knows exactly why, except that this job turned out to be far more exacting and required far more supervision and more ingenuity and action than did the construction of a reasonably safe control line alone. Both on this occasion and at other times during the fire the rate of production of a reasonably acceptable control line, including burning out, did not represent the rate at which the fire was being controlled.

This raises a question of tactics where fire line is being built rapidly. The job of holding the line built calls for far more than is implied by either the term patrol or mop-up. It represents on a fast-running fire a desperate defense action, since the advance crew cannot wait to see the fire finally die down behind it, but must pass on to the follow-up crews the responsibility of making good the advantage gained. When 2 to 3 miles (3–5 km) of such line is handed to a sector boss he must drastically change the approved method of organizing the job, which was based on mopping up a dying fire edge. Apparently this was not well enough done. The conclusion then is that organization of crews must be handled on a very different basis than the conventional mop-up or patrol action when fire line is put in rapidly by an advance crew or by mechanical means.

A further experience on the McVey fire that was baffling to sector bosses was the tendency of backfires to spread inward toward the oncoming crown fire in the surface litter just as intended, and to go into the crowns just before reaching the main fire. But when the two met they seemed to "bounce" right back through the unburned crowns toward the fire line without any noticeable drop in intensity. This did not always occur but happened so often as to make backfiring ineffective at close range and very risky at longer distances. Apparently the nature and force of the convection drafts is the deciding factor. It is a challenge to backfiring theory and strategy.

Challenges to Theory and Practice

Out of these experiences there may be resolved several points of challenge to existing fire-fighting theory and practices. These points, rather than the lessons discussed, will be listed in the form of questions.

1. How can forest fire-fighting theory and practice take better account of fire as a force to be dealt with which varies as a problem not only with the area involved but also with the varying rate at which heat units are being released and with the convection forces being generated?
2. How can the requirements of successful control action for each individual fire be predicted more successfully?
3. What principles of fire-control strategy can be defined and set up for general application?
4. What changes in crew organization should be adopted to insure holding long stretches of fire-control line built rapidly along the perimeter of an active fire?
5. How can the use of backfiring be reduced to a dependable practice in combating crown fires? ■

An Analysis of the Honey Fire*

C.F. Olsen

Original editor's note: Although the Honey Fire occurred almost 2 years ago the following analysis is published because of its value to other fire control personnel. The data were gathered by research personnel who were present throughout the period of the fire and who were free from any suppression duties. A "Board of Fire Review" held by the regional forester in 1938 brought out additional information and criticisms which were furnished to the Southern Forest Experiment Station for its study.

Fires of the extreme intensity and rate of spread of the Honey Fire in the longleaf/slash pine type are the exception rather than the rule.

Employees on a south-bound freight train in north-central Louisiana carelessly disposed of a piece of burning waste from a hot box on a crisp January morning in 1938. The bit of flame landed in dead grass at the edge of the tracks inside the boundaries of the Kisatchie National Forest; 30 minutes later this small flame had grown into a forest fire with a perimeter of almost 4 miles (6.4 km) and had spread almost 2 miles (3.2 km) with the wind from the point of origin. A crew of four men, assigned by the Southern Forest Experiment Station to studies in fire behavior, was on the scene within 3 minutes after its start and an unusually complete record of this fire, including its rate of spread and resistance to control, was obtained.**

This fire record will be discussed and analyzed in detail with three objectives:

1. To indicate the rate of spread and behavior of fires burning under extremely critical conditions.
2. To describe the action that was taken to suppress the fire.
3. To use the experience gained from this fire as a guide in planning the action to be taken on other fires burning under similar circumstances.

Location

The Honey Fire, briefly described by Headley (1939), was known locally also as the Dyson Creek Fire. It occurred in the center of the Catahoula District of the Kisatchie National Forest. The fire started along the east side of a railroad right-of-way 1-1/2 miles (2.4 km) north of Bentley, a small settlement approximately 15 miles (24 km) north of Alexandria, headquarters of the forest supervisor. The central tower of the ranger district, the Catahoula Tower, is located 1-1/2 miles (2.4 km) east of Bentley. The highways, railroad, firebreaks, and other physical improvements on the fire area are shown on the accompanying maps.

The area is typical of open cut-over longleaf pine land in the Upper Coastal Plain. The topography ranges from flat to gently rolling, with occasional depressions of wet and boggy land. Several small creek bottoms occur on the area, but because they are in general very narrow, they contribute little or nothing as natural barriers to fast-spreading fires. The principal fuel in the area is grass, broomsedge (*Andropogon* sp.) being predominant. Other components of the fuel are various herbaceous plants, pine needles and cones, and hardwood leaves.

Approximately 150 acres (60 ha) covered by this fire were burned over on February 21, 1935. The remainder of the area, or about 950 acres (384 ha), had been unburned for at least 6 years. Inasmuch as all of the area had been unburned for 3 years or longer and the site is better than average, a uniform and extremely heavy stand of grass covered the

When this article was originally published, C.F. Olsen was a forester for the USDA Forest Service, Southern Forest Experiment Station, Asheville, NC.

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** In order to obtain better data, the forest supervisor had previously agreed that the members of this crew were relieved of any obligation to assist in fire suppression. Usually they were in effect dispatched with the regular suppression crew; in this instance they happened on the fire at about the time it was reported. They were criticized for not trying to control it; but with two fences and a railroad between them and the fire, there is no doubt that their truck was unusable on this fire. It was very definitely too big for them to hold with hand tools alone.

entire area and contributed markedly to the intensity of the fire. Also scattered residual seed trees and some reproduction were present in the western half of the area and the eastern half supported moderately well stocked stands of longleaf pine saplings, light to heavy stands of blackjack oak, and open grass. Following the 1935 fire, 20-foot-wide (6-m-wide) drivable firebreaks were constructed over portions of the area. An 858-acre (347-ha) plantation of slash pine was established by the Forest Service in the center of the burned area during the 1936–37 planting season.

All of the burned area lies within the national-forest protection boundary, but only the east half is national-forest land, the remainder being privately owned.

Weather Conditions

The weather conditions that prevailed in the region immediately before the fire started and on the 2 previous days are shown in table 1.

Since this fire was mapped for rate of spread in connection with a study of fire behavior and the recording of current weather data was an integral part of that study, weather records were made, beginning shortly after the start of the fire. The factors measured were relative humidity (by a hand-operated psychrometer), air temperature, wind movement, wind direction, and sky condition. General notes also were made. Wind movement was taken at 1-minute intervals with a portable anemometer developed by the California Forest and Range Experiment Station. This instrument consisted of a Byram-type fan anemometer resting on a universal joint and mounted on a tripod. The instrument was placed a sufficient distance from the fire to be unaffected by the drafts and currents created during rapid combustion. The anemometer was set with the spindle 3-1/2 feet (1.1 m) above the ground, the standard height for measuring wind velocity in all studies of rate of spread.

A record of the average and maximum wind velocity, relative humidity, air temperature, and fuel and soil moisture content (based on dry weight) is presented in table 2.

Table 1—*Weather conditions preceding the Honey Fire (observations made at Catahoula Tower).*

Date	Temperature		Rainfall		Sky condition	Wind		Visibility
	Max.	Min.	Amount	Time		Direction	Rate	
Jan. 23	73 °F	62 °F	0.93 inches	Noon–6 p.m.	Cloudy	South	Light	Poor
Jan. 24	66 °F	48 °F	0	—	Cloudy and threatening	SW–NW	Moderate	Poor (3 miles)
Jan. 25[a]	42 °F	—	0	—	Clear	NW	Moderate	Good

a. 10 a.m.

Table 2—*Record of weather, fuel moisture, and soil moisture conditions during Honey Fire.*

Period	Wind velocity (mph)		Time	Relative humidity (%)	Air temp. (°F)	Time	Moisture content (% dry weight)	
	Avg.	Max.					Fuel	Soil
10:07–10:37 a.m.	6.7	9.9	10:06 a.m.	33	42	10 a.m.	15.8	34.1
11:28–11:59 a.m.	11.3	16.6	11:20 a.m.	27	50	11:55 a.m.	12.1	34.1
12:20–12:33 p.m.	12.7	14.3	12:33 p.m.	26	46	1:45 p.m.	11.6	—
—	—	—	2:17 p.m.	26	46	—	—	—

The Fire

> The combination of high, shifting winds and low fuel-moisture content prevailing at the time of the fire created critical burning conditions.

Time of Start. The Honey Fire started at 9:50 a.m. on January 25, 1938, in the manner described. The fire-behavior crew, having been traveling south along U.S. 167 about 1 mile (1.6 km) behind the train, arrived at the fire at 9:53 a.m. At the moment, the fire had advanced more than 100 feet (30 m).

Rate of Spread. Three members of the crew started mapping the fire at 9:55 a.m., while the fourth member collected fuel and soil samples and set up instruments to obtain weather data. The main head of the fire and the north flank were mapped at that time and at each 5-minute interval thereafter. After the first 5 minutes, during which it had moved almost 6 chains (396 feet [121 m]) forward from the point of origin, the head of the fire advanced at a rate ranging from 25 to 35 chains (1,650 to 2,310 feet [503–705 m]) for each 5-minute period. This head, labeled *A* on the accompanying map (fig. 1) showing the progress of those parts of the fire that could be reached for mapping with the limited fire-behavior crew available, stopped of its own accord when it reached an abandoned Civilian Conservation Corps (CCC) camp site on which a heavy cover of carpet grass was present.

Because of distinct shifts in wind direction from northwest to southwest, however, a new head *B* developed along the north flank (fig. 1). A total of eight heads were mapped during the course of this fire; all of the heads labeled from *B* through *H* developed either by wind shifts along the north flank of the main head *A* and its subsequent heads or from spotting across roads or burned firebreaks.

There were great differences in the rates of spread of the flames at different points on the fire. In the main, however, the fire spread forward at the rate of 5 to 6 chains (330 to 396 feet [101–121 m]) per minute. The greatest rate of spread measured in a forward direction was 8 chains (528 feet [101 m]) in 1 minute. In the easternmost part of the area, where the fire was finally brought under control and

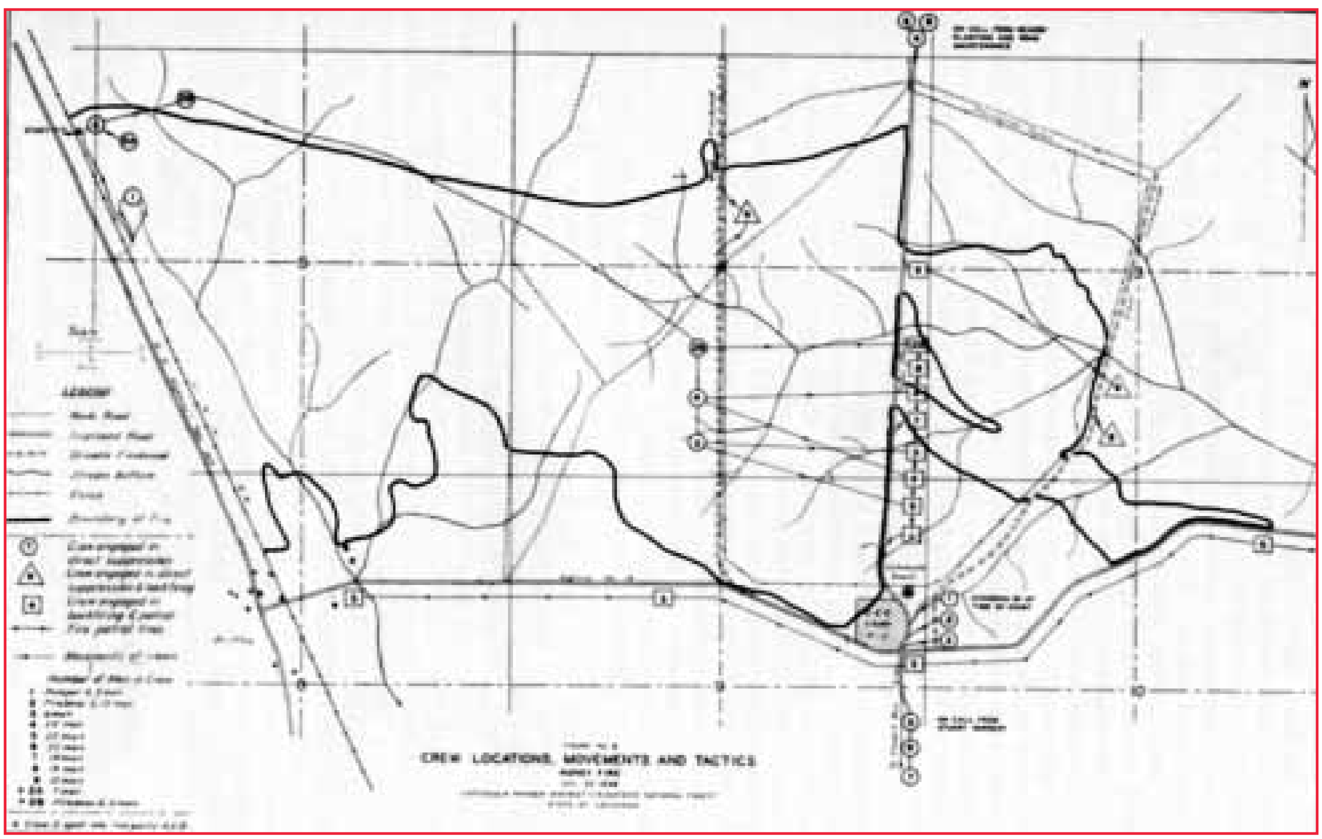

Figure 1—*Map of the Honey Fire, showing rate of spread and fire behavior.*

where there were dense stands of blackjack oak in which the carrying fuel was considerably less than in the open longleaf pine areas, the forward rate of spread dropped to as low as 1 chain (66 feet [20 m]) per minute.

The perimeter and area increases that accompany the forward rates of spread on fast-moving fires are also very high; the figures for the main head *A* are given in table 3.

Fire Behavior. Besides collecting data on the rate of spread of the fire, the mapping crew recorded observations of various items of fire behavior that influence fire-suppression action. Among these were flame height, width of the burning line, incidence and distance of spotting, and difficulties experienced by the fire fighters.

The flames at the head frequently reached out in long tongues extending 100 feet (30 m) or more in advance of the actual burning of the fuel; on the flanks, a slight shift in wind direction would increase the flame height from an average of 3 to 4 feet (1–1.2 m) to 20 to 25 feet (6–8 m), with the width of the burning line 15 feet (5 m) or more.

There were numerous cases of spotting for a considerable distance ahead of the fire; in one instance, when the wind velocity was 13 miles per hour (21 km/h), fire spotted over 200 feet (60 m) in advance of the head. An unusual case of spotting occurred when a dead snag, located 95 feet (30 m) from the nearest edge of fire, ignited at a height of 12 feet (4 m) above the ground. Hardwood leaves, especially those from blackjack oaks, were responsible for all spot fires noted.

The spread of the fire was stopped and the fire corralled at 2:43 p.m.; the fire was controlled and mop-up completed at 6:45 p.m.

The final total area burned in this fire was 1,092 acres (442 ha), of which 493 acres (200 ha) were on national-forest land and the remainder, or 599 acres (242 ha), on privately owned land within the national-forest boundary. Of the national-forest land burned, 396 acres (160 ha) were in the slash-pine plantations mentioned earlier.

Available Suppression Crews and Equipment. On the morning of January 25, nine crews of fire fighters were available to the fire dispatcher for fire duty. The crews were made up of CCC and Work Projects Administration men who worked either at the Stuart Nursery or on planting and road maintenance jobs within easy driving distance of the central tower. The crew organization is shown in table 4.

The standard fire tools, with which all except crew No. 1 were equipped, consisted of flaps (swatters), hand-operated back-pack pumps, fire rakes, water buckets, railroad "fusee" torches, axes, etc., all of which were kept in a wooden box on the trucks transporting the men. The pumper truck was equipped with dual wheels, a 350-gallon (1,325-L), water tank, and a pressure pump unit driven from the fan-belt of the engine.

Discovery. The fire was discovered by the lookout on the Catahoula

Table 3—*Rate of spread on main head (A) of Honey Fire.*

Time elapsed after start	*Forward progress (chains [ft])*		*Perimeter (chains [ft])*		*Area (acres)*	
	Total	*Increase*	*Total*	*Increase*	*Total*	*Increase*
5 min	5.7 (376)	5.7 (376)	13.6 (898)	13.6 (898)	0.9	0.9
10 min	32.8 (2,165)	27.1 (1,789)	70.4 (4,646)	56.8 (3,749)	10.2	9.3
15 min	57.4 (3,788)	24.6 (1,624)	121.3 (8,006)	50.9 (3,359)	27.1	16.9
20 min	93.4 (6,164)	36.0 (2,376)	195.9 (12,929)	74.6 (4,924)	60.5	33.4
25 min	126.0 (8,316)	32.6 (2,152)	263.4 (17,384)	67.5 (4,455)	109.2	48.7
30 min	148.2 (9,781)	22.2 (1,465)	311.9 (20,585)	48.5 (3,201)	167.4	58.2
35 min	175.9 (11,609)	27.7 (1,828)	368.6 (24,328)	56.7 (3,742)	250.8	83.4

Table 4—*Crews and equipment available for suppression of Honey Fire.*

Crew No.	*Firefighters*	*Supervisory personnel*	*Total*	*Equipment*
1	1	1	2	Pumper truck, 350-gallon capacity.
2	12	1	13	Standard fire tools.
3	5	1	6	Do.
4	24	1	25	Do.
5	20	2	22	Do.
6	21	1	22	Do.
7	17	2	19	Do.
8	18	1	19	Do.
9	11	1	12	Do.
Misc. superv. pers.	—	8	8	—
Total	129	19	148	—

Tower, located 2 miles (3.2 km) to the east, at 9:52 a.m. (2 minutes after the start) and reported immediately to the fire dispatcher. A cross-shot was obtained from the Colfax Tower lookout, 4 miles (6.4 km) to the west at 9:53 a.m. The fire dispatcher, therefore, had a reasonably definite location of the fire within 3 minutes of its start. At that moment, however, it was impossible to determine with absolute certainty on which side of the railroad track the fire was burning. There was still a possibility that the fire was burning in the 150 feet (50 m) of grassland between U.S. 167 and the west side of the railroad track or even west of the highway.

Crew Dispatch and Initial Attack. The map showing the initial and subsequent crew locations (fig. 2) indicates the points at which the fire was attacked before control was attained.

Crew 1, consisting of the pumper truck with a driver and hoseman, was the first crew dispatched to the fire. It left Catahoula Tower, where it was standing by for emergency use, at 9:53 a.m. and went directly to the origin of the fire near U.S. 167. While enroute, the driver determined definitely that the fire was on the east side of the railroad track. The train momentarily delayed him by blocking the road crossing leading into the fire. He then made an attempt to reach the fire, but the pitcher-plant (*Sarracenia* spp.) land which it was then burning was so wet and boggy that this was impossible. He returned, therefore, to Catahoula Tower and received instructions to wet down the fuel and be prepared to extinguish spots along the east side of Tower Road, starting near the tower, while crews 3 and 4, who had meanwhile reported at Catahoula Tower for fire duty, burned a backfire along the west side of Tower Road.

Meanwhile, crew 2, the leader of which was fire boss, left Catahoula Tower for the fire at 9:55 a.m., going to the point of origin. Thus crew was momentarily delayed by the train at the road crossing. It is estimated that the fire had a perimeter of 40 chains (2,640 feet [805 m]) upon their arrival. They started to extinguish fire along the north flank near the head for the purpose of checking the fire by cutting it into a cultivated field located about three-quarters mile (1.2 km) southeast of the origin. These tactics failed when the head passed to the north of the field; the forward progress of the south flank, however, was checked when it reached the field. The crew leader then split his crew; he left 7 men to suppress the fire, starting from the tail and working toward the head, and led the remaining 5 men (crew 2B) on foot across country to the west firebreak.

The main head of the fire, meanwhile, had reached Tower Road, where it was stopped by the abandoned CCC camp and the fireline burned by crews 3 and 4 and the pumper truck; crews 3 and 4 then went to the west firebreak to burn more backfire similar to that which they had just completed on Tower

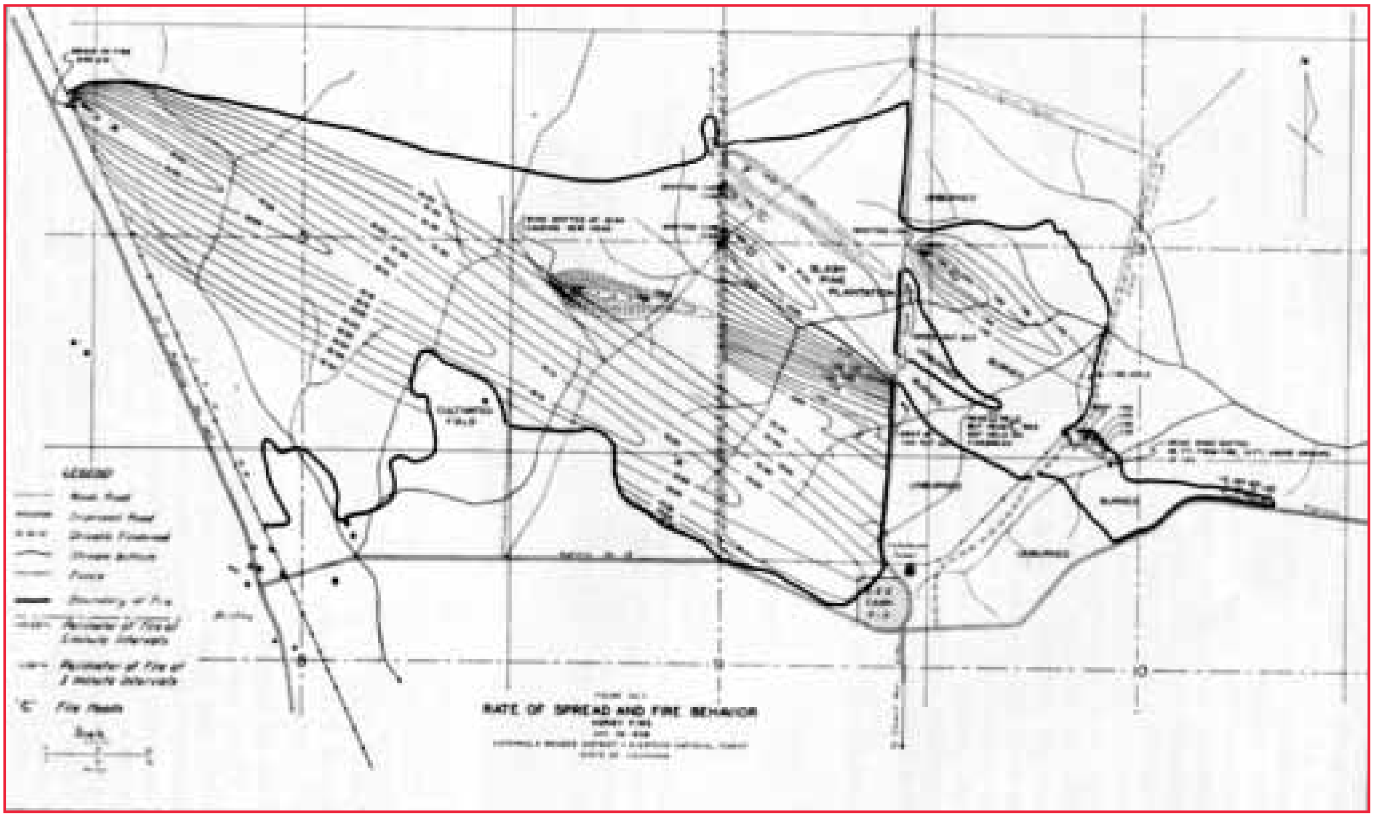

Figure 2—*Map showing points at which the Honey Fire was attacked.*

Road. There the fire boss assembled crews 3 and 4 and his own 5 men (a total of 37 men) on the west firebreak and attacked the north flank near the head and worked toward the tail. Progress by this large crew in extinguishing the fire along the north flank was encouraging; a boundary length of 33 chains (2,178 feet [634 m]) was put out and being held successfully.

Up to this time, the wind had blown steadily out of the northwest, with little or no evidence of shifting markedly in direction. At 10:44 a.m., the wind distinctly veered from northwest to southwest, resulting in a big sweep in the flank and the formation of a new head. The suppressed crew was forced to yield ground. The new head (*B*), which wiped out all the line that had been held up to that time, reached the west firebreak in 9 minutes (at 10:53 a.m.) and was held at that point when the head hit the backfire.

Later Attack and Tactics. Following the initial attack described, during which two different heads on fast-moving fires were stopped by indirect attack or backfiring but on which the fire on the north flanks was not controllable, the crews resorted to further backfiring along the west firebreak, Tower Road, State Highway 19, and the east firebreak, and to patrolling the east side of these roads to prevent the formation of new heads by spotting when an oncoming head reached a backfire.

Efforts to extinguish the north flanks were made only when it was reasonably certain that the head could be held at the backfire. In all the heads mapped, the backfire effectively stopped the progress of the head of the fire. Heads *G* and *H* resulted from spotting across Tower Road before adequate backfires were completed.

In extinguishing the fire along the north flanks, the crews, with one exception, attacked the fire from a point near the head and worked toward the tail. The only fire fighting on the north flank from the tail toward the head was done by the original crew (2A) of 7 men, who were left near the tail when crew 2 was split. As a consequence, a considerable distance along the north flank (for the most part, 1 mile [1.6 km] or more) between the tail and the west firebreak was left to burn freely, and with each shift in wind direction to the southwest new heads would develop. Examples of mapped heads that resulted from this situation are *C*, *D*, and *F*; several unmapped heads developed previously in the area west of the west firebreak, causing heads *C*, *D*, and *F* by spotting across this firebreak.

Fire along the south flank was of minor concern during the run of the fire, small roving patrols were stationed at strategic points along State Highway 19 to backfire wide strips and to watch for spotting across the road when heads reached the road. The large cultivated field located three-quarters of a mile (1.2 km) southeast of the origin did much to lessen the fire danger along the south flank. The shift in wind direction from northwest to southwest also reduced the fire danger along the south flank, since it resulted in a relatively slow-moving flank burning into the wind with only occasional minor sweeps when the wind changed back to the northwest.

Final Attack. In the final attack on the fire, during which it was brought under control, wider firebreaks were burned along Tower Road and the east firebreak. The suppression crews also attacked the north flank of the fires from the tail toward the head by reinforcing the small crew left originally at the tail to work east. The pumper truck did very effective work along the north flank where the ground was solid enough so that it would not bog down. Throughout the final attack, effective and rapid suppression on the north flank was accomplished by working from the tail toward the head and mopping up the edges of the fire simultaneously.

Output of Held Line. During the course of the fire, measurements were taken of the line extinguished by various crews. The amount of line held per man-hour varied greatly at different points on the fire, depending upon the behavior of the fire and the conditions under which it was being fought. In table 5 a record is given of the output of held line per man-hour for different sized crews with remarks concerning the conditions under which they worked.

Record of Stringing Backfire. Data on the rate at which backfires or burned firebreaks were strung by different methods were obtained at several points on the fire. These data do not include the manpower required to keep the backfire under control by patrolling and mopping up spot fires. The data given in table 6 are only for stringing fire in a straight line without regard to the width of the backfire burned.

Ratio of Line Actually Extinguished to Total Needed for Control. As pointed out above in the discussions of the initial attack and the output of held line, considerable line was lost because of the behavior of the fire at certain points. No accurate record of the total line extinguished but later lost is available. It has been conservatively estimated by Kisatchie National Forest personnel, however, that of the 864 chains (57,024 feet [17,831 m]) of line actually built to corral the fire, 240 chains (15,840 feet [4,828 m], or 27.9 percent) were lost during the suppression action and did not contribute toward the control of the fire. The difference, or 624 chains (41,184 feet [12,553 m]), therefore, would have been sufficient to attain control of the fire.

The ratio of line actually extinguished, but later lost, to the total needed for control is 240 chains (15,840 feet [4,828 m]) to 624 chains (41,184 feet [16,667 m]);

Table 5—*Rate of held line per man-hour at various points on Honey Fire.*

Location of suppression action	*Number men in crew*	*Held line per man-hour (chains [ft])*	*Remarks*
North flank—head *A*	19	4.7 (309)	No shift in wind.
North flank—head *A*	6	–11.6 (–765)	Line lost—shifting wind.
North flank—head *D*	14	5.8 (385)	Some crew members idle or resting.
North flank—head *G*	14	9.1 (601)	In heavy cover of oak leaves.
North flank—head *H*	18	9.15 (604)	In heavy oak brush—medium fuel.
North flank—heads *F*, *G*	Pumper truck	126.6 (8,356)	Average difficulties with trees and soft ground.
North flank—head *A*	10	5.03 (332)	Average conditions—men placed too much reliance on water.

thus, 38.5 percent more line was built than actually needed. The final perimeter of the fire when controlled was 934 chains (61,644 feet [18,789 m]). The discrepancy between the final perimeter and the length of line actually needed for control, or 310 chains (20,460 feet [6,236 m]), is accounted for by the fact that practically none of the south flank required suppression, because the fire went out of its own accord when it reached the cultivated field, the abandoned CCC camp, Highway 19, and the backfire along Tower Road.

Difficulties Encountered by Fire Fighters. The suppression crews were under tremendous handicaps and personal discomfort, caused by the heavy, choking smoke and the dense cloud of ashes, soot, and sparks, when patrolling an onrushing head as it hit a backfire. At such times, it was impossible for them to face toward the head; not only was the visibility extremely bad, but also the dense ashes and sparks, carried swiftly by the draft of the fire, compelled the fire fighters to turn their backs to the fire and cover their smarting eyes with their hands. The fire fighters experienced considerable difficulty in walking against and in using their equipment in the strong wind currents created near the head of the fire. Thus, the efficiency of the fire fighters stationed at these points to extinguish break-overs and spot fires was greatly reduced. Further, the roar of the fire and wind at these points made it impossible for the crews to hear verbal orders of their foremen.

The heat on the north flanks when the wind shifted was oppressive, and the danger of a crew getting trapped by the high, oncoming flames was great. The hose man on the pumper truck was particularly handicapped by the heat because he had to get very close to the fire to place the water effectively.

Because of the relatively flat terrain and the dense smoke, the fire boss was unable to get the clear and complete picture of the progress of the fire that he needed for the most effective use of his men in controlling the fire.

Critique

Recognition of Danger. In evaluating the suppression action taken on this fire, it must be realized that no satisfactory methods and technique were then available to the fire dispatcher to rate the fire danger existing at the time of the fire. His experience in judging fire danger during several preceding fire seasons, however, made it clear to him that the weather conditions then prevailing would cause a fast rate of spread and that speedy and adequate dispatch of suppression crews was essential. Consequently, he had prepared and organized all crews for speedy dispatch. Even after dispatching all available firefighters, he was quick to recognize the extreme conditions and to inform the supervisor's office that the fire was out of control by reporting, "I cannot hold it."

A fire-danger meter, recently developed by the Southern Forest Experiment Station (Bickford and Bruce 1939), should prove exceedingly useful to a fire dispatcher in recognizing fire danger, particularly under conditions similar to

Table 6—*Rate of stringing fire for backfires on Honey Fire.*

Backfire location	*Length burned per man-hour (chains [ft])*	*Medium used*	*Remarks*
West firebreak—near heads *C, D, F*	52.7 (3,480)	Gasoline torch	Inexperienced men.
Tower Road—head *D*	26.9 (1,776)	Bunches of grass	Backfire only 20 ft wide, not enough to keep head C from crossing Tower Road.
Tower Road—head *F*	51.8 (3,420)	Rakes	—
Highway 19—head *E*	26.2 (1,726)	Bunches of grass	In oak brush and leaves.
East firebreak—head *G*	20.9 (1,378)	Bunches of grass	In heavy blackjack oak.
Tower Road—head *D*	45.1 (2,978)	Rakes	—

those prevailing at the time of the Honey Fire. The present fire-danger meter, for these conditions, would have shown the danger as class 5, or extreme. With a prompt recognition of the fire danger and with adequate plans for the fire action to be taken in the event of a fire, it is expected that fires occurring during times of great danger can be checked early and controlled while still of small size.

Fire-Discovery Time. Fire-discovery time was excellent and the towermen are to be commended for their alertness. With good visibility and with a clear view of the origin of the fire available from Catahoula Tower, conditions were very favorable for quick discovery. Furthermore, when the train made an unusual stop, it was viewed with suspicion by the Catahoula lookout.

A cross shot was quickly obtained from Colfax Tower, located 4 miles (6.4 km) west of the origin. Because of the obtuse angle of this cross shot, which the fire dispatcher received within 3 minutes of the start of the fire, it was impossible to get a precise location. Moreover, he was under specific orders from the ranger and forest supervisor to dispatch the stand-by crew immediately upon obtaining a cross shot.

Under ordinary conditions the location of the fire, as indicated by the reported conditions, would be highly satisfactory for a prompt attack. In this particular case, however, a precise location was essential, since the subsequent fire action depended upon this point. Had the fire started on the highway west of the railroad track, the logical action would have been for the fire boss to lead the first crews to the tail of the fire; but since this fire started on the east side of the track the preferred action, had the real danger been fully recognized, would have been to place the initial crews along the west firebreak to string backfire and send subsequent crews to extinguish the fire along the north flank.

The fire fighters experienced considerable difficulty in walking against and in using their equipment in the strong wind currents created near the head of the fire.

It can be argued that, under the circumstances, the fire dispatcher should have momentarily delayed initial dispatch of crews until he had received verification from the Catahoula towerman on this seemingly trivial point. However, to have made such verification at that time would have been contrary to the forest supervisor's instructions; under other circumstances, even the slightest delay in dispatch would have been costly insofar as size of fire was concerned.

Preparedness. Adequate preparations and crew organization had been made for fighting fires on bad fire days. A total of 148 men, divided into 9 properly supervised, trained, and equipped crews, were ready to respond promptly to a fire call from the dispatcher. These crews were distributed at strategic points on the ranger district and had telephone connections with the fire dispatcher's office. All feasible measures of preparedness had been taken.

Dispatch of Crews. The dispatch to the fire of all the crews available on the ranger district was effected promptly and with a minimum of confusion. Their assignments to specific points on the fire were given clearly and definitely by the fire dispatcher. The chain of communications to the individual crews previous to their initial dispatch to the fire was, for the most part, very satisfactory. Some delay was experienced in reaching the crews that were working in the Stuart Nursery quickly, because the telephone in the nursery office was unmanned for several minutes; when word finally reached the nursery, the three crews were promptly dispatched to the fire.

Supervision. All the crews were supervised by men who had had considerable experience fighting grass fires in the cut-over longleaf pine type. Fires of the extreme intensity and rate of spread of the Honey Fire, however, are the exception rather than the rule. Consequently, it was natural to expect that some mistakes in judgment and action on the part of the supervisory personnel would be made. The writer points out what he considers as mistakes only to guide the actions of supervisory personnel in the future under similar circumstances.

Every member of the supervisory personnel, including the fire boss, used a flap, a back-pack pump, or some other fire-fighting tool. It is commendable that they were so earnest and eager to get the fire extinguished that they helped in the physical work, but it is much more important and necessary for those in charge of fire crews to expend their energies and use their superior training in analyzing ever-changing situations on a fire, in

The crew leaders should use their heads and eyes instead of their hands. Had this been done, they would have quickly realized the futility of the tactics chosen.

directing their men to work efficiently, in discovering and remedying weaknesses in their work, in anticipating and planning actions, and in urging the men toward their best efforts. The crew leaders should use their heads and eyes instead of their hands. Had this been done, they would have quickly realized the futility of suppressing the north flanks from the head toward the tail of the fire. Actually, the physical efforts of the supervisory personnel in suppressing the fire were of minor consequence, considering the fire as a whole.

The fire boss should make it his job to keep up with every change in the situation, know the location of all his crews, and continually plan the action to bring the fire under control at the earliest moment. His decisions should be direct, definite, and well-planned. On the Honey Fire, the fire boss, instead of placing himself at all times at a central point to gather information regarding the situation and to direct and dispatch crews, was off on the fire line with suppression crews for considerable periods of time. As a result, the desired movement of some crews to critical areas was delayed.

Anyone on the Catahoula Tower could have obtained an excellent grasp of much of the situation. When the fire passed close to the tower the smoke was heavy and visibility was bad; later, however, the view from the tower would have given the fire boss a comprehensive picture of the fire and helped him tremendously in planning crew locations and actions. In similar situations, the fire boss should always size up the fire either from a highpoint such as a ridge or tree top, or by cruising the area by car, sending scouts out for information, or by referring to aerial photographs. It is strongly recommended that on a large fire the fire boss have at his disposal two or three men to reconnoiter and to serve as messengers to carry his orders to the leaders of the individual suppression crews.

Morale of Fire Fighters. The morale and determination of all men were excellent, and in many cases remarkable. Virtually all of them used their flaps and backpack pumps effectively, showing that the training they had received was very much worth while. During the hot flank attacks, however, the flapmen relied heavily upon the pumpmen spraying water to knock down the flames. The men should be trained to rely less upon water in fighting the flanks by having the crew leaders temporarily stop suppression and rest the crews when the wind shifts on a flank, resulting in a very hot fire to fight. More line on the flanks will be extinguished and held by resting a crew while the fire is burning intensely and then efficiently directing them when the heat and flames have diminished.

Crew leaders should strive to keep their crews working in units of five or six men. A crew of this size is very flexible and mobile and, when trained for perfect coordination and teamwork, it can hold a long line. Large crews working as a unit are generally inefficient either because they stumble over one another or because the work is unbalanced, the first men bearing the brunt of the attack and the stragglers expending their energies chiefly by running to keep up with them and doing relatively little productive work. The morale of a crew weakens when the work load is not evenly divided among all its members.

Equipment. On the whole, the fire-fighting equipment was in excellent condition. In only one instance was failure of equipment noted, namely, the railroad fusees intended for stringing backfire, which would not ignite, undoubtedly because they had become damp from atmospheric moisture. The crew attempting to extend the backfire along the west firebreak one-half mile (0.8 km) north of Highway 19 was delayed while trying to make the fusees ignite. The result was that heads *C*, *D*, and later *F* crossed the graded firebreak, and eventually led to heads *G* and *H*. The need for having *all* equipment in perfect order was strongly exemplified by this one small but important failure.

The supply of tools for all fire fighters was automatic in that each crew had an adequate amount of standard fire-fighting equipment in the truck on which they traveled to the fire. No delays were noted on this account.

The urgent need for accessory equipment on fires of this type was brought out by the handicaps and difficulties encountered by the fire fighters. Emphatically, the crews assigned to backfiring and patrolling backfires should be supplied with smokeproof goggles so that they can work efficiently in the smoke and flying ashes. The value of such goggles was indicated by the fact that one fire fighter, normally working as a welder in the shop, wore his dark welding glasses while patrolling, and later commented that he experienced no great discomfort from ashes, soot, or sparks when the head reached the backfire. Respirators should also be investigated to determine whether or not the patrol crews could perform more effectively with such equipment. Since the hose man on a pumper truck is subject to intense heat and smoke over a prolonged period, he also should be provided with special equipment to enable him to do his job better. Asbestos hoods and suits have already been developed for such use and might upon trial prove ideal for this specific purpose.

More line on the flanks will be extinguished and held by resting a crew while the fire is burning intensely and then efficiently directing them when the heat and flames have diminished.

Technique of Attack. The logical point of initial attack on the Honey Fire, as already discussed, depended on a very accurate location of its origin. As soon as the fire boss saw that the fire was definitely on the east side of the railroad track with a large area of dense grass before it for its run, he should have directed his crew (No. 2) together with crew 3 to start backfiring immediately and liberally along the west side of the west firebreak. The pumper truck should also have been available at this point to support the fire fighters. Crews 4 and 5, comprising 47 men, should then have been dispatched to the tail to extinguish the north flank from the tail toward the head. Crew 6 of 22 men and, if needed crew 7 of 19 men, should then have been dispatched to patrol highway 19 and the south flank. The 2 remaining crews, comprising 31 men, if called at all by the fire dispatcher and fire boss, should have been held at the Cataholua Tower as stand-by crews. These positions are shown on the suggested locations and tactics map (fig. 3).

Initial backfiring should have been started promptly along the west firebreak instead of along Tower Road. The woods road, located one-half mile (0.8 km) to the west, could not have been used for the

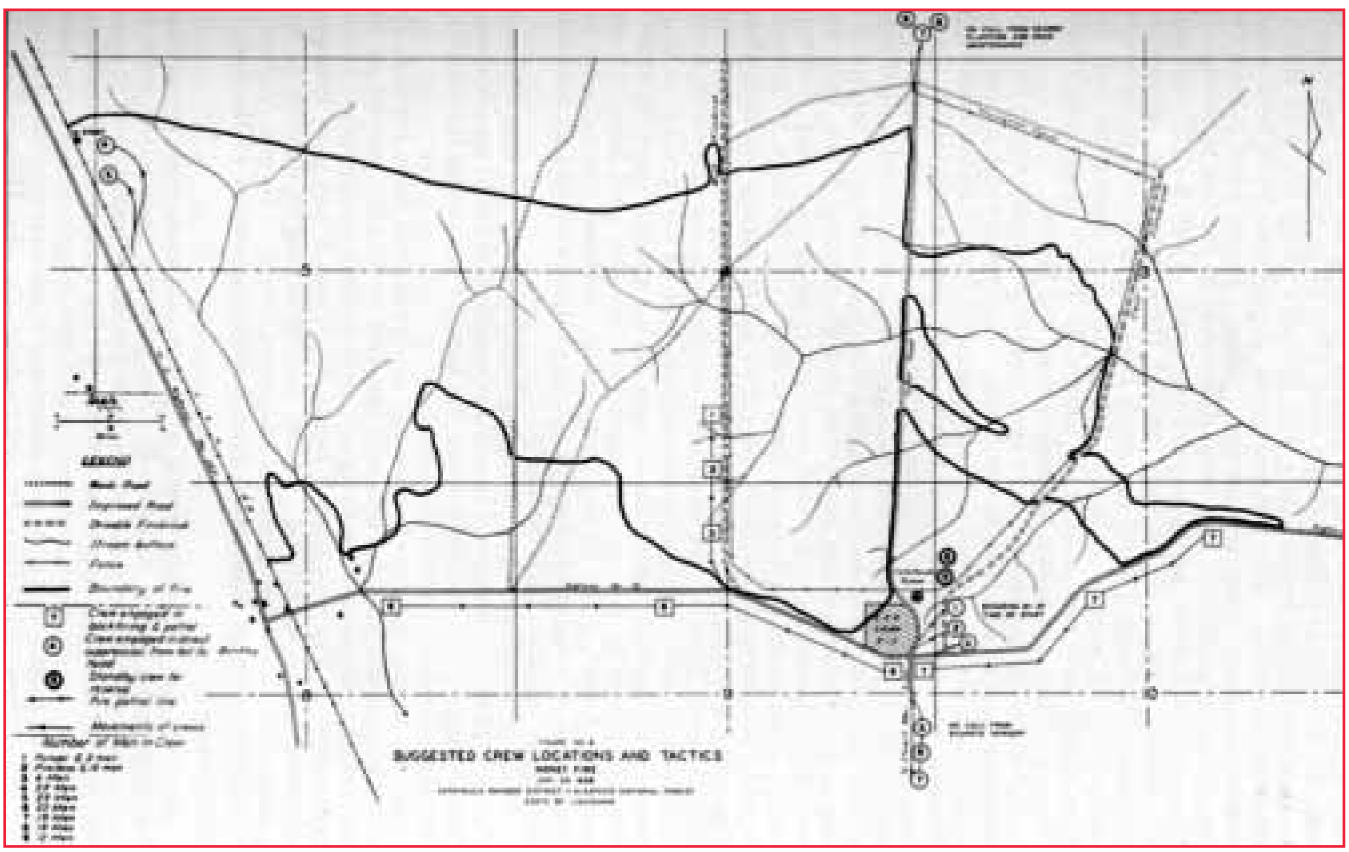

Figure 3—*Map showing suggested crew locations and tactics.*

> It is very important that backfires be sufficiently long to stop the onrushing head even if a shifting wind has changed its direction, and sufficiently wide to prevent spotting across the backfire.

initial backfiring because (1) insufficient time would have been available to string an adequate backfire along the woods road before the main head reached it, and (2) there could be legal complications and violation of policy had a backfire been strung on privately owned land not bordering Government-owned land, even though national-forest land was seriously threatened. Prompt backfiring along the west firebreak would have overcome both of these difficulties.

At least 20 minutes would have been available to the crews for stringing backfire along the west firebreak, since the main head did not reach this point until 10:20 a.m. This would have been ample time for the three crews available to have strung at least one-half mile (0.8 km) of backfire 100 or more feet (30+ m) wide. It was impossible to burn such a protection strip around the plantation earlier in the season because the land involved was privately owned. The 20-foot-wide (6-m-wide) graded firebreak surrounding the plantation was scraped clean of all vegetation and was an exce1lent line from which to backfire safely.

Had the initial attack of stringing backfire along the west firebreak failed so that the fire spread into the plantation, the next attack should have been to string backfield along the Tower Road, using the stand-by crews available at Catahou1a Tower.

At all places where an adequate firebreak had been burned, the onrushing head was checked and the few spots that started in the unburned grass across the firebreak were quickly extinguished by the patrol crew. The checking of heads *B*, *D*, and *F* are good examples of control with backfiring. When the backfiring is delayed or the patrol crew inadequate, as for example on heads *C*, *G*, and *H*, break-overs occur almost invariably, greatly delaying control of the fire.

Backfiring. Backfire can be safely strung at a fast rate even with the crudest, equipment, as shown in table 6. The greatest precautions must be taken, however, to keep the backfire always under control and to avoid the misfortune of letting it get away. At the same time, a backfire, to be effective, must be of sufficient width and length to hold the main head being fought as well as any additional heads that may subsequently develop before the flanks are controlled.

On the Honey Fire, the backfiring crews strung fire too timidly, particularly insofar as the length of the backfire was concerned. It was most fortunate that the backfires were so successful, since they were seldom more than 50 feet (15 m) wide. Furthermore, had the crews not been so reluctant to string long backfires, control of the fire could undoubtedly have been gained much earlier. This reluctance can in part be accounted for by the fact that backfiring along the Tower Road and the east firebreak would necessarily mean deliberately burning part of the plantation. The acreage consumed in backfire, however, is negligible; each mile of backfire 100 feet (30 m) wide requires only 12 acres (5 ha). This would have been a trivial loss for the great protection it offered.

The following technique for stringing backfire has been effectively and safely used and is recommended for use whenever backfiring must be resorted to in order to obtain control: Organize the crew into fire stringers and patrolmen. The latter should take their positions across the line from which the backfire is being burned. Their only job is to keep alert for possible spotting along the entire backfire line and to extinguish spots quickly, as they occur. The stringers, three or four selected men in each crew, should be given special training in the methods of stringing fire, using bunches of grass, a fire rake, a torch, or other available equipment. The first man should string his line of fire parallel to and approximately 10 feet (3 m) from the line from which the backfire is being made. The width will, of course, depend upon numerous factors, among which are the type and density of the fuel, the wind velocity, and the width and condition of the line (road, etc.) from which it is being made.

The greatest precautions should be taken to put the initial backfire line in safely. Waiting until the first man has safely burned approximately 100 feet (30 m) of his line of fire, the second man should start his line of fire parallel to but 20 feet (6 m) from the first line. The third stringer, in turn, should wait until 100 feet (30 m) of the second line has been, safely burned and then string his line parallel to but 30 or 40 feet (9–12 m) from the second line. If four stringers are used with intervals between lines of 10, 20, 30, and 50 feet (3, 6, 9, and 15 m), a backfire 110 feet (34 m) wide can be burned with great rapidity. There should be an interval of at least 100 feet (30 m) between stringers at all times.

The crew foreman must be very alert when backfires are being burned so that they do not get out of control. If two crews are available, the backfire should be started at a point where the main head is expected to hit and the crews string backfire in opposite directions along the line from which it is being burned. The crews should continue to string fire for at least seven hundred or even 1,000 feet (210–300 m) beyond the points where the danger is critical; a crew will not be criticized for stringing too much backfire if it has done so safely.

Stand-by Crews and Reinforcements. As previously brought out, all of the firefighters available on the ranger district were dispatched to this fire before it was finally brought under control. Two other fires occurred on the Catahoula Ranger District during the Honey Fire; they were extinguished by crews dispatched from the Honey Fire without undue loss of time or acreage, indicating that the fire organization was prepared to cope with serious fire conditions.

The local force was strengthened by the fine cooperation and judgment of the ranger on the adjoining district, who, upon passing the scene of the fire while enroute to his office after attending a court trial in Alexandria, on his own initiative phoned ahead to his dispatcher to call in all work crews for the emergency and to send two of them to stand by at a CCC side camp located about 10 miles (16 km) north of Bentley. The ranger is to be commended because he took definite action when he saw the need.

Summary

A detailed analysis of the Honey Fire is presented in order (1) to show the rapid rate of spread and the behavior of a fire burning under critical weather conditions in the southern pine type of a coastal plain, (2) to describe the suppression action taken, and (3) to offer constructive criticism and suggestions as a guide in planning suppression action for future fires burning under similar conditions.

The combination of high, shifting winds and low fuel-moisture content prevailing at the time of the fire created critical burning conditions. The rate of spread was extremely high, the maximum forward increase measured being 8 chains (528 feet [160 m]) in 1 minute or at a rate of a mile in 10 minutes (97 km/h).

In order to control such a fire it is necessary to have an adequately equipped suppression force available at a moment's notice. The difficulties experienced by fire fighters at various parts of the Honey Fire are stated and suggestions are made for the use of accessory equipment in overcoming such handicaps. There is a distinct need also for efficient supervision of each crew, as well as able leadership, including well-planned tactics, by the fire boss.

The futility of attempting to control the flanks by suppressing a rapidly spreading fire from a point near the head toward the tail of the fire is brought out. Such tactics lead to a great loss in what would otherwise be held line and make it possible for new uncontrollable heads to form with each relatively slight change in wind direction.

The heads of rapidly spreading fires cannot be stopped by direct attack with the equipment now available; one must resort to an indirect attack involving the use of backfiring. Fighting fire with fire can be very dangerous, however, and the greatest care must be exercised in its use if an adequate backfire is to be attained and if break-overs are to be prevented. A method of backfiring, in which fire is simultaneously strung by three or four men separated by definite distance and width intervals, is outlined. It is very important that backfires be sufficiently long to stop the onrushing head even in case its direction of burning has been changed by a shift in the wind, and sufficiently wide to prevent spotting across the backfire, which may start new heads.

Acknowledgment

Grateful acknowledgment is given to A.H. Antonie, R. Brooks, and C.A. Bickford for invaluable assistance not only in mapping and recording data but also in constructive criticism and review of the manuscript.

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The Bower Cave Fire*

Leon R. Thomas

The Bower Cave Fire of August 13, 1947, on the Tuolumne District of the Stanislaus National Forest is being reviewed to show how a fast-moving fire, which was burning in steep terrain and in heavy cover, was readily and quickly controlled, after the first attack had failed, by effective use of modern equipment, and by the local people and trained Forest Service personnel working effectively as a team.

> Extended attack went according to schedule, and the night work was so efficient that by midnight most of the lines had been built and burned out.

Dangerous Fire Month

August is a most dangerous fire month in this area. The weather is normally hot, fuel moisture is low, and rapid spread of fires can always be expected. At the time of this fire normal weather conditions prevailed throughout the district and no important changes were forecast. It is estimated that there was an upslope wind of 8 miles per hour (13 km/h) blowing at the fire when the first crews arrived. It increased in velocity during the day but never blew hard. There is a normal downdraft at night with increase in humidity.

Bower Cave, a former resort, is located near the old Coulterville–Yosemite road where the road crosses the North Fork of the Merced River (fig. 1). The ridge between Bower Cave and McCauley ranch and Scott Ridge to the north of the river have moderate to steep slopes and are covered with scattered ponderosa pine and black oak with a heavy ground cover of manzanita and scrub oak. Elevation ranged from 2,350 feet (720 m) at Bower Cave to 3,400 feet (1,040 m) at the higher reaches of the fire perimeter. The sets were on a grassy, pine–oak flat with the steeper slopes and heavier cover just to the north.

For many years there has been an incendiary problem on this part of the ranger district. Sets are always in high hazard types; and several severe fires have been the result. This fire appeared to be another of that type.

First Report

The first report was received in the district ranger's office at 9:25 a.m. August 13, 1947. The ranger, fire control assistant, and the district clerk-dispatcher were in the office when the report was phoned in by the caretaker at Bower Cave. He reported that there were several small fires burning on the upper side of the McCauley road between Bower Cave and the miners' cabins one-half mile (0.8 km) up the road (fig. 1). The area is blind to all lookouts and not until 9:40 a.m. did the lookout on Pilot Peak report smoke coming up over the ridge that blanked out the area for him.

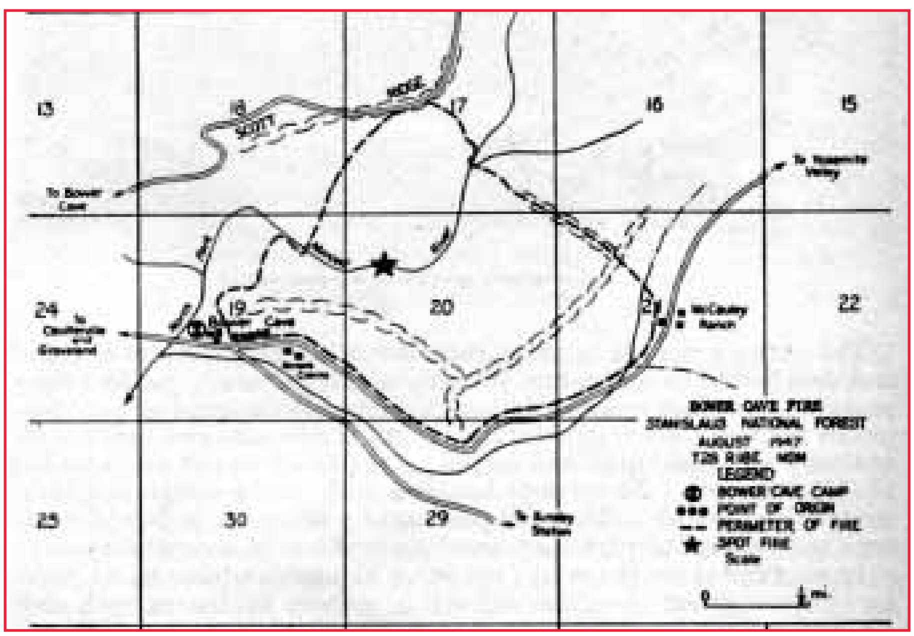

Figure 1—*Map of Bower Cave Fire, Stanislaus National Forest, CA.*

When this article was originally published, Leon Thomas was a fire control officer for the USDA Forest Service, Sequoia National Forest, CA.

* The article is reprinted from *Fire Control Notes* 10(2) [Spring 1949]: 26–31.

The Kinsley Station crew, being the nearest organized fire suppression crew, consisting that day of two men and a light pickup tanker, was immediately dispatched. They arrived at the fire at 9:48 a.m. The fire control assistant and one fireman arrived at 9:56 a.m.

The ranger station crew of two men and a tanker was dispatched as was the third organized fire crew on the district, the McDiarmid Station crew of four men and a tanker.

The district ranger helped the clerk notify the central dispatcher and a few local people and was at the fire by 10:05 a.m. with a radio-equipped pickup.

The Kinsley crew found five separate fires burning on the upper side of the road within a distance of about 100 yards (90 m). Two Pacific Gas & Electric Co. power line construction employees, who had seen the smoke while working on a nearby line, were already putting a line around the fire nearest Bower Cave. These two men corralled this fire, the smallest of the five, at about one-tenth of an acre (0.04 ha) in size. The Kinsley foreman left his one man on the second fire and attempted to handle the other three alone with the aid of a light tanker. These three fires were the largest of the five and were rapidly burning together. They were burning in the grass and pine needles and were working toward the steep slope above.

Little effective control work had been accomplished on the upper four fires when the fire control assistant arrived at 9:56 a.m. He and the one man with him joined the Kinsley foreman in attempting to cut off the head of the main fire at the toe of the steep slope. The Bower Cave caretaker had also arrived and was assisting the foreman.

> The early and efficient dispatching of personnel and equipment by the district and the central dispatcher was an important factor.

Initial Attack Failure

The fire was burning very hot and was spotting badly up the steep slope when the ranger arrived at 10:05 a.m. He fell in with the other men in attempting to cut off the head and control the spots. The fires which had now burned into one were just too hot to handle and the light tanker was ineffective.

By 10:15 a.m. it was fully realized that the initial attack had failed. The heavier tankers from the ranger station and the McDiarmid Station did not arrive until too late to be of value on initial attack.

The ranger and the fire control assistant made plans for and immediately started a flanking action to keep the fire narrow and possibly pinch it out on the ridge above, should sufficient help arrive soon enough. There was a very good possibility of control on top of the ridge above Bower Cave since once the fire reached the top it would have to burn along the ridge or downhill for a considerable distance. The cover was also lighter along the ridge and on the north slope.

The dispatcher was notified of the situation by radio and a request was sent in to the supervisor's office to have the fire and the area scouted from the air. Orders were sent in to get all the help possible from the local sawmills, woods crews, Pacific Gas & Electric Co. construction crew, and the local ranchers. Two 15-main district road construction crews and a 50-man district blister rust crew were also ordered. A fire camp was to be set up at Bower Cave. It was calculated that this number of men could corral and hold the fire on the ridge that afternoon with an estimated area of about 200 acres (80 ha). After 10 a.m. the men began to arrive rapidly, as indicated by the number on the fire in table 1.

The forest fire control officer flew the fire at 11:15 a.m. in a conventional aircraft and reported to the ground by radio that the flanking action was making good progress and that it had a very good chance for success by the early afternoon.

Spot Fire

At 12 noon the ranger and a local rancher scouted the ridge in front of the fire and kept in communication with an SX radio. At 12:16 p.m. the lookout on Pilot Peak reported a smoke in the bottom of the Merced River about one-half mile (0.8 km) to the northeast of the original fire (fig. 1). In a few minutes the ranger could see the smoke from his position on the ridge. It appeared to be burning on both sides of the canyon and spreading toward Scott Ridge and the McCauley ranch as well as back toward the original fire.

The forest fire control officer again scouted the fire from the air at 2 p.m. The ranger in the meantime had gone around and scouted the new fire from the Scott Ridge side.

Table 1—*Personnel on the Bower Cave Fire, by time of arrival.*

Time of arrival	Personnel on the fire		
	Local labor	Forest Service	Cumulative total
9:30 a.m.	2	0	2
9:48 a.m.	1	2	5
9:56 a.m.	0	2	7
10:05 a.m.	0	2	9
11:00 a.m.	81	40	130
12:00 noon	21	0	151

Note: The fire was first reported at 9:25 a.m.

Through radio discussion with the fire control officer in the plane and with the ground scouting information, it was determined that the fires would burn together before they could be controlled. It was then decided that both fires should be handled as one.

The cause of the spot fire was not determined. It may have been another set. No attempt was made to send men to it as it was spreading rapidly when first discovered and an initial action crew would have been ineffective.

It was realized now that control lines would embrace an area of a thousand acres (400 ha) or more and that a good deal of the line on Scott Ridge and the McCauley area was a bulldozer show. Additional tractors were ordered. Two D–7 caterpillars were walked to the McCauley ranch from a nearby Forest Service road construction job. One D–7 caterpillar was trucked in from another Forest Service road job on the district and a TD–14, the Forest Service fire standby tractor, was trucked in from the supervisor's headquarters. Two bulldozers were already on the fire, a D–6 from a nearby gold dredge and an AC tractor from a nearby sawmill. These last two arrived early but were of little use on the original fire.

Extended Attack

All effort was now turned toward handling the two fires as one along the following plan: The hand line that had been constructed along the west side of the fire above Bower Cave was to be dropped in to the river to the north and held. The front of the fire on Scott Ridge was to be headed and a line dropped to the river along each flank. The line on the west side was to tie to the hand line at the river. Each of the lines from Scott Ridge was a bulldozer show until they reached the steep river slope. A line was to be built from McCauley's over the ridge to the north and then to the river and tie to the east line from Scott Ridge. The road from the McCauley ranch to Bower Cave was to be backfired. Four of the bulldozers were walked to Scott Ridge where two were to work on each of the lines from Scott Ridge to the river. Two tractors were to operate from McCauley's.

The camp was now in full swing and all incoming men were organized into crews with sufficient Forest Service overhead for good management.

The fire control officer and the forest supervisor came into the camp at about 4 p.m. With the aid of scouting information and aerial photos the final control routes were determined. The fire was divided into four divisions and the division overhead personnel were briefed on the construction and the backfiring plan. By 6 p.m. all crews, tractors, and other equipment were on the line and prepared for a night operation.

The plan went according to schedule and the night work was so efficient that by midnight most of the lines had been built and burned out. Many of the dangerous snags were felled by power-saw crews before the backfires were started. This was an important factor in reducing the possibility of spot fires as well as cutting down mop-up and patrol work later. The fire was declared to be under control by 9 a.m.

Mop-Up

A look at the available Forest Service manpower in the early evening indicated that there was not enough for the mop-up job the next day. Needs were calculated and an order was placed for one division team from another forest and 150 off-forest laborers. The division team was flown in from the Sequoia Forest and the 150 laborers were picked up in Stockton in the San Joaquin Valley. All were at camp in time for the next day's shift. The Sequoia team did an excellent job on a division unit and returned to their home forest after one shift.

Mop-up proceeded rapidly during the early morning and the next day with tractors widening lines, with tankers working along the bulldozer lines and the roads, and with power saws felling the remaining snags. Especially important on mop-up was a 4-by-4 blister rust spray rig. This four-wheel-drive unit with its long light hoses reached many places that were inaccessible to the conventional tankers.

Two Pacific marine portable pumpers and hose were taken into the river on the east side of the fire by pack horses and were used very effectively on mop-up on the river slopes. The fire boss was equipped with a jeep and a portable radio during the mop-up period. He was able to cover all of the fire lines in the jeep except the steep river slopes. The fire was declared to be officially out on August 23.

Factors for Success

There were many factors working together that contributed to the control of the fire prior to the burning period of the second day. The most outstanding ones are listed in the following paragraphs.

The early and efficient dispatching of personnel and equipment by the district and the central dispatcher was an important factor. Men and materials were ready to go. Sufficient experienced Forest Service and local men were readily available. Exceptionally good cooperation was received from the local people—labor from the sawmills, woods crews with power-felling equipment, electric power line construction employees, and experienced local ranchers. There were 210 men on the line during the night shift and 272 on the line during the next day. Men were released rapidly after the end of the second day's shift.

The use of aerial scouting and aerial photos for plotting the fire and the control line aided greatly in early control.

The effectiveness of the work during the first night was an outstanding factor in the early control of the fire. Control could not have been effected by 9 a.m. the following morning, however, even with the manpower available had it not been for the efficient work of the tractor operators in the heavy manzanita cover. Lights on the six tractors enabled them to work all night. Wide effective lines were the result. Total perimeter of the fire was 598 chains (39,468 feet [12,030 m]) handled as shown in table 2.

Excellent radio communication during the entire fire made administration fairly easy. The radio net centered around the Pilot Peak lookout who used a T set for receiving and relaying messages. Division bosses were equipped with portable SX sets. A mobile unit and then an SX set were used by the fire boss. A mobile set was used in the fire camp.

A telephone connection was made to a nearby line and run to the fire camp. This took a load off the radio net.

The use of aerial scouting and aerial photos for plotting the fire and the control line aided greatly in early control. This combined with limited ground scouting proved very effective.

The camp was well located near the fire and was rapidly put in full operation by experienced personnel. Lunches, lights, water, and other equipment were always ready to go before departure time scheduled for crews. Adequate transportation was available and ably coordinated under the camp boss.

This fire, burning in steep heavily covered terrain, was readily controlled before the second burning period at 1,223 acres (495 ha) because of the effective use of modern fire fighting equipment, the excellent cooperation of local people, and the efficient work of Forest Service personnel. ■

Table 2—*Fireline on the Bower Cave Fire, by type.*

Type of line	*Line constructed*		*Line backfired*	
	Chains	*Meters*	*Chains*	*Meters*
Hand	160	3,200	50	1,000
Tractor	200	4,000	200	4,000
Road	238	4,760	238	4,760

The Possible Relation of Air Turbulence to Erratic Fire Behavior in the Southeast*

George M. Byram and Ralph M. Nelson

Editor's note: Early issues of Fire Control Notes *often prefaced articles with substantive remarks by the journal's editors. A.A. Brown, an early leader in Forest Service fire research and management, prefaced the article by Byram and Nelson with the remarks in the sidebar.*

Fire control men have long suspected that there are unidentified factors that contribute to the strange behavior and spread of some fires. H.T. Gisborne, G.L. Hayes, and A.A. Brown, among others, have believed that atmospheric instability might in part explain some of the western blow-up fires. Brown (1950) and Crosby (1949) speaking more generally have stated that when sufficient heat is generated by a fire in an unstable atmosphere, erratic fire behavior can be expected. In a report from Australia (Foley 1947), turbulence is stated to be an important factor in the degree of severity of bush fires and that it is of value in compiling forecasts of fire weather. There is now reason to believe that turbulence may also be associated with certain severe fires in the South. Some evidence on this point was obtained from fires that burned in an unusual manner in the Coastal Plain of South Carolina during a few days of the 1950 spring fire season.

If the degree of local stability in the atmosphere proves to be a key factor in unexpected and dangerous fire behavior, skill in control of large fires can be greatly advanced.

Southeastern States experienced an unusually severe season during that period. A prolonged drought, interrupted only by occasional rains, began in November and persisted in some areas until May. This brought about abnormally low fuel moistures which, combined with high winds, resulted in a large number of fires and a large acreage burned. Apparently there were two rather definite types of severe fires. The first, driven by high winds, was characterized by high rates of spread, especially while crowning. From the standpoint of the safety of suppression crews and their equipment, this type of fire has not

Prefatory Remarks by A.A. Brown

"Blowups" and other forms of unaccountable fire behavior, that characterize many of our more disastrous fires every year, were a special topic that was given much emphasis at the fire meeting held in Ogden, UT, in January 1950. New research on this problem was urged and all research men were urged too to make available every bit of new information that might be useful to the fire strategist even though this might mean some reporting ahead of final evaluation.

I am very happy to present this report by George M. Byram and Ralph M. Nelson, two members of the research group, as new information that I personally believe is highly significant though further confirmation, evaluation, and means of prediction are needed and will require much further investigation. If the degree of local stability in the atmosphere proves to be a key factor in the unexpected and often dangerous behavior of many of our large fires, and it can be identified in advance, one more of the unknowns will be eliminated and skill in control of large fires can be greatly advanced.

This preliminary report should be a challenge to all experienced fire fighters and research men alike. Have we been ignoring one of the controlling factors in big fire behavior?

When this article was originally published, George Byram and Ralph Nelson worked for the USDA Forest Service, Division of Fire Research, Southeastern Forest Experiment Station, Asheville, NC.

* The article is reprinted from *Fire Control Notes* 12(3) [Summer 1951]: 1–8.

been considered dangerous for experienced firefighters in the Southeast. The second type differed from the first in that its peculiar whirling nature and unpredictable behavior made even a flank attack dangerous. It is with the second type that this report is concerned.

The Buckle Island and Farewell Fires*

Following is a description of two whirling fires that occurred on the Francis Marion National Forest in South Carolina. So far as can be ascertained, they had characteristics of behavior common to fires that burned elsewhere in the Coastal Plain of that State during the five or six most severe days of the spring season.

The Buckle Island No. 144 fire burned on March 26 in a densely stocked stand of loblolly pine 10 to 35 feet (3–11 m) in height. The day was sunny with little wind during the morning hours. The relative humidity was medium (about 35 percent) and the records of the Weather Bureau airport station, located approximately 40 miles (64 km) from the burned area, indicated a layer of highly unstable air about 400 or 500 feet (120–150 m) deep at 10 a.m. The layer probably had become even more unstable and somewhat deeper at the time the fire started in the early afternoon. However, the increased turbulence may have been partly offset by an increase in wind velocity which took place at about noon.

Apparently no large whirl developed until the fire reached a size of 40 or more acres (16+ ha). One then enclosed the head and created trouble for the plow crews. Because the early spread of the fire was nearly at right angles to the road, no short cut to the head was possible. Therefore, a flanking attack on both sides was made. As the plow crews progressed, the fire on the left flank had a tendency to cross in front of the crew, and on the right flank, behind the crew. One large counterclockwise whirl or two such whirls, one on each flank, could account for this strange behavior. It was later found that there was at least one small whirl on the right flank, although from the plane observer Mitchum saw only one large whirl.

> In one instance, the plow crew observed flames directly overhead while the main fire was still some distance away.

The Buckle Island fire differed somewhat from other whirling fires in that it apparently maintained a fairly constant direction of spread. The wind velocity was also greater and steadier than on other fires. Even so, the spread was erratic. At times the fire would quiet down and then suddenly burn with fierce intensity. These bursts may have been caused by the almost simultaneous ignition of several acres by the whirl. In one instance, the plow crew observed flames directly overhead while the main fire was still some distance away.

The most severe fire on the Francis Marion National Forest during the spring season from the standpoint of erratic behavior and its whirling nature was Farewell No. 172. It burned on April 11, with a light but variable southwest wind in a stand of loblolly reproduction 10 to 35 feet (3–11 m) in height which contained a scattering of mature trees. Weather Bureau records indicated a high degree of atmospheric instability also on that day.

There were three large whirls in this fire and at least two small ones. The paths of the larger whirls were approximately parallel and were separated by less severely burned strips 75 to 100 feet (23–30 m) in width. Needles on tree crowns in the strips were not consumed, and in a number of places the tops of crowns of trees 25 feet (8 m) high remained alive. However, in the paths of the whirls the crown foliage was generally completely consumed, on some trees to a height of 80 feet (24 m). Needles are not completely consumed unless they are well within the flames, so it is estimated that the flames may have ranged from 50 to 150 feet (15–45 m) in height.

After becoming established, the whirls moved rapidly ahead of the main fire with sufficient updraft to carry burning embers aloft. These embers are reported to have started fires a considerable distance ahead of the main fire. Airplane observer Mitchum believes that two of the three whirls burned at the same time. He also observed that flames came out of the center of the tops of the cone-shaped whirls. The flames did not spring directly upward but had the same rotary motion, spiralling upward, as the smoke in the outer parts of the whirls.

Some Characteristics of Erratic Fires

Evidence from the Buckle Island and Farewell fires, and from others

* Acknowledgment is made to John T. Koen, formerly ranger on the Francis Marion National Forest, to John T. Hills, Jr., and Aiken Mitchum of the National Forest staff for eyewitness accounts of the fires reported upon.

Fires with erratic behavior are most likely to occur on sunny days when there is strong surface heating.

that burned in South Carolina during the spring season of 1950, indicates that erratic fires in the Southeast may have some common characteristics. Also, there appear to be certain conditions of weather, fuel, and type—not fully identified—which are conducive to such fires. Although some of the following conclusions regarding fire behavior and possible causes are speculative, they appear reasonable in view of what is known of certain physical laws. Confirmation or disproval will require further observation and analysis.

- Fires with erratic behavior are most likely to occur on sunny days when there is strong surface heating. There may be little or no wind during the early part of the day, and even while the fire is burning, usually in the afternoon, the general wind is light or moderate. The most favorable wind for this type may be somewhere between 8 and 16 miles per hour (13–26 km/h) as measured 20 feet (6 m) above tree tops.
- Erratic fires have a tendency to develop one or more violent whirls after reaching a certain critical size. The size is probably not the same for all fires and may be somewhere between 20 and 75 acres (8–30 ha). This, however, is merely conjecture.
- From the air, the diameter of larger whirls appeared to remain approximately constant and to cover an area of about 10 acres (4 ha). An increase in size after they had formed was not observed. Possibly they appear suddenly and may be nearly full-size when born. After becoming established, the whirls apparently can move rapidly away from the main fire and take the direction of the light wind prevailing at the time. They can consume strips of reproduction 500 to 800 feet (150–240 m) wide. The velocity with which these whirls travel is one of their most dangerous characteristics because their speed may be equal to, or nearly equal to, the velocity of prevailing winds.
- Field men state that most of the worst fires occur on days with a southwest wind. This indicates a characteristic pressure system which may also account for some of the turbulence. Observers in airplanes have noticed that the air was always bumpy on days when whirling fires occurred. Also, when the flying became smooth in the late afternoon whirls did not occur.
- It cannot be assumed that whirls will always rotate counterclockwise like large-scale vortex storms such as hurricanes in the northern hemisphere. The counterclockwise rotation of the hurricane is caused by the rotation of the earth. This should have but little effect on small-scale whirls like dust devils or whirling fires. For this reason the chances are probably about equal that the whirls will be in either direction.
- The depth of the turbulent layer may be a dominating factor in determining the maximum size of the whirls, although other variables such as quantity of fuel should also have some effect.
- In flat country it is doubtful that large whirls could develop if the air were absolutely calm, regardless of turbulence. Some wind movement would be necessary to move them over fresh fuel. A high wind, on the other hand, would reduce turbulence and might also tend to break up the whirls. This does not mean that fires burning in a high wind will be less intense than fires burning in a light wind. A large majority of severe fires probably burn on days of high wind velocity, and rate of spread will increase with increasing wind velocity.
- The effects of turbulence in areas of rough or rolling topography would be considerably more complex than in flat country. Turbulence near the ground surface would probably never be as great as in flat country but this would possibly be more than offset by complex topographic effects. For example, large whirls could travel up slope rapidly even in an absolute calm.
- An important factor in the occurrence of the whirling type of fire may be the fairly recent change in stand type in much of the Southeast. During the past 15 years extensive stands of dense pine reproduction have become established on areas formerly kept clear of pine by repeated fires. This may be one reason why there have not been more of these fires in former years. On the other hand, they may have occurred more often than is supposed. It is difficult for ground crews to recognize large whirls because of smoke and a limited field of view. They can be seen best from the air.
- Perhaps too much emphasis should not be placed on just the whirling characteristics of fires burning in turbulent air.

Turbulence could have a pronounced effect on the draft of a fire long before it reaches the whirling stage. It was noticed that on days when there was high turbulence, even small fires burned with strong drafts. The opposite of this has long been familiar to fire fighters. Fires usually undergo a pronounced change in behavior in late afternoon and evening when the atmosphere becomes more stable. This change has often been attributed to the increase in relative humidity which accompanies the drop in temperature of the lower air layers. It is possible that an increase in air stability may have as great, or greater influence on behavior than a combination of increased fuel moisture and decreased fuel temperature.

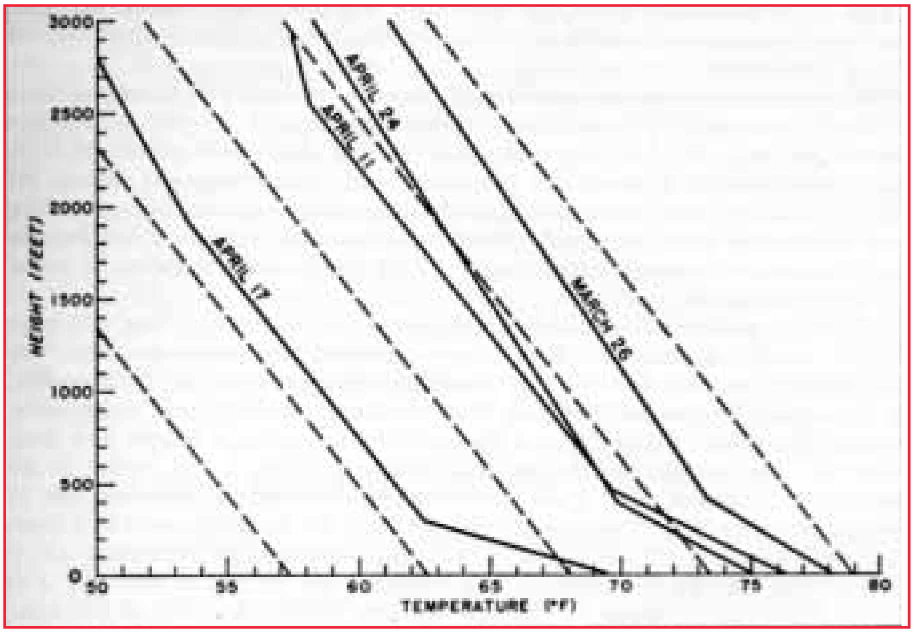

Figure 1—*Ten a.m. lapse rates for March 26, April 11, 17, and 24, 1950. The straight dashed lines represent the dry adiabatic lapse rates, i.e., a decrease of 0.53 °F per hundred feet (0.96 °C/100 m) in height.*

The Influence of Atmospheric Instability on Fires

Unusual fire behavior, not previously experienced, was reported for the Francis Marion National Forest on March 26, April 11, 17, and 24, by suppression crews. This behavior, characterized by one or more whirlwinds and by sudden fierce upward bursts of flames, could not be accounted for by any exceptional conditions of fuel or wind. This led the writers to suspect that some unusual atmospheric conditions existed at the time of the fires. Accordingly, 10 a.m. lapse-rate records for the 4 days mentioned were obtained from the Weather Bureau station at the Charleston airport. These are graphed in figure 1.

The straight dashed lines in the graph represent the dry adiabatic lapse rates, that is, a decrease in air temperature of 0.53 °F per hundred feet (0.96 °C/100 m) in height. At this rate of decrease the atmosphere is neutrally stable. The greater the drop in temperature with height, the greater the air instability. Conversely, the less the drop in temperature with height, the less the instability. For example, on calm, clear nights, the air temperature often does not decrease with height but even increases. The atmosphere is then highly stable and the upward movement of smoke and heated gas may stop completely after reaching a certain height. From the graph it will be seen that the unbroken lines, representing lapse rates for the 4 days, inclined sharply to the left of the dashed lines for a distance equivalent to a height of 300 to 500 feet (90–150 m). This means that layers of highly unstable air existed at these depths. These conditions of air turbulence, coinciding with certain fuel and stand conditions, and size of fire or rate of energy output, are believed to explain the strange fire behavior on the days mentioned.

There is usually some turbulence on clear sunny days, but the average value of the turbulence factor* is not known for the Coastal Plain in early spring. Its value may be somewhere between 20 and 50. In contrast, the turbulence factors for March 26, April 11, 17, and 24, were respectively 110, 160, 390, and 135. It is possible that there were other days during the spring season that had equally high turbulence factors, but whirls or erratic fire behavior were not observed. If highly turbulent days did occur, it may be that fires were controlled while small or before they reached the breaking point, or that they did not burn under the fuel and stand conditions most favorable to turbulence. Further analysis should clarify this point.

* A turbulence factor T will be defined by the equation

$$T = 100 \left\{ \frac{L_e}{L_a} - 1 \right\}$$

where Le is the existing lapse rate and L_a is the dry adiabatic lapse rate. When $L_e = L_a$, the air is neutrally stable and $T = 0$. Whenever T is greater than 0 there is always some turbulence.

An important factor in the occurrence of the whirling type of fire may be the fairly recent change in stand type in much of the Southeast.

As has been pointed out previously, very severe fires can occur on days when the atmosphere is relatively stable. On March 27 the turbulence factor was only 16, but this was a severe fire day. As a result of high wind velocity—30 to 40 miles per hour (48–64 km/h) with gusts reaching almost 60 miles per hour (97 km/h) at the Charleston airport—there were intense, fast-spreading fires which did great damage. There was nothing erratic or baffling in their behavior, however, that could not be explained in terms of wind and fuel conditions.

When a fire burns in a stable atmosphere, the hot gases must not only expend energy as they lift their masses through the stable air, but they also expend part of their energy in dragging a part of the surrounding air upwards. The stable air acts like a ceiling so that on a calm clear evening the smoke rising above a fire will reach a certain height and then level off. The conditions are entirely different when a fire burns in an unstable atmosphere. The gases do not expend energy as they rise but in their ascent they may even acquire energy from the atmosphere. Their path upward creates a chimney into which the surrounding unstable air is drawn. The potential energy of the unstable air is then converted into kinetic energy as it enters the chimney created by the fire. When the total rate of energy release (rate of energy output of fire plus rate of energy change in the unstable atmosphere) is great enough, then whirls should develop.

Atmospheric Instability and Dust Devils

There appears to be similarity in some of the conditions which favor the development of whirls on some erratic fires and dust devils. These are strong surface heating on clear days, and winds of not more than moderate velocity. Ives (1947) gives the following account of the conditions favorable for their formation:

> *In geographically favorable areas dust devils occur most frequently in clear weather, when the surface has been heated for some hours, and there is little surface wind. Under these conditions the surface air is very hot with respect to that a few hundred feet aloft. Typically favorable conditions, measured during a "Great-Basin-High regime" are: surface temperature, 160 °F (71 °C); one foot (0.3 m) above surface, 142 °F (61 °C); five feet (1.5 m) above surface, 116 °F (47 °C); 500 feet (150 m) above surface, 100 °F (38 °C); 2,000 feet (610 m) above surface, 92 °F (33 °C).*

Such a pronounced drop in temperature means, of course, an extremely unstable atmosphere near the ground. Ives further states that the upward velocity of the air in a dust devil may exceed 35 miles per hour (56 km/h) and that measured horizontal winds within the whirl can accelerate from near zero to speeds of from 50 to more than 90 miles per hour (80–140+ km/h) and then return to their former velocity within 30 to 100 seconds. Velocities within the whirls on the southeastern fires are not known, but they are strong enough to carry burning embers for considerable distances ahead of the main fire.

Williams (1948) gives the range in size for dust devils as varying from 20 to 200 feet (6–60 m) in diameter and from 10 to 4,000 feet (3–1,200 m) in height. It thus appears that the largest dust devils occupy an area only about one-tenth as great as the area of the larger whirls on the South Carolina fires. The main difference between dust devils and whirls on fires is that the former must obtain all of their energy from the potential energy of the atmosphere, whereas the latter obtain their energy from burning fuel as well as the atmosphere. In the same article Williams states:

> *These occurrence times were from 1 to 5 hours before the times of maximum temperatures. The reason for this fact is that the wind speeds normally increase as the times of maximum temperatures are approached and certain critical speeds are reached beyond which the dust whirls cannot exist. These critical speeds have not yet been determined, but vary with lapse rate, topography, and probably other factors.*

Brown (1950) states that dust devils are an ominous sign to fire fighters. Whirls of a similar nature on fires may account for many blow-ups.

Lapse Rate is Related to Fire Control

If the conclusions reached regarding the effect of air turbulence on fire behavior are substantiated by additional work (see the sidebar), a new aspect of fire control in the Southeast will have been recognized. Although erratic fires in this section may not be common, their potential danger to suppression crews and damage to timber stands, particularly in the younger age classes, will justify the taking of extra precautions during especially hazardous periods. Radiosonde observations, where available, will be helpful but the extent of the adjacent area to which these apply will have to be determined. Forecasts of high impending turbulence a day or two in advance would be most useful, although a forewarning of even a few hours might mean considerable for the safety of men and equipment.

Although erratic fires in the Southeast may not be common, their potential danger to suppression crews will justify taking extra precautions during especially hazardous periods.

Suppression crews during such periods could be alerted to make the fastest possible attack so as to restrict any fire to the smallest possible acreage and before it reached the breaking point. In short, they could be warned to expect crowning and the sudden formation of large whirls, unusual backfire behavior, exceptional rates of spread considering existing wind velocities, gustiness and quick changes in wind direction, and the likelihood of danger even in making flank attacks.

It should be emphasized again that the changing fuel and stand types occurring in the Southeast may be a necessary condition for the large whirling fires which burned in South Carolina last year. These fires burned in dense stands of reproduction (predominantly loblolly pine) in which the compact crowns constituted the main source of fuel. In turn, the availability of this green fuel for combustion was increased by an unstable atmosphere plus a high rate of energy release in the ground fuels.

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Additional Evidence

Since this report was written, data have been obtained from the Weather Bureau which give the upper air temperatures at the Charleston airport for all days in the period from March 20 to April 30. Although a complete analysis has not yet been made, these data indicate that there were only eight days in this period with a highly unstable atmosphere. Four of these days were March 26, April 11, 17, and 24 when severe whirling fires occurred.

On the other four unstable days, no whirling fires were reported. On April 27, the atmosphere was very unstable at 10:00 a.m., but 0.41 inches (1.04 cm) of rain fell later in the day before 5:00 p.m. Similar turbulent conditions existed on April 6 and 27, but 0.33 inch (0.84 cm) of rain fell on April 5 and 0.60 inches (1.52 cm) on April 27 and 28. The chances were very slight for fires starting and building up to a high rate of energy output on these days, especially in dense stands of young loblolly pine. On April 19 there was a highly unstable layer of surface air but it was only 150 feet (46 m) deep. In addition, the next layer above was deep and stable. It is doubtful if large whirling fires could develop on such a day. However, the shallow layer should have had a marked effect on the behavior of small fires.

The Pinyon–Juniper Fuel Type Can Really Burn*

Dwight A. Hester

In the Rocky Mountain Region, we are rapidly losing any illusions that our fuel types are of the "asbestos" variety. Aspen used to be considered fairly fireproof until certain crown fires, gathering speed in adjacent conifer stands, rolled through without loss of momentum. The moist, high-altitude spruce type has been even more deceptive on disastrous occasions.

But at the lower elevation, in the southwestern part of the region, is the familiar pinyon–juniper type, and this never gave any trouble. Most of it is outside the national forest boundaries, and it is usually grazed so heavily that all fuel is gone except the trees themselves (fig. 1). The records show that our neighbor to the south, the Mesa Verde National Park, had a big fire in such a type in the drought-ridden thirties, but that seemed to be a "one-in-a-million" occurrence.

Unusual Conditions

Then, in 1950, we suddenly found out that under extreme conditions the fuel-sparse pinyon–juniper type will not only burn, but will literally explode. Since this type is widespread through the Southwest, perhaps other fire control personnel could profit by our experience.

During the early part of June 1950, the weather was fair and dry in western Colorado. Land managers were not concerned since there had been normal snowfall during the winter, and the early spring had been cold, if dry. The spruce type well above the pinyon–juniper still held considerable snow. By June 10 the weather had turned warm, and strong winds came up with regularity during the afternoons. Relative humidity was down to 7 percent.

It was during this period that a coal mine, abandoned and burning deep underground for some 20 years, chose to explode. This explosion, according to an eyewitness, occurred at 3:10 p.m., and the fire seemed to be in the crowns at once. By 5 p.m. the fire had traveled about a mile (1.6 km) "on the back of a strong wind" and showed no signs of abating (fig. 2).

We soon learned that natural barriers, such as ridges, cliffs, and roads, were of no value in heading off this type of fire.

Extreme Fire Behavior

We soon learned that natural barriers, such as ridges, cliffs, and roads, were of no value in heading off this type of fire. The country

Figure 1—*Typical pinyon–juniper type, showing scattered stand, sparse vegetation, and intermingled areas of bare ground. Photo: USDA Forest Service.*

When this article was originally published, Dwight Hester was a district ranger for the USDA Forest Servicae, Grand Mesa National Forest, CO.

* The article is reprinted from *Fire Control Notes* 13(1) [Winter 1952]: 26–29.

Figure 2—*The fire as seen from a point 15 miles away, 2 hours after origin. Photo: USDA Forest Service.*

was too broken and rocky for bulldozers to be used effectively. The shaggy bark of the juniper made fire brands to Satan's liking. Flaming strips of this bark, often 2 feet (0.6 m) or more in length, were hurled ahead to wrap themselves around other trees which caught fire with a roar and gave off ropelike strips of bark to repeat the process.

Distance between trees and width of natural barriers seemed to have little influence on this type of spread. In one instance, a cleared, 40-foot (12-m) fire lane was crossed in its entire length by the fire without detectable hesitation. Backfiring was not practicable since the only fuel was standing trees which had to be crowned out to burn, and a crowning juniper in a high wind is not to be fooled with.

Not only can the fire explode during the afternoon, it can continue this blowup well into the night. On our fire, the expected evening wind shift did not take place until about 8 p.m. This occurred as a 90-degree change of direction (a down-mountain draft) with no appreciable change in wind velocity, and the fire really rolled downhill. The rapid rate of spread continued until 11 p.m., at which time the wind velocity fell from an estimated 20 to 30 miles per hour (32–48 km/h) to a gentle breeze.

Suppression Tactics

Judging from the behavior of our fire, I believe that the head of such a fire should not be attacked until the crowning stops, unless there are means available for creating extremely wide barriers. Once the fire is out of the crowns, men can work relatively close to the fire and can work in most of the burn within 2 hours.

I believe the best bet is to fell a swath of burning trees at least 100 yards (90 m) wide, working from the edge toward the interior of the burn. One power saw per 4-man crew seems to be the answer for this work. In this short-tree type 2 men can operate the saw with a reasonable degree of safety, and the other 2 haul away the felled debris. Mop-up usually has to be done with little or no water since much of this type is without "living" water of any kind.

Figure 3—*The intensity of the fire denudes the soil to a point where watershed damage of long duration will result. Ditch and gully in the foreground were cut before the area burned. Photo: USDA Forest Service.*

One cannot count on the oak brush above the pinyon–juniper type to serve as a buffer. On our fire, the oak brush, although only about one-half leafed out, burned readily and crowned out in most places. As was found in Maine in 1947, hardwoods are not immune to crowning.

Fire Effects

Although the bulk of the trees remain standing after the fire, the heat is quite intense and leaves the ground well cooked (fig. 3). Regrowth of any kind is bound to be slow and erosion will be a problem. On the fire described, the wind started drifting the soil before the fire was out and continued througout the summer. Only two rainstorms of relatively light intensity occurred during the summer, but small gullies were in evidence by fall.

While our pinyon–juniper type can hardly be classified as a high fire risk, it is not fireproof. When conditions are right, it can be quite explosive, resulting in fires that are difficult to control. A burn in this type will be slow to heal and can result in a long-term watershed problem. ■

A Firewhirl of Tornadic Violence*

Howard E. Graham

> The winds in this tube were so extreme that a Douglas-fir, which at breast height was about 40 inches, was quickly twisted and broken off

Whirlwinds occasionally have been reported occurring within various types of fires. Accounts sufficiently detailed to give the reader a definite idea of what the reporter had actually seen are rare. Since the fire-whirlwind is a phenomenon of considerable importance to fire fighters, I will attempt to describe one which was observed by Robert S. Stevens, Forester, Oregon State Board of Forestry, and myself at 2 p.m., August 23, 1951, on the Vincent Creek Fire in southwest Oregon. Figure 1 portrays the spectacular wind conditions.

Tornado-Like Tube

From our vantage point about 200 yards (180 m) away it was evident that violent whirling surface winds existed over a diameter of some 100 to 200 feet (30–60 m). In the middle of this circulation was a dark tornado-like tube which extended upward, the top being obscured by drift smoke above approximately 1,000 feet (300 m). The winds in this tube were so extreme that a green Douglas-fir tree, which at breast height was about 40 inches (100 cm) in diameter, was quickly twisted and broken off about 20 feet (6 m) above the ground.

In the area of the whirlwind, the fire flames leaped several times higher than those surrounding. A large tree top burst into flame like the flash of a powder keg when the whirl passed by. Within the tube, gases and debris were moving upward at a high velocity. The whirling column remained nearly stationary during its activity, moving a little more than 50 yards (45 m). Had that not been the case, extremely rapid fire spread might have resulted. The whirlwind rapidly disappeared and as rapidly reformed a moment later, repeating this procedure at least 3 times during a 10-minute interval.

The general fire was on a 50-percent south–southwest slope. The trees were widely spaced with fuels consisting of low brush, weeds, snags, and down logs typical of an old burn in this region. The fire front was moving steadily along

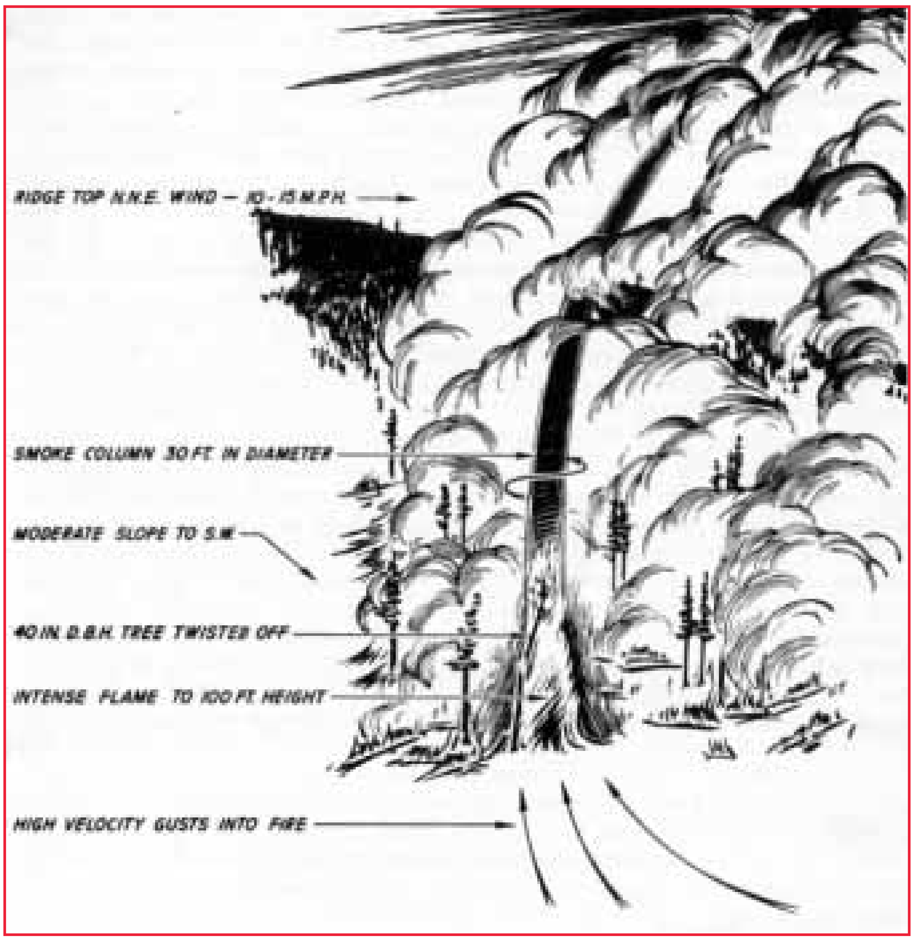

Figure 1—*Diagram of a fire-whirlwind observed on the Vincent Creek Fire.*

When this article was originally published, Howard Graham was a meteorologist for the Fire Weather Service, U.S. Weather Bureau, Portland, OR.

* The article is reprinted from *Fire Control Notes* 13(2) [Spring 1952]: 22–24.

the contours and extended up the entire slope, about one-half mile (0.8 km) from top to bottom. Flames along the front were about 5 feet (1.5 m) in height. Shorter flames persisted to a distance of about 50 feet (15 m) behind.

A slight spur ridge projected from the slope so that updrafts were moving from both the south and the southwest into the area of the whirlwind. The fire-whirlwind developed a few feet behind the fire front 150 yards (140 m) from the summit of the main ridge and on the spur ridge.

Atmospheric Instability

The meteorological condition of the atmosphere was one of conditional instability. Overturning of the air in the lower layers could readily occur if the surface were heated sufficiently. No cumulus clouds were to be seen. Winds at ridge top were north–northeast from 10 to 15 miles per hour (16–24 km/h). Above the ridge top level, winds were from north–northwest to north–northeast and ranged from 8 to 16 miles per hour (13–26 km/h) up to 10,000 feet (3,000 m). The relative humidity was 46 percent and the temperature 67 °F (19 °C), neither of which was unusual.

There has been much written on various types of whirlwinds and their causes. Much is yet to be learned. Meteorologists know that these whirlwinds are present only where the atmosphere is in a particular condition of unstable equilibrium—where the temperature decreases so rapidly with height that the warmer air below, being lighter than the cooler air above it, tends to rise, and conversely, the cooler air aloft tends to sink. The result is intensive vertical currents throughout the unstable layer.

Meteorologists know that these whirlwinds are present only where the atmosphere is in a particular condition of unstable equilibrium.

In this case, we have the heat from the fire which caused the unstable conditions. However, this is an entirely normal situation over a large fire. Since these violent fire-whirlwinds are infrequent, there must be some condition other than heating to cause their formation. Perhaps the answer lies in the interplay of wind currents and topography.

Interplay of Wind/Topography

In the case under discussion, consider the position of the whirl near the top of a sunlit south–southwest slope where it was fed by upslope drafts from the south and southwest in the surface layers. Above the level of the ridge the rising currents from the fire were played upon by the prevailing gentle to moderate north–northeasterly wind.

Perhaps herein lies the answer. There were two opposing air currents with a column of rapidly rising gases between. This is an ideal condition for the formation of mechanically induced eddy currents. An eddy current, once started, might be sustained by the energy of the rising hot gases. This theory is substantiated by the repeated reappearance of the fire-whirlwind in the same spot. As the leading edge of the main fire progressed, the fuels in the area of the whirl were consumed and the volume and heat of the ascending gases became apparently insufficient to support the whirlwind. As the fire moved on to new fuel and new topographic features no further disturbance was noted.

From this analysis it would seem likely that there are certain ideal combinations of conditions under which this type of fire-whirlwind of extreme violence might occur. The necessary factors seem to be for the fire to be on the lee slope sheltered from the prevailing ridge top winds, a moderate or stronger wind at the ridge top, and strong converging surface updraft currents along the burning or sun-heated slopes.

More Accounts Needed

It would be desirable to have the necessary combination of conditions more positively identified so that fire fighters could learn to anticipate at least this one type of blow-up fire behavior. Additional detailed accounts of similar phenomena would contribute to the understanding of their causes and their effects on fire behavior. These accounts should attempt to describe the topography, surface wind, ridge top wind, fire intensity, cloud types, smoke column characteristics, and the intensity of the fire-whirlwind. ■

Rate of Spread on a Washington Fern Fire*

William G. Morris

Rate of spread, fuel moisture, and climatic conditions were measured on the 4,000-acre (1,600-ha) Livingston Mountain fire east of Vancouver, WA, on April 11 and 12, 1951. In behavior, this fire typified many early spring fires on cutover areas in the foothill zone of the Douglas-fir region. Some of the measurements of rate of spread will be given as an example of this type of fire.

In behavior, this fire typified many early spring fires on cutover areas in the foothill zone of the Douglas-fir region.

Burning Conditions

The fire burned across a gentle to moderate south-facing slope that extended some 3 miles (5 km) from level farmland to the top of a broad hill, 1,500 feet (460 m) higher. At the steepest points, the slope was about 40 percent.

As in much of the foothill country, ground cover was mostly western bracken fern, intermingled with annual weeds, trailing blackberry, and salal, an evergreen shrub 6 to 15 inches (15–38 cm) high. In this locality, bracken grows to a height of 2-1/2 feet (76 cm) and forms a dense ground cover. In April, however, the dead crowns are bent to the ground and form a loose, flashy fuel about 1 foot (30 cm) deep. Hazel brush, about 8 feet (2.4 m) tall and not yet in leaf, formed a sparse overstory. Here and there pole-size Douglas-fir had survived previous fires and occurred in large blocks, small patches, or as single trees. Scattered Douglas-fir seedlings and saplings were also present in some areas of bracken and brush.

The weather was unusually favorable for fires. The preceding 10 days had been clear and unseasonably warm with dry winds. Before this period, rainfall had been normal. On April 11 the relative humidity fell to 14 percent, and wind speed measured with a portable anemometer 6 feet (1.8 m) above the ground was consistently 18 to 20 miles per hour (29–32 km/h). Moisture content of dead bracken fuel was 9 percent or less even though the soil was still moist 1/4 inch (6.4 mm) below the surface.

Rapid Rates of Spread

Lineal spread and contributing factors were measured on heads and flanks of the sprawling, irregular fire. Measurements were taken mostly during short periods when wind speed, direction of spread, topography, and fuels were fairly uniform. Spread was usually measured for a distance of 50 feet (15 m) or less although occasionally for 0.1 to 0.5 mile (0.16–0.8 km). On April 11, when the wind speed was 18 to 20 miles per hour (29–32 km/h) and the relative humidity was 16 percent, rates of spread beyond the shelter of trees varied from 660 feet per hour to 7,900 feet per hour (200–2,400 m/h) (table 1). On April 12, when the wind speed was 7 to 8 miles per hour (11–13 km/h) and the relative humidity was 26 percent, rates of spread beyond the shelter of trees varied from 80 feet per hour to 1,600 feet per hour (24–490 m/h) (table 2).

On April 11 the fire spread so rapidly that control through flank attack would have required construction of control line at a rate of more than 1/2 mile per hour (0.8 km/h) along both flanks. During short periods when flames rose in the crowns of scattered conifers and embers flew far ahead, more than 1-1/2 miles of control line would have to be constructed per hour (2.4 km/h). In flash fuel of this kind, a frontal attack with a slower rate of line construction could be effectively used to check the head of the fire.

Typical Rates of Spread

Although effects of wind speed and relative humidity cannot be separated in these observations, rate of spread apparently increased 4 to 5 times when wind speed increased 2-1/2 times and was accompanied by an appreciable drop in relative

When this article was originally published, William Morris was a forester for the USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR.

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humidity. Measurements on many other fires show that a lineal spread of 400 to 900 feet per hour (120–270 m/h), as recorded in table 2, is typical of fires in brush, bracken, and weed cover on nearly level ground in the Pacific Northwest. Spread is of course grater on steep slopes.

In the litter of the normally dense coniferous forests, rate of spread is a small fraction of that shown in table 2. In the unburned logging slash of these forests, rate of spread is greater than shown in table 2 owing to large numbers of windborne embers that set new fires far in advance of the surface fire. ■

Table 1—*Rates of spread and contributing factors measured on a Washington fern fire April 11, 1951.*

Rate of lineal spread (ft/h)	*Position on fire*	*Direction of spread with reference to slope*	*Slope [a] (percent)*	*Remarks*
7,900	Head	—	0	Crowns of scattered conifers afire. Spotted ahead. Measured on 0.1-mi spread.
3,300	do	—	0	No spotting.
2,400	Flank	Down	15	Spread only 350 ft/hour while flames drew inward just previous to this measurement. Drafts then became turbulent and flames surged outward.
2,400	Head	—	0	—
2,400	do	Down	25	Some spotting. Measured on 0.3-mi spread.
2,100	do	—	0	Some spotting. Measured on 0.5-mi spread.
1,320	Flank	Down	15	—
1,320	Head	—	0	Flames 6–8 ft high and intermittently drawing outward or inward.
1,320	do	Down	10	Measured on 0.5-mi spread.
1,000	do	—	0	—
800	Flank	—	0	—
660	do	—	0	—
400	Head	—	0	In dense stand of Douglas-fir 50 ft tall. Wind at treetops about 20 mph, and at 6 feet above ground, 4 mph. Fire spread in twig litter 2–3 in deep and produced a blazing border 4 ft wide in which flames were vertical and less than 2 ft high.
100	do	—	0	Same stand and wind as above. Flames drew inward toward fire and formed a border only 1 ft wide.

Note: Wind, east 18–20 mph; relative humidity, 16%; temperature, 71 °F to 75 °F.
[a] South aspect.

A lineal spread of 400 to 900 feet per hour is typical of fires in brush, bracken, and weed cover on nearly level ground in the Pacific Northwest.

Table 2—*Rates of spread and contributing factors measured on a Washington fern fire April 12, 1951.*

Rate of lineal spread (ft/h)	*Position on fire*	*Direction of spread with reference to slope*	*Slope [a] (percent)*	*Remarks*
1,580	Head	Up	5	Spread at right angles to overhead wind. The flames, 1–3 ft in height, drew outward although just previous to this measurement they drew inward.
990	do	—	0	—
730	do	—	0	—
630	do	Down	10 (E)	—
530	do	—	0	Flames 1–3 ft high in strip 2 ft wide drew inward.
500	do	Down	10 (E)	—
360	do	—	0	—
340	Flank	—	0	—
280	Head	Down	10 (E)	—
200	do	Up	5	Spread at right angles to overhead wind.
150	do	Up	5	Spread at right angles to overhead wind. Flames drew inward.
130	Rear	—	0	Bracken flattened to 3-in layer.
120	Head	Up	5	Spread at right angles to overhead and wind. Flames drew inward.
110	Flank	Up	5	—
80	Head	Up	5	Do.

Note: Wind, west 7–8 mph; relative humidity, 26%; temperature, 77 °F.
[a] South aspect, except for three observations (indicated by "E") on east aspects.

FIRE-WHIRLWIND FORMATION AS FAVORED BY TOPOGRAPHY AND UPPER WINDS*

Howard E. Graham

A fire started at a logging operation during the afternoon of October l, 1952. Toward evening the size had slowly increased to 20 acres (8 ha). About 9:30 p. m. the fire suddenly became a raging inferno as whirling winds formed within the fire and abruptly multiplied its speed to such strength that chunks of wood and bark up to 8 inches (20 cm) in diameter were thrown about like straws. Logger fire fighters fled for their lives. Within minutes the fire raced though unburned areas for half a mile (0.8 km), increasing to 240 acres (100 ha). The whirling winds remained over the fire for about an hour, hurling burning embers for considerable distances and preventing the loggers from pressing their attack (table 1, whirlwind 4).

> Local violent winds, frequently whirlwinds, have many times caused unusually rapid fire spread due both to direct fanning and to spotting.

Firewhirls and Large Fires

Fire whirlwind is a phenomenon that has been known to be associated with large fires (whirlwinds 1, 2, and 3) (Hissong 1926). It has become more common in recent years in the Northwest as a result of the increase in number of necessary slash burning operations.

In another fire that occurred November 8, 1952, a Crown Zellerback fire patrolman was making a routine 8:30 a.m. visit to a nearly cold 2-acre (0.8-ha) slash fire on the west slope of the Washington Cascades near the Columbia Gorge. Although the lookout on a ridge a short distance eastward reported east winds from 50 to 60 miles per hour (80–96 km/h), these winds had not been hitting the fire area. Suddenly an intense whirlwind formed in adjacent green timber and passed over the dormant slash fire. The fire leaped to life with an eruption of sparks and flame and ran for over a mile (1.6 km) finally joining a second fire (whirlwind 9).

Fire whirlwinds have received little attention from meteorologists, probably because such winds are usually observed only by foresters and fire fighters who are too busy fighting fires to make detailed weather observations. With greater attention being given to the study of blowup fires (whirlwinds 1 and 4), it is fitting that this particular type of violent fire behavior be explored from both the empirical and theoretical standpoints.

Winds are of great concern to fire fighters. Fire spread is a function of wind speed, although not a simple function. Local violent winds, frequently whirlwinds, have many times caused unusually rapid fire spread due both to direct fanning and to spotting. A typical fire whirlwind frequently has a central tube made visible by whirling smoke and debris. Extreme variations in height, diameter, and intensity are common. Witnesses have described fire whirlwind diameters from a few feet to several hundred feet and heights from a few feet to about 4,000 feet (1,200 m). Intensity varies from that of a dust devil to a whirlwind that pitches logs about and snaps off large trees (Graham 1952). Velocities in the vortex are extremely high, and, as in other forms of whirlwinds, the greatest speed occurs near the center. A strong vertical current at the center is capable of raising burning debris to great heights.

Favorable Topographic Features

The 28 fire whirlwinds that form the basis for this discussion were all observed in mountainous terrain. Their individual characteristics are indicated in table 1. Of the 28 whirlwinds, 20 occurred on lee slopes, 1 under calm conditions, 2 with wind at right angles to the slope, and 4 on windward slopes. Of the several additional whirlwinds described to the author and not included in table 1, all occurred on lee slopes.

The mechanical action of airflow over a mountain is a factor in fire

When this article was originally published, Howard Graham was a fire-weather forecaster with the U.S. Weather Bureau, Portland, OR.

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Table 1—*Descriptive details for 28 fire whirlwinds in the Pacific Northwest.*

Whirlwind	Date, hour[a]	Whirls				Size of debris picked up	Relation wind to topography	Ridgetop wind	
		Number	Duration	Diameter	Height			Direction	Velocity
1	7/20/51, 1600	1	2 h	1,200 ft	2,500 ft	logs, 30 in by 30 ft	lee slope	N	—
2	8/23/51, 1400	3	10 min	200 ft	1,000 ft	large tree broken off	lee slope	N–NE	10–15 mph
3	9/21/51, 1300	1	1 h	200 ft	4,000 ft	logs, 15 in by 15 ft	lee slope	N–NE	—
4	10/1/52, 2140	Several	Several min each for 1 h	50 ft	200 ft	6- to 8-in chunks	lee slope	E	30 mph
5	10/15/52, 1500	Several	each 30 sec	40 ft	150 ft	3 by 4 by 16 in	lee slope	NE	10 mph
6	10/24/52, 1030	Several	each 30 sec	40 ft	300 ft	log, 12 in by 16 ft	lee slope	E	10 mph
7	10/25/52, 1100	Several	each 2 min	20 ft	150 ft	bark, 2 by 4 by 12 in	ridgetop	W	—
8	11/4/52, 1400	1	few min	Unknown	Unknown	Unknown	parallel to contours	SW	10 mph
9	11/8/52, 0830	1	Unknown	Unknown	Unknown	small debris	lee slope	E	50–60 mph
10	11/8/52, 1500	1	1 h	5 ft	100 ft	small sticks	lee slope	E	10 mph
11	9/ ?/53, 1100	1	10 min	50 ft	100 ft	small limbs and snapped tree top, 8- to 10-in diameter	flat	clam	—
12	9/16/53, 1345	1	2 min	75 ft	125 ft	bark and wood, 4–5 lb	lee slope	S–SW	4 mph
13	9/21/53, 1530	1	3/4 h	25 ft	100 ft	6- to 8-in diameter	lee slope	SW	15 mph
14	9/29/53, 1000	Several	each 30–60 sec	10 ft	50 ft	up to 8 sq in	windward	SW	10 mph
15	9/29/53, 1130	1	1-1/2 h	400 ft	400 ft	up to 3 by 3 in	lee	W	2 mph
16	10/3/53, 1600	Several	each 2 min for 8 h	10 ft	30 ft	up to 15 lb	windward?	E	30 mph
17	10/4/53, 1150	Several	3 min	40 ft	300 ft	2 by 6 by 18 in and a cedar post	lee slope	NE	5 mph
18	10/6/53, 1530	1	1-1/2 h	50 ft	200 ft	Unknown	calm	calm	—
19	10/6/53, 1530	Several	1/2 h	20 ft	60 ft	bark, 4 by 6 in	lee slope	E	8 mph
20	10/7/53, 1500	Several	each 30 sec	30 ft	100 ft	1-1/2 in diameter	windward?	SW	10 mph
21	10/8/53, 1600	Several	each 4–20 sec for 4 h	10 ft	200 ft	under 11b	windward	W	10 mph
22	10/9/53, 1640	1	8 min	140 ft	170 ft	2 by 6 by 24 in and larger	lee slope	NE	5 mph
23	10/9/53, 2000	Several	1–2 min each for 2 h	75 ft	100 ft	1 by 2 by 3 in	lee slope	SW	10–15 mph
24	10/10/53, 1730	5	1 h	50 ft	125 ft	large sparks	lee slope	W	5 mph
25	10/13/53, 1830	Several	1 min each	30 ft	200 ft	small twigs	lee slope	W	8 mph
26	10/15/53, 1500	Several	each 1–2 min for 1 h	50 ft	150 ft	branches and bark	lee slope	W	5 mph
27	10/29/53, 1830	1	10 min	100 ft	80 ft	bark and limb, 4 by 5 in	lee slope	N	3 mph
28	10/29/53, 1500	Several	each 10 sec to 4 min for 2 h	30 ft	60 ft	large material including a 20-lb piece of sheet metal	lee slope	W	5 mph

[a] Pacific standard time.

whirlwind formation. Aerodynamic theory tells us that favorable conditions for the starting of a whirl occur where abrupt edges of mountainous terrain create shear in the air stream. As has been found true with dust devils, shearing motion is undoubtedly a major factor in whirl formation. Although mountainous terrain provides many topographic situations favorable to fire whirlwind occurrence, the fact that it is not an essential condition is indicated by several examples which occurred on flatland in Eastern United States (Byram and Nelson 1951).

Meteorological Aspects

Dust devils are normal in flat areas when the wind speed is low and the lapse rate is steep, i.e., relatively rapid temperature decrease with height. Fire whirlwinds also appear to depend upon steep lapse rates in the layer near the ground. Roy R. Silen, Pacific Northwest Forest and Range Experiment Station forester, moved a fire whirlwind downhill by rolling debris against the fuel in the hot spot over which it had formed. As the hottest portion of the fire was carried down the slope, the fire whirlwind followed. Fire whirlwind occurrence seems to be directly related to the local thermal instability set up by the fire and not otherwise relieved.

The degree of upper air stability as indicated by the lapse rate between 850 and 500 millibars, i.e., pressure surfaces near 5,000 feet and 18,000 feet (1,500–5,500 m), at nearby weather stations has little or no effect on fire whirlwind occurrence. Data on the lapse rate at lower levels is unavailable. Obviously the lapse rate in the lower level over the fire is extremely unstable because of intense heating near the ground.

> Fire whirlwinds have become more common in recent years in the Northwest as a result of the increase in number of necessary slash burning operations.

The distribution of upper air wind velocities also was checked from pilot balloon data at the nearest weather station. The results showed that 75 percent of the whirlwinds reviewed occurred, with winds of less than 17 miles per hour (27 km/h) below the 5,000-foot (1,500-m) level. This is to be expected since the majority of whirlwinds were on controlled burns. The remaining 25 percent showed rapid wind speed increase with height. The wind speed profiles are of variable shape and show no typical occurrence of the “jet point” discussed by Byram (1954) with relation to blowup fires.

Mountain Barriers and Their Effects on Airflow

The upper end of a fire whirlwind when on a lee slope near a ridgetop seems to extend into a region of low pressure that occurs in the vicinity of a ridgetop whenever windflow is at right angles to the ridge. This follows the Bernoulli principle which states that changes in pressure are inversely proportional to changes in fluid velocity. Pilots are taught this principle as the explanation altimeter errors experienced over mountains.

The theory of pressure reduction along a ridge oriented at right angles to the direction of airflow is well supported by evidence.

According to a U.S. Weather Bureau study of strong winds over mountain barriers, the pressure reduction over a mountain crest was proportional to the square of the wind speed. Where the air was saturated, the pressure deficiency was nearly doubled. The greatest pressure deficiency occurred along a mountain barrier with a ridge profile corresponding to the upper surface of an airfoil where the maximum drop would be near the topmost part of the airfoil camber. Theoretically a topographic barrier should best approximate an airfoil when the lee slope is less than 33 percent and relatively smooth. This corresponds very closely to the upper limits of the change in direction of airflow over the upper surface of airfoils on slow speed airplanes.

Conclusion

Because of the direct relationship between fire whirlwind occurrence and combustion heat, the meteorologist can predict likely areas of occurrence only if he is familiar with both the attendant meteorological and topographic conditions and the occurrence of heavy fuel concentrations. The forester with intimate knowledge of areas under his management will usually be more able to predict combustion heat over a given area.

Fire whirlwinds seem to develop more readily on lee slopes close to ridgetops. It is suggested that this is favored by pressure deficiencies resulting from flow over an

The most favorable condition for fire whirlwind occurrence is over a hot fire near the top of a steep lee slope with strong winds over the ridgetop.

abruptly terminating airfoil. The wind velocity above the ridgetop thus becomes an important factor in determining the likelihood and magnitude of a whirlwind.

We may conclude that the most favorable condition for fire whirlwind occurrence is over a hot fire near the top of a steep lee slope with strong winds over the ridgetop. Fire whirlwinds are frequently characterized by destructive violence. Therefore when any fire—large or small, quiet or running—is on a lee slope, the fire fighters should consider the danger of fire whirlwind formation.

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Fire Whirlwinds Studied in the Lab*

Because of their importance as a hazard to firefighters and as a cause of rapid and erratic fire spread, fire whirlwinds are one of the fire behavior phenomena being studied at the Southern Forest Fire Laboratory in Macon, Ga. These whirlwinds can be produced readily on a small scale and studied by modeling techniques.

*See Byram, G.M.; Martin, R.E. 1962. Fire whirlwinds in the laboratory. *Fire Control Notes*. 23(1) [Winter 1962]: 13–17.

Relationship of Weather Factors to Rate of Spread of the Robie Creek Fire*

R.T. Small

Original editor's note: The Robie Creek Fire in the Boise National Forest, ID, September 5–9, 1955, is described, and concurrent weather conditions are analyzed. The fire exhibits four different types of behavior during the 5 days. On four of the days, the behavior follows patterns previously recognized as being usually associated with the prevailing weather conditions. The exceptions occur on the third day, which is meteorologically similar to the second day but exhibits a different fire behavior. Some implications that this study has for forecasting and research are pointed out.

Many observations have been made regarding the cause of forest and range fire spread and a number of well-qualified men have made investigations and contributed valuable reports and technical papers on this complex subject. There is general agreement that weather is the most important variable in fire spread, and that the conditions which lead to "blowups" are very complex and difficult to predict.

This paper consists of a report of the weather conditions which existed during the Robie Creek Fire in the Boise National Forest, Idaho, September 5–9, 1955, and an analysis of the relationship of those conditions to the fire behavior.

> The greatest blowup potential is when the wind reaches maximum speed within the first 1,000 feet above the fire and then decreases in speed with elevation.

There are several reasons why this fire adapts itself to an analysis of this type: (1) The fire occurred only 10 to 15 airline miles (16–24 km) northeast of the Boise Weather Bureau Airport Station (WBAS) where regular surface and upper air observations are made. (2) The fire area was bracketed by two fire-weather stations, Shafer Butte Lookout, six miles north of Robie Creek at an elevation of 7,590 feet (2,313 m), and Idaho City Ranger Station some 12 miles (19 km) northeast of the fire, at an elevation of 3,950 feet (1,204 m), in the main Mores Creek drainage. (3) The fire went through four different types of behavior-day: a blowup, a long run, a potentially critical but quiet day, and a quiet day.

Description of the Fire

The Robie Creek Fire in the Boise National Forest started in the early afternoon of Labor Day, September 5, 1955. It was a hot, dry day; the 45th day since there was measurable precipitation in that area and the 21st consecutive day with the maximum temperature above normal. The maximum temperature at nearby Idaho City Ranger Station that day was 101°F (38 °C) and the relative humidity was 6 percent resulting in a very high fire danger (Burning Index of 72 on the Forest Service Model 8 Meter).

The fire apparently started on the east side of the Boise Ridge and at a point on a minor slope exposed to the southeast. The point of ignition was in well-cured grass in a light stand of chokeberry brush. Fuel in the general area consisted mostly of dry grass, several kinds of brush, and second growth ponderosa pine. The fire started at an elevation of about 5,000 feet (1,500 m), but eventually spread over an elevation range from 4,000 to 5,500 feet (1,200–1,700 m). Although winds were light and variable, the other factors were very conducive to fire spread. Within 2 hours of the time that fire began there were 15 to 20 people from the nearby Karney Lakes Resort, four smokejumpers, and a crew of 20 trained fire fighters at the scene, but the rate of spread was so great that the fire fighters had to retreat from the fire area.

The fire started on Monday, September 5, and was brought under control on Friday, September 9. Of the 5 days, major runs or "blowups" occurred on 3 days: Monday, Tuesday, and Thursday.

When this article was originally published, R. T. Small was with the Weather Bureau, U.S. Department of Commerce, Boise, ID.

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Forecasters on large fires should consider carefully the wind speed profiles and surface temperature distribution as well as temperature lapse rates and other observational material.

On Wednesday there were minor flareups, but no sustained run occurred. There was very little spread on Friday as established lines were widened and mopup commenced (fig. 1).

During the 5 days the fire spread over 8,310 acres (3,363 ha) of private and national-forest land. At the peak of the attack over 700 men were employed and total suppression costs were in excess of $100,000.

Weather Conditions

In the attempt to determine which weather parameters had the most influence on the fire behavior during the 5-day period, comparisons were made of the various weather data. The upper air measurements give the values of temperature and humidity at different heights. The decrease in temperature with altitude is called the lapse rate. When this value becomes 5-1/2 °F per 1,000 feet (10 °C/1,000 m) the lapse rate is known as the dry adiabatic lapse rate. With lapse rates considerably less than dry adiabatic, the atmosphere is more stable. Where the lapse rate approaches or is greater than the dry adiabatic rate the air becomes unstable and upward motion is greatly increased.

On the assumption that stability would be an important factor, a comparison was made of the twice-daily Boise radiosonde observations (fig. 2). The lapse rate was very nearly dry adiabatic on Monday, Tuesday, and Wednesday and only more stable on Thursday and Friday.

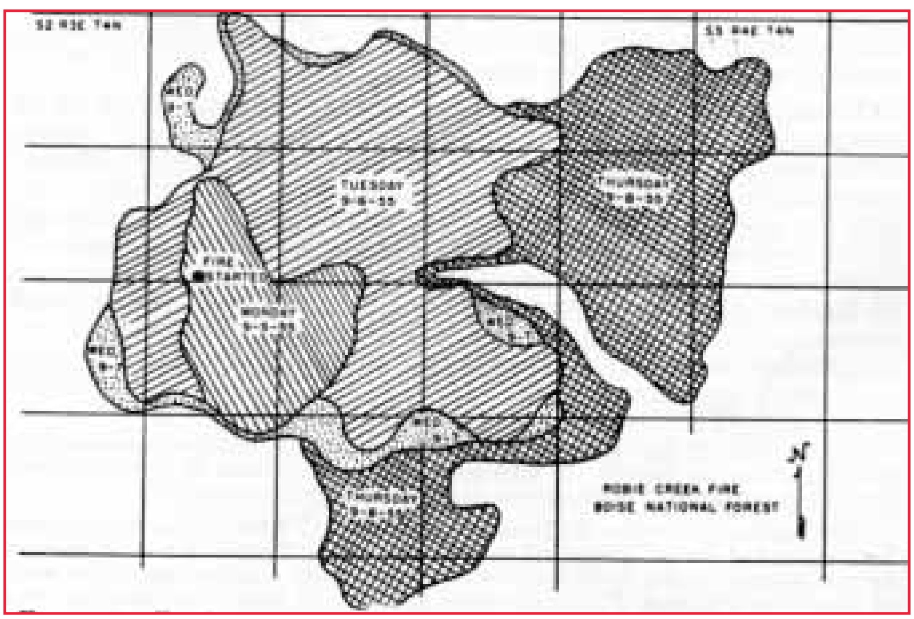

Figure 1—*Total area of the Robie Creek Fire showing location where fire started on Monday, September 5, 1955, and its spread on succeeding days. Grid interval equals 1 mile (1.6 km).*

Plotting the maximum surface temperatures at Shafer Butte, Idaho City, and Boise WBAS on the soundings show that superadiabatic lapse rates existed on Monday and Tuesday near the surface, but the layer near the surface was more stable on Wednesday and Thursday.

The surface conditions as shown in table 1 reveal that the weather was hot and dry all 5 days, but that there was a definite cooling on Thursday and Friday.

The wind speed profiles for the 0800 mountain standard time (MST) and 1400 MST Boise winds aloft observations are shown in figure 3. The wind speeds over 7,000 feet (2,134 m) above mean sea level increased gradually during the first 4 days of the fire and then slacked off again at the end of the week.

Fire Behavior

The fire behavior on Monday was very similar to that of Tuesday and most of the weather data were strikingly similar on those 2 days, except for minor changes in the winds aloft patterns.

Monday and Tuesday both had some of the characteristics associated with a blowup pattern; i.e., steep lapse rates, high temperatures, low humidity, dry fuel, and relatively light winds aloft. On both Monday and Tuesday the major spread occurred in the middle and late afternoon and was accompanied by a nearly vertical smoke column which was topped by a well-developed cumulus cloud. Both Monday night and Tuesday night the smoke filled the surrounding valleys and remained low until upslope motion

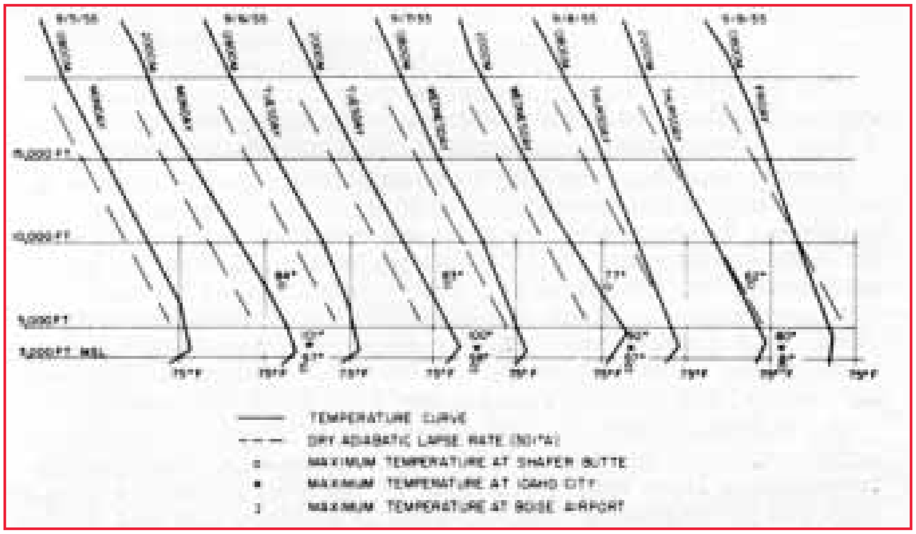

Figure 2—*Radiosonde temperature observations at Weather Bureau Airport Station Boise, Idaho, during period of Robie Creek Fire. Daily maximum temperatures for Shafer Butte Lookout, Idaho City Ranger Station, and Boise Airport are plotted at their relative elevations.*

commenced at 1000 MST on Tuesday and 1100 MST Wednesday.

On Wednesday the fire spread over only about 500 additional acres (200 ha) compared to over 3,000 acres (1,200 ha) on Tuesday. However, the temperature lapse rate was almost as steep as on the previous 2 days and the minimum relative humidity at Idaho City and Shafer Butte was the same as on Tuesday. There were minor changes in maximum temperature with a drop of 6 °F (3.3 °C) at Shafer Butte and 8 °F (4.5 °C) at Idaho City. Winds aloft were weaker at low elevations and stronger at high elevations as shown by the wind speed profiles. On Wednesday there was no towering cloud-capped smoke column, only small areas of billowing smoke during the afternoon. In contrast to the previous nights, the fire continued to spread during the night, especially near the ridgetops, and there was very little smoke hanging in the valleys Thursday morning.

On Thursday cooler air was obviously moving into the fire area with moderate westerly winds across the Boise Ridge and down onto the fire. In the early morning the fire was moving rapidly up the slopes exposed to the west, and throughout the morning and afternoon the fire continued to spread in an easterly direction. Maximum temperatures were down about 20 F° (11 °C) from Tuesday and minimum relative humidity was up 10 to 20 percent. Although the fire covered nearly as great an area on this day as on Tuesday the behavior was different. The wind was relatively consistent in both speed and direction and the fire moved from west to east, up slope and down. The forest officials described it as more of a steady "push" than a blowup. The smoke column leaned to the east and although small cumulus tops appeared frequently they disappeared almost as quickly as they formed.

On Friday winds were light and variable, temperatures were about the same as on Thursday, and the relative humidity was higher by 5 to 10 percent. In the afternoon a few minor dust whirls were visible

Table 1—*The maximum temperature and 1600 mountain standard time relative humidity for the 5 days of the Robie Creek Fire, Boise National Forest, ID, September 5–9, 1955.*

	Boise Weather Bureau Airport Station		***Idaho City Ranger Station***		***Shafer Butte***	
Day	***Max. temp.***	***Rel. humidity***	***Max. temp.***	***Rel. humidity***	***Max. temp.***	***Rel. humidity***
Monday	97 °F	24%	101 °F	6%	84 °F	12%
Tuesday	98 °F	23%	100 °F	12%	83 °F	14%
Wednesday	97 °F	17%	92 °F	12%	77 °F	14%
Thursday	81 °F	27%	80 °F	19%	62 °F	34%
Friday	80 °F	30%	81 °F	25%	62 °F	40%

If it were possible to dispatch a mobile radiosonde observational unit to large fires the information gained would be very valuable to the forecaster in predicting fire behavior.

in the ashes and smoke stumps, but at no time was there a serious flareup or threat to the firelines. By this time the suppression attack was organized and lines were well established and manned.

Discussion

Arnold and Buck (1954) have listed five atmospheric situations under which fire blowups may occur:

1. Fire burning under a weak inversion.
2. Fire burning in hot air beneath a cool air mass.
3. Combustible gases from a fire accumulating near the ground.
4. Fire exposed to a steady-flow convection wind.
5. Fire burning near a cell of vertical air circulation.

The rapid spread on Monday and Tuesday corresponded to situation 5, and the conditions on Thursday seemed to fit situation 4. On Monday and Tuesday there appeared to be a "chimney effect" reaching to an estimated 25,000 to 30,000 feet (7,600–9,100 m) which induced a strong draft at the base of the column.

Byram (1954) states that for the greatest blowup potential the wind should reach a maximum within the first 1,000 feet (300 m) above the fire and then decrease in speed with elevation for the next several thousand feet. He refers to this point of maximum wind speed immediately above the fire as the "jet point" and states that the wind speed near the jet point for most dangerous fires will be 18 to 24 miles per hour (29–39 km/h) for light to medium fuels. Byram has classified the wind speed profiles into four main types, each with two or more subtypes (fig. 3).

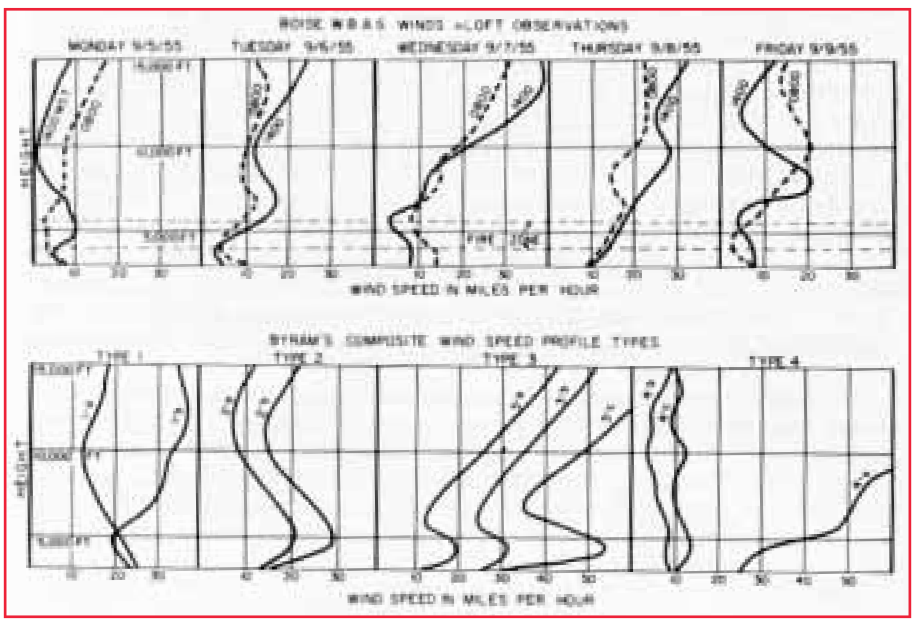

Figure 3—*Daily winds aloft observations taken at Weather Bureau Airport Station, Boise, during period of Robie Creek Fire (upper graphs) compared with Byram's wind speed profile types.*

In comparing the wind speed profiles of the 1400 MST Boise winds aloft reports for the 5 days of this discussion we find that the profile for Monday resembles Byram's Type 1-a except for wind speed. The wind blowing up slope tended to offset this low velocity.

The wind speed profile at 1400 MST on Tuesday for Boise closely resembles Byram's Type 3-a with the jet point just above the fire zone. This type has strong winds at high levels, but with a layer of decreasing speed just above the jet point. Byram says of this particular profile "for a fire near 7,000 feet (2,100 m) it resembles the dangerous Type 1-a and it is doubtful if the wind speeds at high levels are strong enough to shear off the convection column." Type 3-a and 3-b may be accompanied by strong whirlwinds and rapid fire spread when jet point winds are 20 miles per hour (32 km/h) or more. The winds at the jet point level at Boise WBAS were below Byram's minima, but speeds must have been higher just above the fire. Fire crews reported spotting as much as a quarter of a mile (0.4 km) ahead of the fire Tuesday afternoon which would indicate some of the whirlwind activity mentioned by Byram.

On Wednesday the wind speed profile resembles Byram's Type 1-b, except that wind speeds in the fire zone were much below the limits shown. The strong winds above 10,000 feet (3,000 m) would tend to prevent formation of a convection column which might induce strong winds at the surface. Colson (1956) states "the convection column will not attain great heights if the wind speed increases too rapidly with height. Too strong a wind speed may cause the column to be broken away from its energy source."

Byram's Type 4-a resembles the wind speed profile and also the fire behavior on Thursday. Regarding Type 4-a Byram states "fires were intense and fast-spreading, but they could not be considered dangerous to experienced crews, nor were there any erratic and unusual aspects to their behavior."

The speed profile at 1400 MST on Friday closely resembles Byram's Type 2-a, but other conditions reduced the fire danger.

The fire behavior on Monday, Tuesday, Thursday, and Friday followed previously recognized patterns usually associated with the prevailing weather variables. However, the meteorological similarity between Tuesday and Wednesday was remarkable while the fire behavior was very different. Following is a comparison of the 2 days:

1. Fuel conditions on Wednesday were essentially the same as on Tuesday with fuel remaining on all sides of the fire. Lines had been established on some of the fire boundary, but the long run the following day indicates that the spread potential was present.
2. Figure 2 indicates that stability was not the prime differentiating factor.
3. When the maximum surface temperatures at Idaho City, Shafer Butte, and Boise were plotted on the tephigram with the Boise radiosonde observations (fig. 2) it appeared that there must have been a superadiabatic lapse rate near the surface at Idaho City and Shafer Butte on Monday and Tuesday which was not nearly so pronounced on Wednesday. This superheating effect was at a maximum on Monday and Tuesday, was at a minimum on Wednesday, and gradually increased again on Thursday and Friday.
4. Minimum relative humidity was the same both days.
5. Maximum temperatures were the same at Boise and 5 °F to 8 °F (2.7–4.5 °C) lower at Idaho City and Shafer Butte on Wednesday, but that change in itself hardly seems great enough to be critical.
6. The winds aloft at Boise WBAS show minor differences in direction on the 2 days, but wind speed profiles (fig. 3) varied considerably. Byram's wind speed profile types are different for the 2 days and they offer a possible explanation for the variation in fire behavior between the 2 days.

Conclusions

The principal objective in an analysis of this type is to develop means of improving forecast and warning techniques. Byram's wind speed profiles have considerable merit, as the evidence has shown, but, from a forecaster's standpoint, it would be difficult to separate the blowup days from the quiet days on the basis of projected 0800 MST wind speed profiles. This is a field in which a further study seems warranted.

This study indicates that the forecasters on large fires should consider carefully the wind speed profiles and surface temperature distribution as well as temperature lapse rates, surface weather charts, and other observational material. If it were possible to dispatch a mobile radiosonde observational unit to large fires the information gained would be very valuable to the forecaster in predicting fire behavior. The cost of constructing and operating a mobile radiosonde unit would be considerable, but in view of the terrific property losses and suppression costs on large fires, such a unit would be justified. Pilot balloon observations would be impractical because of visibility restrictions, and only very rarely does a large fire occur close enough to an upper air observational station to make the data representative of conditions over the fire.

Acknowledgments

Our thanks to George M. Byram and Charles C. Buck of the U.S. Forest Service and to DeVer Colson of the U.S. Weather Bureau for their reviews and comments on the first draft of this paper. Our thanks also to the staff of the Boise National Forest for their patience in answering questions and supplying data.

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A Key to Blowup Conditions in the Southwest?*

Robert W. Bates

Can minimum nighttime temperatures be used in some areas as an indicator of one type of blowup conditions? A preliminary study of several project fires occurring on the Tonto, Sitgreaves, and Prescott National Forests in the years 1951 to 1961 showed that the night before each of these fires blew out of control was unusually warm. Of particular significance is the fact that most of them occurred following the warmest nights of the critical June fire period and often occurred at a peak after several consecutive days of rapidly rising temperatures. For some fires which occurred in July and September this also appeared to be true. Only 4 of the 13 fires in the study failed to show this, but even for those 4 the temperatures were at or above what is believed to be the critical point. Tempera-tures on the nights preceding the start, or blowup, of these fires varied from a high of 81°F (27 °C) in the semidesert to 52 °F (11 °C) in the pine above the Mogollon Rim. These temperatures were all unusually high for the area where the fire occurred.

A deadly one-two combination of an unusually warm night followed by a warm day may indicate blowup fire conditions.

One-Two Combination

Why, in June, are some fires controlled at small size while others defy control no matter what the action taken? Why can you reach some lightning fires while they are still in the tree, yet others explode into major fires? Why does a quiet or apparently controlled fire suddenly act up? A look at relative humidity showed day-to-day fluctuations and seemed not to be an adequate answer to these questions. This study seems to indicate that a deadly one-two combination of an unusually warm night followed by a warm day may be the key.

If further study should prove this to be reliable, we could determine more accurately when to increase emergency fire forces and signal the start of intensive fire prevention. Following lightning, extra efforts to ensure early detection could be undertaken. By taking 8:00 a.m. readings of the previous night's minimum temperature and plotting them on a graph, it might be possible to spot the beginning of potential blowup conditions. There is usually a very sharp rise from relatively cool nights to hot nights over a period of only 2 or 3 days (figs. 1–4). Since this leaves very little time to get ready, the use of nighttime temperatures may be a better indicator than daytime temperatures because it allows more time to prepare.

Too, the charts on the 13 fires studied actually indicate a better tie-in using minimum rather than maximum temperatures.

Fire control organizations are not fully aware of this change in conditions as it is not indicated in present fire-danger meters by any definite rise in the index. During June, the Southwest is in extreme conditions already—so it might be said that conditions have suddenly gone from critical to supercritical.

Critical Nighttime Temperatures

An attempt to expand on this theory and determine an average date at which this temperature rise occurred proved futile. It can apparently happen almost any time in June in this area and may occur as early as May or as late as July in other southwestern localities. In 1956, the condition seems to have appeared in September on the Tonto National Forest on the Buckhorn Fire, coinciding with a dry fall period. However, June 10 is often mentioned as the breaking point on the Tonto. Each forest—possibly each district—would have to chart this separately and watch for the start of the temperature rise. From this temperature study, I have arbitrarily said that nighttime temperatures above 45° (7° C)

When this article was originally published, Robert Bates was a district ranger for the USDA Forest Service, Tonto National Forest.

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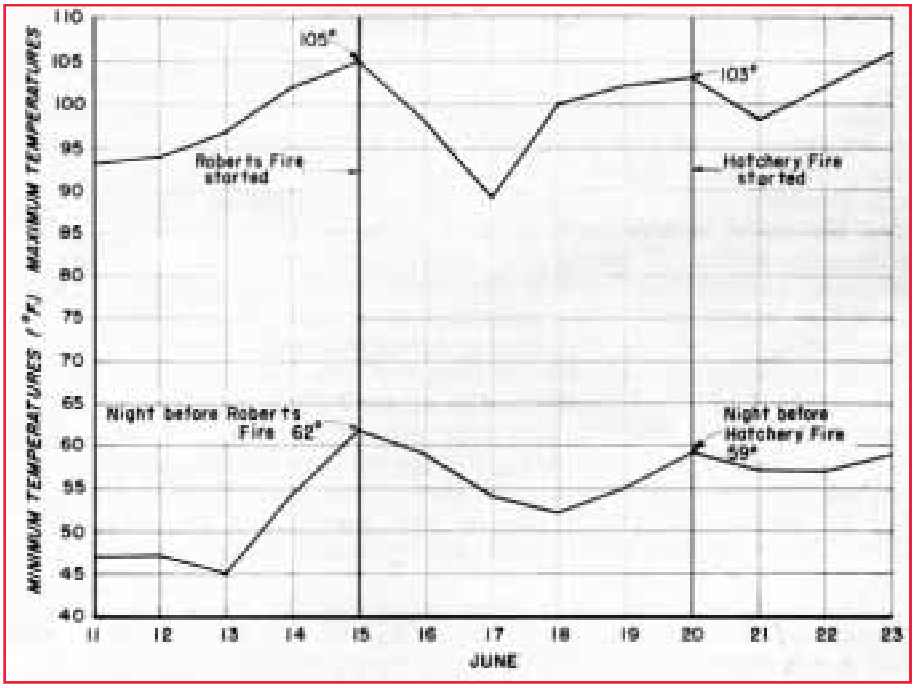

Figure 1—*Roberts and Hatchery Fires, June 1961.*

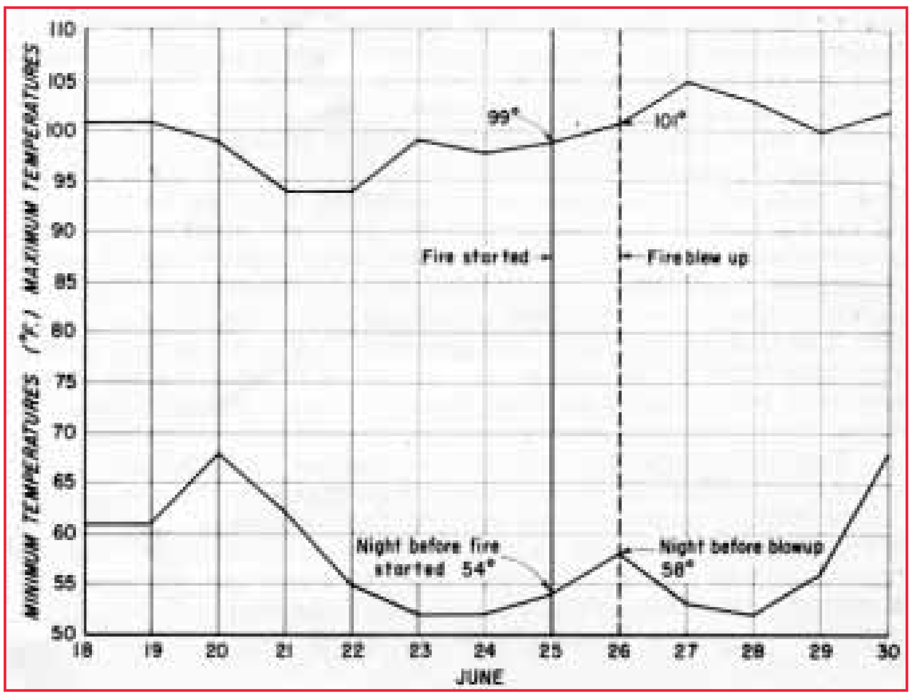

Figure 2—*Russell Gulch Fire, June 1951.*

are critical; and with those above 55° (13° C) blowup conditions exist. Cloudy nights keep nighttime temperatures high and may or may not be serious depending on whether the clouds disappear by morning. During June, there is probably only a small likelihood of nighttime clouds.

It is recognized that factors other than temperatures also contribute to fire size. Some areas have large fires during periods of high early spring winds; some fires are large because of organizational breakdowns, others because of topography; California has its Santa Ana winds; and so on. Undoubtedly, most of these fires would show temperature correlation only through coincidence. On the fires studied there was no attempt to make a complete analysis of all factors affecting the particular fire such as topography, wind, relative humidity, human error, time of day, fuels, and aspect. What was suggested by the study is that this one common denominator may provide a predictable basis for increased manning and a crash prevention effort during the critical periods.

Assumptions and Recommendations

Some assumptions and recommendations that can be made from this limited study follow.

1. High nighttime temperatures do not of themselves cause fires to blow up, but under these conditions, all other factors which tend to cause large fires are maximized.

2. If nighttime temperatures are rising, going fires must be secured before temperatures rise above the critical point. This is seen in the case of fires which blow up on the third or fourth day after start.
3. Fires occurring before and after temperature peaks are controlled at small size; some of them under much worse rate-of-spread conditions.
4. Spotting was a big factor in most of these fires although winds were not exceptionally strong. This fact was mentioned consistently in discussing these fires with people who had participated in the suppression. Some of these fires became big even though firefighters were on them at the very start when they were only a few feet across.
5. In June, before the summer lightning period, temperatures can be used as the basis for increased prevention effort at all levels.
6. When lightning occurs, detection forces could be augmented, especially in the case of long aerial patrol routes where some areas are not covered until 3 or 4 hours after daylight.
7. It might be possible to develop new rules for prescribed burning. Limit burning to times when nighttime temperatures are less than 45 °F (7 °C) and to a time when the temperature trend is down.
8. In the June dry period, rapidly rising nighttime temperatures often seem to presage the first lightning storm of the season. These high nighttime temperatures usually occur from 24 to 48 hours before the lightning storms occur. These first storms are often dry. ■

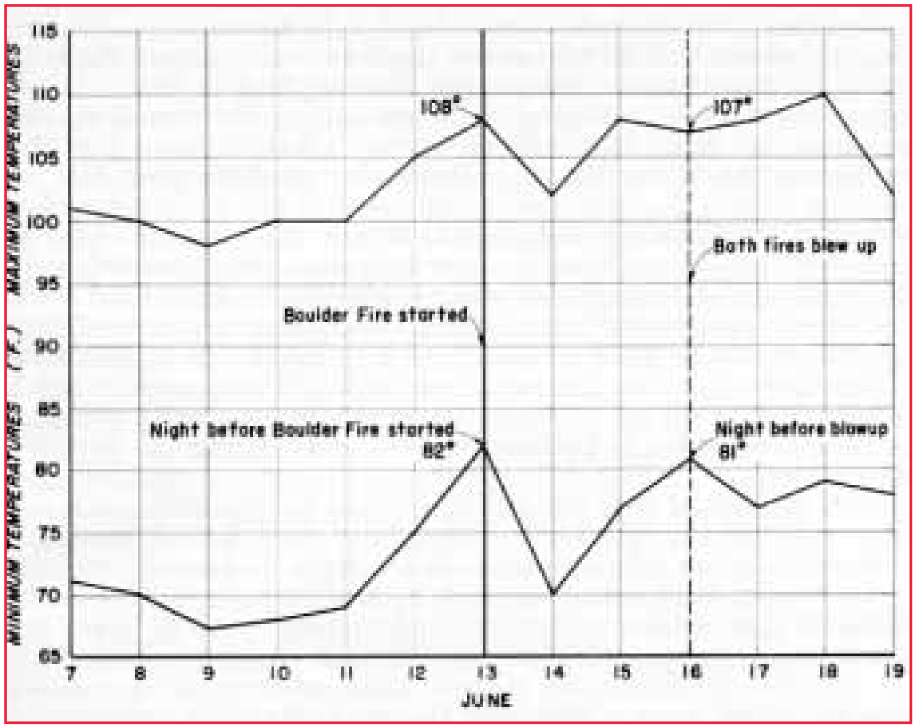

Figure 3—*Boulder and Pranty Fires, June 1959.*

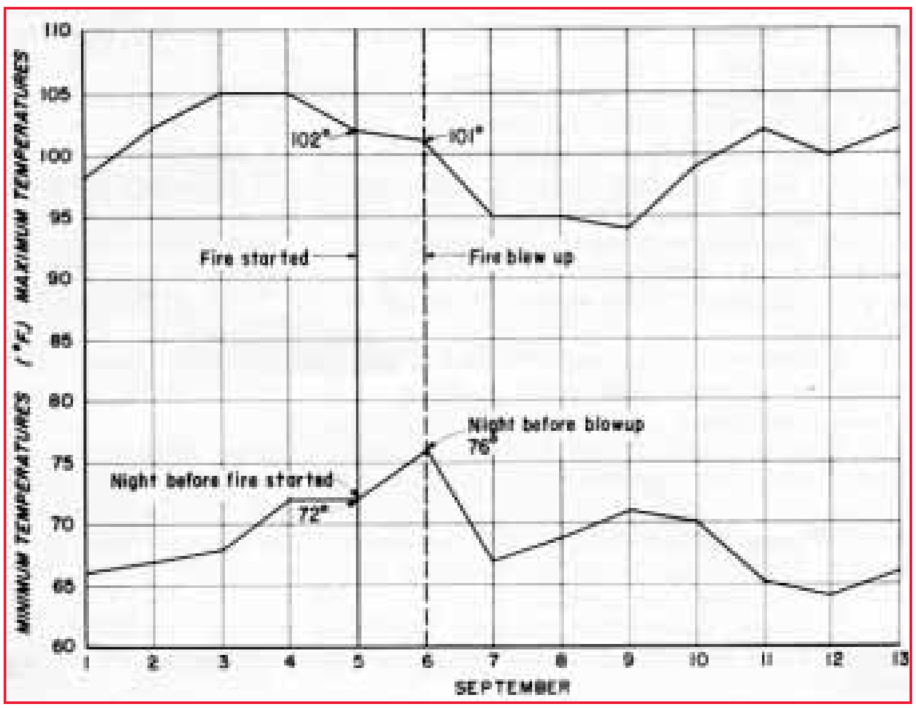

Figure 4—*Buckhorn Fire, September 1961.*

A Fire-Whirlwind in Alabama*

Gordon Powell

On the afternoon of February 7, 1962, Forest Ranger George Nunnelee and I were making routine equipment inspections in Covington County, AL. At approximately 2:30 p.m., while on higher elevations in the north end of the county, I commented to Mr. Nunnelee that a tall smoke in the south end of the county had the appearance of a potential "blowup fire." "Blowup" seemed highly improbable because of the condition of vegetation following a 0.1-inch (0.25-cm) rain two nights before. My comment was based on the appearance of the smoke which to me indicated adverse wind patterns over a control fire approximately 21 miles (34 km) due north of us.

Singular Smoke Column

The column of white smoke (fig. 1) formed an angle of approximately 75 degrees from the ground, rising toward the southwest. At approximately 5,000 feet (1,500 m) it bent to rise straight up to approximately 9,000 feet (2,700 m). At that altitude the smoke column reached a stratum of haze and scattered flattened clouds.

Like the smoke columns from other control fires in this vicinity (fig. 1), the column ascended to the stratum and flattened out in all directions. Smoke from the different columns then drifted in the haze layer toward the southeast. Nevertheless, this column was different from the other visible columns in that it was the only one that bent upwards and had a "mushroom" of vapor beginning to form immediately over the smoke column that penetrated the stratum "barrier."

> This smoke column was different from the others in that it bent upwards and had a "mushroom" of vapor that penetrated the stratum "barrier."

As we neared the control fire the billowing smoke indicated that it was very hot. Approximately 2 hours elapsed between the time we first noticed the smoke until we arrived in the vicinity. The fire had been set along a north–south road to back eastward into the wind through some heavy logging slash and grassy vegetation. An east–west road was the boundary on the north; firelines were maintained on the east and south. The fire had burned about 500 yards (450 m) from the north–south road.

Ribbon of Smoke

At approximately 4:50 p.m. we passed by about one mile (1.6 km) north of the fire and observed that the eastern part of the burn was the hottest. Driving southwest to approximately one-half mile (0.8 km) west of the fire we noticed something unusual about the western part in that there was a smooth appearing ribbon of smoke, steady and lighter in color than the surrounding smoke. This "ribbon" of smoke ran from the

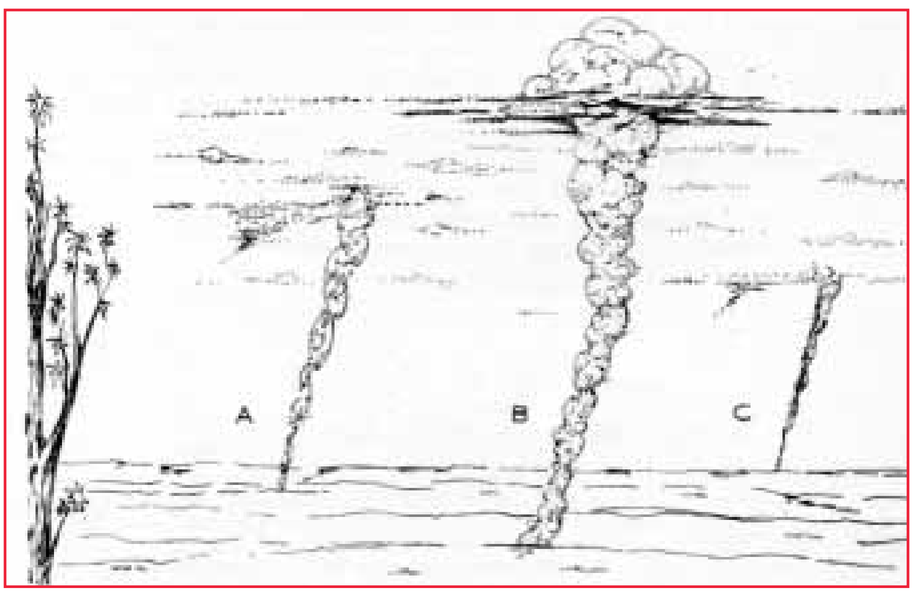

Figure 1—*Smoke columns over control fires as seen from a distance of 21 miles (34 km] to the north. Column B is the smoke with which we came in direct contact. Columns A and C are from fires several miles from B.*

When this article was originally published, Gordon Powell was a management forester for the Alabama Division of Forestry.

* The article is reprinted from *Fire Control Notes* 24(1) [Winter 1949]: 20–24.

A smooth ribbon of smoke, steady and lighter in color, ran from the ground to the "vapor cloud" over the smoke column.

ground to the "vapor cloud" over the smoke column. We felt that better judgment would tell us that this was a light refraction from the sun, yet it closely resembled a tornado funnel as it stood motionless amid the boiling smoke around it (fig. 2). Feeling as foolish as boys trying to find the end of the rainbow, we drove toward the ribbon of smoke.

The "hot part" of the smoke column was rising from the burning fuel with the wind to a point over the edge of the old burn and at that point rising straight up to the vapor mushroom and flattening out under the vapor in a very flat layer. Starting at the vapor mushroom there was a funnel of whirling smoke, small in diameter, reaching downward through the column of smoke, but not bending quite so abruptly as the other smoke, so that the base of the funnel was outside the fire and *in the old burn* near the east–west road on the north edge of the burn. It was there that we found it.

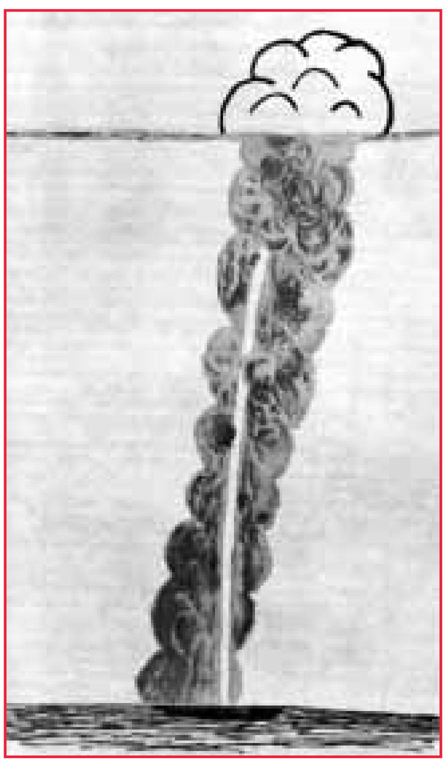

Figure 2—*Appearance of funnel as seen from the west.*

From any distance the funnel was whiter than the other smoke, but close observation revealed particles of burned litter whirling vigorously in the funnel. Some of these particles were released at higher elevations so that many burned particles were floating down from the smoke and settling over a wide area. The funnel was only about 6 to 10 feet (1.8–3 m) in diameter and appeared to be *the same diameter at the top as at the base*. The smoke in the old burn slowly drifted counter-clockwise around the funnel which was also whirling counter-clockwise.

Funnel Behavior

A close look at the funnel showed that it was not stationary as it first appeared, because the base wandered slowly around in an area about 50 feet (15 m) in diameter inside the old burn. As the funnel wandered slowly around, we followed closely on foot, studying its actions.

While the base moved through the burn, it "sucked up" all the ash in the center 15 to 20 inches (38–51 cm), exposing mineral soil. (However, it left no mineral soil exposed in the path because more ash was blown into it as the funnel moved off.) As this center 15 to 20 inches passed over a smoking limb or log, it caused a sudden vigorous spewing of flame in 4 directions, with each arm of flame resembling that from a blowtorch, and the 4 arms forming a cross quartering a circle by right angles of flames.

I stepped into the funnel and it proved to be quite intensive in wind velocity. In fact, it filled my clothes with particles of ash and made my ears "pop."

At about 5:20 p.m. there was a sudden rush of cool wind from the south, then from the northeast, and then from the west; and the funnel was gone. Then a steady, gentle breeze caused the smoke in the old burn to drift northward at first and then to drift back into the column of billowing smoke still rising as before from the burning tops of slash.

About 30 minutes elapsed between the time we first saw the whirlwind and the time that it disappeared. The map in figure 3 shows the general path of the funnel base and its position with respect to the fire.

Unusual Firewhirl

While watching this whirlwind, I realized it was not the usual "firedevil" or "dustdevil" type often seen in or near forest fires; nevertheless, I had no idea that others had seen and reported similar whirlwinds. However, having read other accounts (Graham 1952, 1957), this whirlwind seemed different in that acreage of the associated fire was small, the terrain is relatively flat, and the base of the funnel was in a cool part of the old burn. Passage over "hot spots" seemed purely accidental. It also

As the center of the funnel passed over a smoking limb or log, it caused a sudden vigorous spewing of flame in four directions.

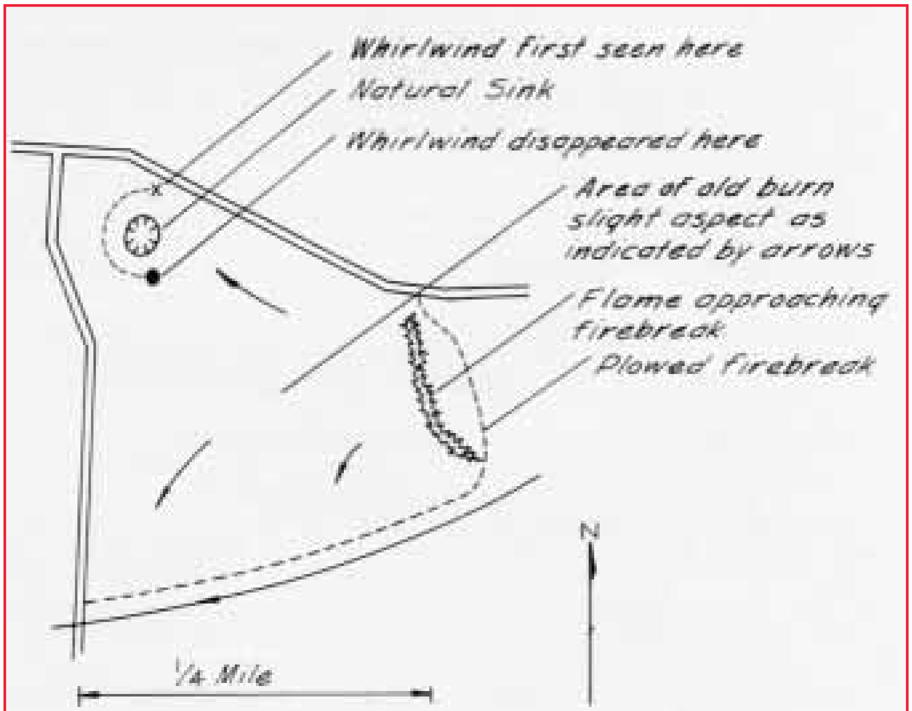

Figure 3—*Map of the fire area.*

appeared to be of a different type from the small firewhirls produced on a model scale (Byram and Martin 1962).

Worth mentioning is that had this firewhirl wandered into the flame it probably would have drawn up flame and burning particles rather than burned particles. Also, it might have increased considerably in violence.

Explaining its triggering and cause would be strictly a guess with me. Perhaps the intense heat of burning logging slash, perhaps the adverse wind patterns, or perhaps the cumulus cloud cap might be the key.

Environmental Factors

The weather, too, seems worthy of mention in association with the occurrence of the fire-whirlwind. According to information gathered from a nearby fire danger rating station and information furnished by the Southern Forest Fire Laboratory, there are several interesting area weather features.

At ground level the relative humidity was 22 percent, and the wind was from the east and northeast at 4 miles per hour (6.4 km/h). At 5,000 feet (1,500 m) the relative humidity was 55 percent, and the wind was variable up to 10 miles per hour (16 km/h). At 10,000 feet (3,000 m) the relative humidity was 70 percent, and the wind was from the northwest at 28 miles per hour (45 km/h). For what it may be worth, weather maps show that on the morning before the fire, there was a 100-mile-per-hour (160-km/h) jet stream over the area at 35,000 feet (10,700 m).

On the 8–100 meter type fire danger rating station at nearby Lawrence Tower site, the buildup index was recorded as 34, the highest fuel moisture percent was 6.5, and the burning index was 12 in Fire Class 3.

More Information Needed

Fire-whirlwinds have frequently been observed in all parts of the country where fires occur, and appear to have important effects on forest fires. It is likely that these funnels have often been observed but not reported in Alabama; or perhaps we are too busy fighting fire to see the whirls that are present. There is hardly enough information available to fully substantiate the theories of the cause of fire whirlwinds, yet such knowledge might answer many questions concerning unusual fire behavior that unexpectedly becomes peculiarly hazardous to men and equipment. I join other observers in hoping that more detailed observations will be reported.

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The Forest Fires of April 1963 in New Jersey Point the Way to Better Protection and Management*

Wayne G. Banks and Silas Little

In the spring of 1963, conditions conducive to severe forest fires prevailed rather generally throughout the Northeastern States. Scant rainfall, low humidity, and high winds combined to produce high and extreme fire-danger ratings for prolonged periods. On April 20 fire danger reached a peak in several areas. As a result, fast-moving fires of unusual intensity burned out of control.

The New England States were fortunate in escaping really large fires; the largest was approximately 700 acres (283 ha) in northern Maine. However, New England did have many small fires. Massachusetts, for example, had 4,861 forest fires in April, a record for that State and possibly for any State.

Fire disasters made the headlines of many newspapers. In New Jersey, newspapers reported more than 200,000 acres (80,000 ha) burned and 458 buildings destroyed (fig. 1). These reports listed 7 persons dead, many injured, and 2,500 evacuated—of whom 1,000 were left homeless. New York newspapers reported that a brush fire on Staten Island covered 10 square miles (25.9 km^2) and destroyed 100 homes. In the suburbs of Philadelphia, and elsewhere in

When this article was originally published, Wayne Banks and Silas Little were research foresters for the Northeastern Forest Experiment Station, Newtown Square, PA.

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In the spring of 1963, record low rainfall and humidity and high winds laid the foundation for a blistering fire season in New Jersey.

Pennsylvania, homes were threatened by numerous woods fires. Fast-moving fires were reported in Maryland. West Virginia, Virginia, and Kentucky were also hard pressed to control their many fires. Whether these newspaper statements were correct in all details is probably not very important. But what should be important to foresters and the general public are the reasons for these disasters, the ways of preventing them, and the probability of similar conditions occurring again. The second seems particularly important because on April 20, when most of the damage occurred in southern New Jersey, fire suppression techniques and pre-suppression measures proved woefully inadequate.

Weather Conditions

April 1963 was the driest April on record in New Jersey. Only 0.31 inches (0.79 cm) of rain fell during the first 29 days of the month, and 0.52 inches (1.32 cm) on the 30th.

Figure 1—*New Jersey home and vehicle destroyed by the April 1963 fires.*

On 22 days, maximum wind velocities at Trenton were 20 to 40 miles per hour (32–64 km/h). In the 30 days prior to April 20, precipitation deficiency amounted to 3 inches (7.6 cm).

Relative humidity on that day dropped from 50 percent at 6 a.m. to 23 percent at 10 a.m. and remained between 20 and 23 percent until nearly 5 p.m. Temperature was 80 °F (27 °C) at midday, dropping to 53 °F (12 °C) at midnight. Fuel moisture indicator sticks at two fire-danger stations showed 3.5 and 4.1 percent fuel moisture at 2 p.m. At both stations the buildup index was 100 and the burning index was 200 on the 8–0 meter.

The estimated average wind velocity for April 20 was 20 miles per hour (32 km). The average of the maximum wind velocities reported from the three nearest Weather Bureau offices was 33 miles per hour (53 km), and gusts were probably as high as 50 miles per hour (80 km). Turbulence prevailed at low levels, and many small whirlwinds developed. Prevailing wind direction veered during the day from northwest to west, then back to northwest, and to almost north late at night.

Comparable Conditions in the Past

Because April was such a black day for fire protection in New Jersey and in sections of neighboring states, we attempted to determine the past frequency of such weather conditions. Weather Bureau records for the previous 49 years indicated that the spring fire weather was never quite so bad as in 1963. During that half century only four spring days had conditions that approached those of April 20, 1963. In early May 1930, when fires were rampant in South Jersey, surface burning conditions on two days approached those of April 20. The chief difference was that, in the 30 days preceding April 20, 1963, there had been an inch (2.5 cm) less precipitation than in the 30 days preceding May 2 and 4, 1930.

Foresters and the general public should ask why the fires occurred, how can they be prevented, and what is the likelihood of similar weather conditions occurring in the future.

However, previous seasons have had conditions comparable to April 20 in both wind velocity and drought. Since 1913 there have been six fall days of apparently similar conditions, and one summer day and four fall days when conditions approached those of April 20. However, because of less wind within stands in summer and early fall, the shorter days of fall, and less fresh leaf litter, we doubt that any of these days actually provided burning conditions as critical as on April 20, 1963.

On several other days of that April there were high winds. Fuel moisture was low, and at one danger station the buildup index registered 100 on 10 days. But at no time did all the elements of fire danger combine to create conditions so severe as those on April 20, although April 29 was fairly close.

Fire Behavior

Because of the drought, low humidity, and high winds, some of the fires of April 1963 started and spread in fuels so light that normally they are considered insufficient to maintain a fire. Owing to intensity, rapid spread, and ability to carry across very light fuels, suburban fires were difficult to suppress, and many buildings were lost.

In the heavier and more flammable fuels of the New Jersey Pine Region, the wind-driven fires burned with great intensity and caused severe damage to both oaks and hard pines. Fires spread rapidly across upland sites where there was relatively little fuel, as on areas where prescribed burning had been done 1 or 2 years earlier. On such sites a very light cover of pine needles was sufficient to maintain a fire. Oak leaves, where present, were blown across bare spots so that fires advanced rapidly even in scattered fuels.

Because fuels contained so little moisture and winds were so strong, the rate of spread of fires on April 20 was extreme almost regardless of fuel type. One of the larger fires, which started just north of the Lebanon State Forest, advanced about 3-1/2 miles (5.6 km) in 2 hours and 9 miles (14.5 km) in 6 hours. Probably the rate of spread on April 20, 1963, has been matched or even exceeded by other fires for short periods. However, foresters and wardens with many years' experience in fighting South Jersey fires could recall no case where the sustained rate was as high as on April 20. The Forest Fire Service of the New

> This whirlwind seemed different in that acreage of the associated fire was small, the terrain is relatively flat, and the base of the funnel was in a cool part of the old burn.

Jersey Department of Conservation and Economic Development provided data from 1924–63 that showed only 1930 to be comparable to April 1963 in number of large fires and their rate of spread. The two fires with the greatest area burned per hour were in 1963 and covered about twice as much ground per hour as any of the much publicized 1930 fires for which complete data are available. The data also emphasize the importance of April and May in local protection problems.

Suppression Difficulties

The New Jersey Forest Fire Service uses a combination of suppression techniques and several kinds of machines. The latter include trucks of various sizes up to 500-gallon (1,893-L) tank trucks equipped with 4-wheel drive; aircraft equipped to drop 150 to 200 gallons (568–757 L) of retardant; and tractor and plow units. Backfiring and handtools are also used, and backfiring plays a large part in stopping head fires and tying in flank fires.

On April 20 none of the suppression methods proved effective. For example, only one of the three pilots employed for firefighting was willing to fly, considering the 40-mile-per-hour (64-km/h) winds and the low-level turbulence. Effectiveness of tractor and plow units on April 20 was confined to areas with no more than 1 year's accumulation of litter, and that mostly pine needles. Tank trucks and handtools were useful in controlling spot fires in 1-year needle litter, but in oak leaf litter neither was enough. For example, at about 1:45 p.m. between New Lisbon and Route 70, a spot fire started along a road within 50 feet (15 m) of a tank truck, its crew, and several men with handtools. At that particular moment, a small whirlwind spread this fire for 100 to 200 feet (30–60 m). High winds forced the abandonment of suppression attempts, even though the area had only a year's litter since the last prescribed burn.

The extremely dry and windy conditions caused much difficulty in backfiring. Attempts to backfire and hold the line along sand, gravel, and even blacktop roads had to be done slowly and carefully to prevent the backfires from jumping the road. Backfires along a State highway crossed the road even though the cleared strip in that area ranged from 75 to 120 feet (23–37 m) wide. In some places head fires arrived before backfiring could be completed.

Effectiveness of Prescribed Burns

Prescribed burning in the winter to facilitate suppression of fires in the South Jersey Pine Region has long been advocated. However, this measure too proved less effective on April 20, 1963, than in previous wildfires.

In general, prescribed burning 1 or more years before the wildfires of April 20 did not facilitate suppression appreciably, especially where oak litter was an important component of the fuel complex. In these areas the 1963 fires were not stopped under fuel conditions that had permitted the suppression of earlier wildfires. More recent burns that left some surface fuel remaining only reduced the damage, and others that removed nearly all the fuel did not stop the fire. On one firebreak where the 1962–63 winter burn had consumed only the top litter, the fire burned with sufficient intensity to kill many of the oaks and severely scorch the crowns of the pines (fig. 2).

Rapid combustion of wind-tossed dry fuels in the April 20 fires created extreme temperatures and greater damage on prescribed burn areas than in other years. On areas with 1 year's accumulation of litter after periodic burns, head fires killed most of the oaks but not the overstory pines. Strong flank fires on such areas killed about half of the overstory oaks. Damage to oaks in areas with 2 or more years' accumulation of litter was usually about as severe as in stands with no previous prescribed burning. However, any reduction of fuel was apparently effective in reducing damage to pines.

Preventing Similar Disasters

Prevention. One of the major fires of April 20–21 reportedly started where a debris burner had a permit for night burning. The fire held over in a brush pile and broke out on April 20. At the nearest fire-danger station the buildup index had reached 59 on April 19, climbed steadily to 100 on the

Figure 2—*The stands on both sides of this road had been prescribe-burned in the winter of 1962–63. A good burn had been obtained on the left side, and here the fire of April 20, 1963, burned only a few scattered patches. On the right side, only the top litter had been burned by the winter fire, and much damage was done in April.*

17th, dropped to 97 on the 18th, but was back at 100 on April 19th.

We suggest that no burning permits, for either day or night, be issued when the buildup index is 60 or more according to the system now in use in the Northeast. Any permits issued when the buildup index is less than 60 should be so limited in time that they will expire before the index reaches 60.

Camping should be prohibited at remote sites when the buildup index reaches 60, and at all areas when the index is 80 or more. Prohibiting camping may meet resistance; yet such a measure is needed as much for the safety of the campers as for fire prevention. On April 20, 1963, a large group of Boy Scouts were camped in the Lebanon State Forest, where only a slight shift in wind direction would have brought a head fire, quite possibly before they could have been evacuated.

Another important prevention activity is reduction of fuel through prescribed burning during the winter in types where these burns are silviculturally desirable. Earlier recommendations for the South Jersey Pine Region appear to remain sound:

1. For maximum protection of improved property, burns at 1- or 2-year intervals be used.
2. For extensive forested properties, barrier zones be prepared by the prescribed burning of belts of upland sites, which would reinforce swamps or other natural firebreaks.
3. Eventual development of a checkerboard pattern on upland sites in the larger unimproved holdings, i.e., a pattern of young unburned stands and of older, periodically burned stands. Prescribed burns at 4- or 5-year intervals are considered essential in a protection program.

In years like 1963, only recently burned areas will be effective barriers against fire. But in view of the rarity of such extreme fire danger, an annual and more costly fuel reduction seems justified only near buildings or other improved property.

Management for pine over oak, besides favoring the production of timber, can facilitate fire control under certain conditions. Periodic prescribed burning in areas with few oaks results in less rapid combustion of the rather compact needle litter. In April 1963 the burning needles were not carried long distances by the wind as oak leaves were. Suppression was therefore easier in stands that had few oaks.

Presuppression. What can be done in presuppression to help ensure initial-attack success under fire conditions such as had developed in April 1963? We suggest broadening the scope of the working agreements between the New Jersey Forest Fire Service and other State agencies, companies, and individuals to furnish equipment when it is needed. Needed equipment from outside sources should be on standby whenever the fuel and weather conditions indicate a conflagration threat.

Protection agencies might also consider providing tanks of 500-gallon (1,893-L) capacity or larger and equipped with their own pumping units. These tanks could be strategically located, and stored in such a way that they could be mounted on flat-bed or dump trucks and put into operation quickly.

The responsibilities of most forest fire protection agencies today extend to much more than protecting woodlands alone. The extension of residential building and industry into rural wooded areas, the reversion of farmland to forest, and the development of forest recreational areas are now making high-value improvements and even lives dependent on the efficiency of forest fire suppression. Public recognition of these increasing responsibilities must be encouraged if protection agencies are to receive the financial support that they need.

Suppression. What can be done to control fires under conditions such as prevailed in New Jersey and other parts of the Coastal Plain in April 1963? When the high winds eliminated the small airplane as a working tool, suppression forces found themselves back to conventional weapons—tanker trucks, plows, and hand crews—which were inadequate. Perhaps larger aircraft, carrying heavier loads and effective under windier conditions, and larger tanker trucks with multiple pumping units might be feasible. Although the latter might not be adequate for such fires as occurred in April 1963, they should prove effective against many fires that cannot now be attacked directly. They could also be a valuable aid to backfiring.

Also the use and coordination of equipment could be improved. Much difficulty was experienced in holding backfires, even along wide cleared rights of way. Could tanker units of the type available, supported by large tank trucks for refilling them, adequately fireproof the fuels on the opposite side of the roadway to permit rapid and safe backfiring from such roadway? This type of operation might require planning and practice. It might very well resemble the "one-lick" method used by hand crews, with several tankers proceeding in tandem at a reasonably good speed, each one spraying a designated portion of the fuels. Studies to determine the feasibility of this approach should be initiated. ■

The Harrogate Fire—March 15, 1964*

B.J. Graham

The Harrogate Fire started at about 2:30 p.m. in Section 1938, Hundred Kanmantoo, on Mr. Brice's property (fig. 1). The fire traveled mostly east through valuable grazing land and burned approximately 1,600 acres (650 ha). The exact cause of the fire is not known, but after investigations it is thought to have started from a spark from the exhaust of a chain saw.

Most of the area consisted largely of annual grassland; there was a scattering of Eucalypt trees. The winter and spring preceding the summer of 1964 were very wet, and the summer was mild. Therefore, pasture fuels in this area were abundant and completely cured. The temperature reached 92 °F (33 °C) in the afternoon of March 15, 1964, with a light wind blowing west to northwest. The winds were consistent; the approximate mean velocity was 10 miles per hour (16 km/h).

Fire Behavior

Commencing at Section 1938, Hundred Kanmantoo, the fire swept generally east at 2.5 miles per hour (4 km/h). The rate of spread of the head fire was affected by such topographical features as creeks and ridges. These features and the country's rocky nature restricted access. Where possible, the flanks were worked by fire crews, and the head fire was confined largely to a front of 90 chains (5,940 feet [1,811 m]).

> Where possible, the flanks were worked by fire crews, and the head fire was confined largely to a front of 90 chains.

By 3:05 p.m. the fire had spread for approximately 70 chains (3,960 feet [1,408 m]) east. By 3:12 p.m. it had spread for another 60 chains (3,960 feet [1,207 m]), but the flanks were being controlled and the head fire continued east.

At 3:20 p.m. a pincer movement by units working on both flanks was becoming effective, and the head fire, still moving east, was narrowed to a 70-chain (3,960-foot [1,408-m]) front. The fire had then traveled approximately 2 miles (3.2 km). At about this time the Brukunga Unit was destroyed, and one man (the driver) was badly burned. The farm buildings at White Hut, which were in the fire's path, were saved.

At 3:30 p.m. the head fire hit the Nairne–Harrogate road. It jumped over, but it was controlled after burning 50 acres (20 ha). The rest of the front was controlled along the road, and the fire was considered under control. The time was 3:50 p.m. The fire units then attacked the southern boundary and quickly obtained control.

Several miles of fencing were damaged, and approximately 1 mile (1.6 km) of it must be replaced. Some fences of sawn hardwood and iron droppers withstood the fire, but the wire components will last for a much shorter period because of the deterioration of the galvanizing content.

Effective Suppression

The organization and method of attack employed by fire controllers was extremely efficient and resulted in the saving of large areas of heavily grassed land. Seventeen Emergency Fire Service units, capably supported by private units, attacked the fire on the first day, and a lesser number of conducted patrolling and mopping-up operations on March 16.

The confining of this fire to approximately 1,600 acres (650 ha) is even more praiseworthy when one considers the rocky nature of this inaccessible country and the fact that except for the Nairne–Harrogate road no natural or artificial barrier was near the fire. ■

When this article was originally published, B.J. Graham was a bushfire protection advisor in Australia.

* The article is reprinted from *Fire Control Notes* 27(1) [Winter 1966]: 7, 15. It was originally adapted from the South Australian Emergency Fire Services Manual, 1964.

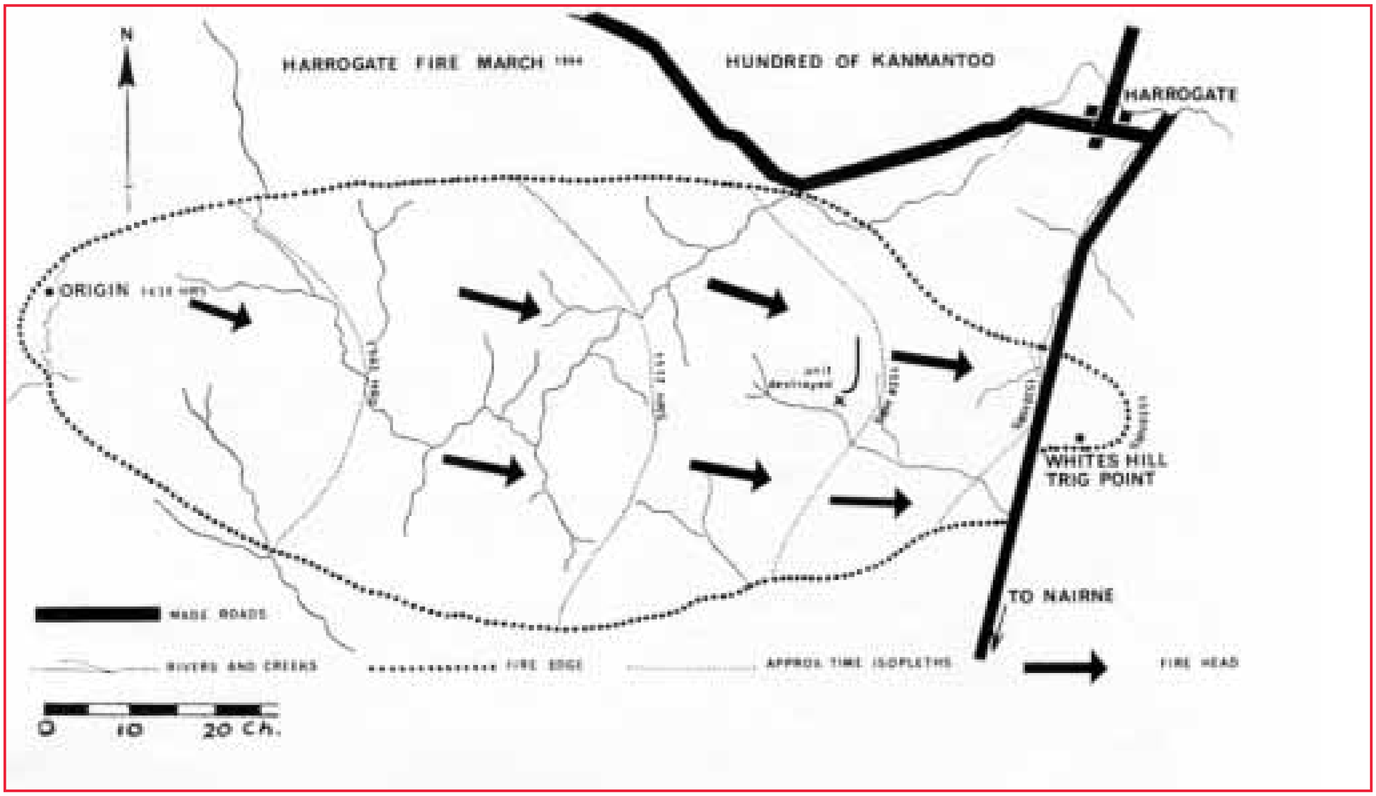


Figure 1—*Map showing progress of the Harrogate Fire.*

Websites on Fire*

Wildfire Mitigation Programs

This national database is a clearinghouse for information on State and local programs for mitigating the risk of wildland fire on private lands. Users can get information on more than 129 nonfederal policies and programs. Information about regulatory programs, educational efforts, homeowner assistance, and community recognition events is easy to find by searching a State or program index or by using the advanced keyword option. Developed by Louisiana State University and the USDA Forest Service's Southern Research Station, the site uses sources ranging from statutes and agency regulations to State, county, and local fire personnel. "Featured programs" have included the Colorado State Forest Service's Wildfire Hazard Mitigation Program, Texas Urban Wildland Interface Exhibits, and Kittitas County Junior Firewise Educational Program.

Found at **<http:www.wildfireprograms.com>**

* Occasionally, *Fire Management Today* briefly describes Websites brought to our attention by the wildland fire community. Readers should not construe the description of these sites as in any way exhaustive or as an official endorsement by the USDA Forest Service. To have a Website described, contact the managing editor, Hutch Brown, at USDA Forest Service, Office of Communication, Mail Stop 1111, 1400 Independence Avenue, SW, Washington, DC 20250-1111, 202-205-1028 (tel.), 202-205-0885 (fax), hutchbrown@fs.fed.us (e-mail).

THE FIRE BEHAVIOR TEAM IN ACTION: THE COYOTE FIRE, 1964*

John D. Dell

On a large wildfire, the fire boss bases much of his strategy on information provided by his staff and other assistants. In 1964, fire behavior teams furnished advice at several forest fires in southern California. Each team, directed by a fire behavior officer, gathered and analyzed vital information on weather, fuels, and topography. The team concept (see the sidebar), originally described by Countryman and Chandler (1963), proved an effective method for evaluating the behavior of fast-moving fires. This article briefly describes how a fire behavior team operated on the 67,000-acre (27,000-ha) Coyote Fire that burned on the Los Padres National Forest in September 1964.

Coyote Fire

At 11 p.m. on September 22, 1964, a fire behavior team was dispatched from the Riverside Forest Fire Laboratory to the Coyote Fire at the request of the Los Padres National Forest. Santa Ana winds, surfacing at night, had swept an almost-controlled brush fire across firelines into heavily populated residential areas. By early morning, the fire, then out of control, had burned more than 600 acres (240 ha). One of the most devastating conflagrations in recent local history was imminent. However, during the day shift the fire ceased to threaten the residential areas as the Santa Ana winds returned aloft. The sea breeze and upslope wind caused the fire to spread into the mountains.

Santa Ana winds, surfacing at night, had swept an almost-controlled brush fire across firelines into heavily populated residential areas.

At the Coyote Fire camp, the fire behavior officer was briefed by the U.S. Weather Bureau's fire weather forecaster on existing and anticipated weather. The fire behavior officer made a behavior forecast ready for the plans chief before each shift so fireline overhead could be thoroughly briefed. Also, any sudden deviations were explained immediately to the fire boss, and a revised forecast was made.

Team members, meanwhile, began taking pilot balloon observations of winds aloft, making ground observations, studying preattack maps, and talking with fireline overhead in order to better understand fire

Role of the Fire Behavior Team

Team observations and the fire behavior officer's interpretation combined with reports of scouts and line overhead are extensively used in fire control planning.

An important function of the fire behavior team is fire weather observation. By working closely with the U.S. Weather Bureau's fire weather forecaster, the team saves much time and avoids duplication of effort. Information provided by the fire weather forecaster includes maps of the latest synoptic weather transmitted by fax from the Weather Bureau.

Fire behavior team takes a pilot balloon observation with theodolite to determine patterns of local winds aloft. Photo: USDA Forest Service.

Team members may also make upper air soundings of humidity and temperature or measure the winds aloft.

When this article was originally published, John Dell was a fire research technician for the USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.

* The article is reprinted from *Fire Control Notes* 27(1) [Winter 1966]: 8–10, 15.

conditions. Equipped with its own transportation, radio net, and instruments, the team was able to disperse to various locations on the fire. A communications net linked the team with the fire behavior officer, and pertinent information was sent regularly. Ground observations were made of temperature, humidity, windspeed, and wind direction; type, density, and condition of fuels in the path of the fire; topography and aspect; current fire behavior; and trouble areas. The fire behavior team made a thorough surveillance of the area above and to the flanks of the main front. It noted that strong northeasterly winds were still aloft, although the layer had been rising since morning. The odds were against these winds surfacing as they had the night before, but the forecast indicated this might happen.

Wider Fire Front

Early on the evening of September 23, a team member was sent to the ridgetop above the fire to observe its behavior and to look for any signs of unusual changes. At 7 p.m., he noted that the humidity had dropped to 14 percent. Light and variable winds gradually developed into a strong northeasterly blast that gusted up to 35 miles per hour (56 km/h). The fire began to intensify on the upper slopes. These factors indicated the fire would probably resume the same pattern as on the previous night—but on a wider front. The fire behavior team immediately reported these observations to the fire behavior officer at fire camp. He, in turn, notified the fire boss so crews on the line would be warned. By 7:40 p.m., these winds were felt in Santa Barbara.

The fire behavior officer made a behavior forecast ready for the plans chief before each shift so fireline overhead could be thoroughly briefed.

These winds continued most of the night. At 2 a.m. (September 24), temperatures as high as 92 °F (33 °C) and humidities as low as 10 percent were reported at the Weather Bureau's fire weather mobile unit at the fire camp. Fire again swept through residential areas in the foothills.

By morning the fire had burned along the entire Santa Barbara front, over the ridge, and down into the Santa Ynez River drainage. Personnel were added to the fire behavior team to increase coverage of the growing conflagration. The fire behavior officer and part of the team were requested to observe and advise on a critical backfiring operation on the west side of the fire. Another team member made an upper air sounding by helicopter, in order to determine moisture in the lower atmosphere and atmospheric stability over the fire.

In the fire behavior forecast for September 24, prepared early that morning, it was predicted that strong Santa Ana conditions would continue at high levels, but would weaken at low levels during the day. It was reported that fuels were very dry and hot runs could be expected where favored by wind or topography. Atmospheric instability would favor the development of large convection columns, spotting, and firewhirls. Santa Ana winds were again likely to surface.

Fire Size Doubled

During the next few shifts the Coyote Fire nearly doubled in size. More than 3,000 firefighters from all parts of the Western United States joined in the battle. Zone fire camps were set up at several points around the fire in order to place the manpower where it could be shifted most efficiently. This, of

The huge Coyote Fire near Santa Barbara, CA (September 22 to October 1, 1964), required the use of three fire behavior teams. The fire burned more than 67,000 acres (27,000 ha) of brush-covered watershed. Photo: USDA Forest Service.

course, created a difficult communications problem for the fire behavior team. Sending fire behavior forecasts to all these zone camps over already overloaded communications systems was difficult, yet very essential. Every effort was made to bridge the communications gap and to relay forecasts to all camps, since many of the line personnel from distant forests were unfamiliar with some of the conditions that affect the behavior of southern California fires.

Another fire behavior team flew from the Northern Forest Fire Laboratory at Missoula, MT. Two more radio-equipped vehicles and extra backpack radios were brought in from Riverside. The fire behavior officer reorganized and divided his enlarged team and located the shifts at four points around the fire (fig. 1; also see the sidebar).

About 270 ground weather observations, 40 pilot balloon observations, and 7 upper air soundings were taken during the 6-day period the fire behavior teams were assigned to the Coyote Fire. From helicopter, truck, jeep, and by walking the fireline, team members observed and reported conditions on the fire almost continually.

Effective Team Approach

The Coyote Fire provided a good example of the effectiveness of the team approach in fire behavior

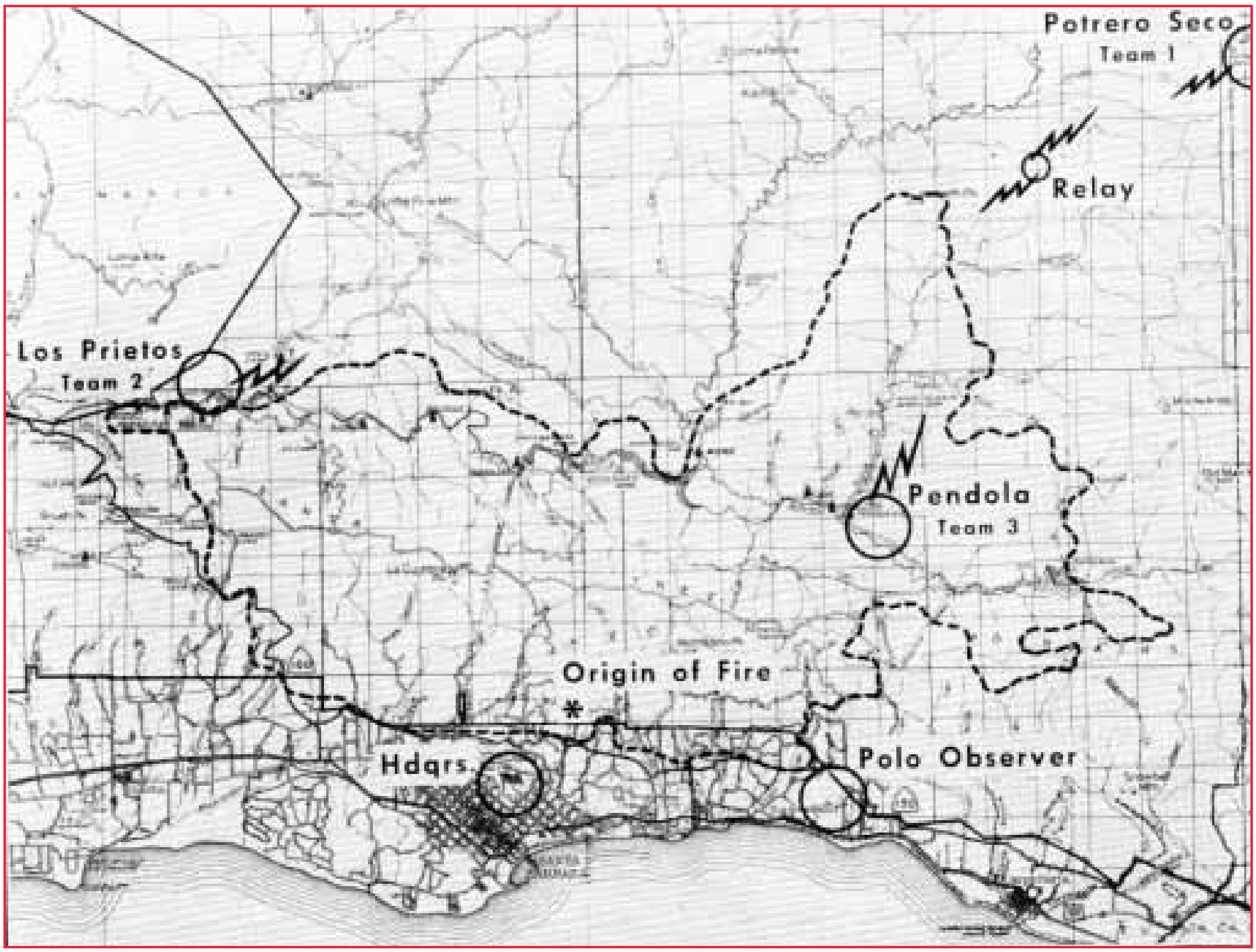


Figure 1—*As the fire spread north, the fire behavior officer divided and relocated his team for better coverage. Photo: USDA Forest Service.*

coverage of conflagrations. With information flowing in from various locations, the fire behavior officer has more time to appraise the situation, consult with the weather forecaster, and furnish a more complete and accurate fire behavior forecast. With team members in constant communication, he can be alerted to areas requiring his special attention. The fire weather forecaster, supplied with frequent weather observations taken by the team, benefits by having more detailed local information on which to base his forecasts.

The fire behavior team, as employed in southern California during 1964, is certainly not the final answer to fire control problems. It is, however, the best approach yet developed for keeping abreast of the behavior of a forest fire. Equipped with the instruments, tools, and trained personnel to do the job, fire behavior teams offer a service that—if properly used—can contribute to more effective fire control operations.

Reference

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

Fire Behavior Team Locations

On the 67,000-acre (27,000-ha) Coyote Fire, the fire behavior team worked from various locations to improve the information flow (fig. 1).

Potrero Seco Camp. The fire behavior officer and fire weather forecaster were headquartered here with the mobile weather unit. Team 1 was assigned to take pilot balloon observations and upper air soundings, and to make ground observations and reconnaissance ahead of the fire.

Los Prietos Camp. Team 2 was assigned ground observations and reconnaissance on the west and northwest sides of the fire.

Pendola Camp. Team 3 was assigned ground observations, pilot balloon observations, and reconnaissance in the upper drainage of the Santa Ynez River.

Polo Camp. One meteorologist was stationed here to take helicopter upper air soundings, ground observations, and reconnaissance on the south side of the fire.

Relay. Here a pickup truck equipped with radio relayed fire behavior observations from the roving teams to the fire behavior officer. The relay system, though makeshift, provided fairly good coverage of the fire, supplied more information on which to base forecasts, and made it easier for the teams to circulate forecasts to the various camps.

"Gleason Complex" Puts Up Huge "Plume": A Tribute to Paul Gleason

Paul Keller

On May 3, 2003, a unique "wildfire" occurred above the spectacular rock walls overlooking the Crooked River in fire-prone central Oregon. Although this incident never appeared in a situation report, in the hearts of the wildland fire community, it put up quite a plume.

Almost 100 men and women—no strangers to fire shovels and pulaskis—passed through the crew check-in area on that morning. Mostly "individual resources," they hailed from all over the Pacific Northwest, California, Idaho, Montana, Colorado—even as far away as Michigan, Massachusetts, and Maine. All for a single-day fire event, a different kind of planned ignition.

Gleason's Family of Fire

Their volunteer dispatch orders for this unforgettable day had been delivered a few weeks in advance. When they got the word—despite all extenuating personal circumstances—they came. They included nurse practitioners, laborers, artists, city planners, teachers, ranchers, business owners, and a gamut of folks working for the USDA Forest Service and other agencies involved in wildland fire management.

Paul Keller served under Paul Gleason as a squad boss on the Zigzag Hotshot Crew from 1985 to 1989. He is now a contract writer/editor for the USDA Forest Service's Fire and Aviation Management Staff, Washington Office, Washington, DC.

What would you want your legacy to be?
Paul Gleason: I suppose I would want my legacy to be that firefighters begin to realize the importance of being a student of fire and that I was able to make that happen.*

From wherever they came, they were *all* from the same original clan: brothers and sisters in the family of fire—more specifically, Paul Gleason's family of fire. That's why they had come from so far and so wide to the memorial "Gleason Complex."

Yes, the heat from this "fire" was the compassion for a fallen comrade. The torching was from the bonding of pure emotions. The flareups were the outbursts of appreciation and gratitude, coupled with the pangs of so many bittersweet memories.

All for Paul Gleason.

Paul Gleason watching over his crew during a prescribed fire. Photo: Tom Iraci, USDA Forest Service, Pacific Northwest Region, Portland, OR, 1988.

Hotshotting Shaped His Core

Any member of the national wildland fire community—from ground-pounder to fire behavior analyst and on up the food chain of the Incident Command System—who hasn't heard of Paul Gleason has obviously been in a deep Rip Van Winkle coma.

Gleason's wildland fire career spanned almost 40 years—from his teenage days as lead brush hook on southern California's Dalton Hotshots in the early 1960s, to his time as an adjunct professor for wildland fire science at Colorado State University, until the cancer burning within him bumped him from us forever in February 2003.

What are the biggest improvements you have witnessed in the wildland fire service?
Paul Gleason: I think that would have to be the increased focus on firefighter safety.

* From an interview with Paul Gleason in February 2003. For the full interview, see p. 91.

The Gleason Complex

A Celebration of Paul's life
& The Fire Community of the Northwest

Please join the Zigzag Hotshots (1976-2003) for a celebration of Paul's life and all of our connections in the fire community of the Northwest…

Date: Saturday, May 3, 2003

Location: **Roby's Farm at Smith Rock, Oregon** (5 miles north of Redmond, 3 miles east of Highway 97 at 9990 NE Smith Rock Loop, Terrebonne)

1300 **Crew Check-In**
Drop off your gear, set up your tent, add your photos to the PLANS BOARD!

1500 **Briefing at the "Barn"** *(A 5-minute walk from Roby's Farm. If driving, instead of turning right to go to Roby's Farm, continue past the gravel road 1/4 mile to the last house/barn on the left…signs will be in place)*
Slide show by Tom Iraci
Guest Speakers
Open Mike… share a story about Paul
*If you would like to speak or have slides to contribute, please coordinate w/Dennis Ghelfi at **dghelfi@fs.fed.us** or call (503) 622-3191 Ext 638*

1700 **Dinner** **please RSVP BY APRIL 20 to *Jeff@Lwarren.com*** or call (503) 622-3444
Burgers, Dogs, Garden Burgers provided *(contributions accepted!)*
Bring a side dish to share
Bring your own Beverages and lawn chairs (coolers/ice provided)

2000 **Night Crew Briefing**
Tactics: Feed the bon fire and tell enough old fire stories to last your lifetime…it might get deep, wear your boots!

Demob: **Sunday AM** ***campers please RSVP BY 4/20 to Jeff@Lwarren.com***
Coffee provided

Logistics: **To get to Roby's Farm:** *Go to Smith Rock State Park, turn right on Smith Rock Loop, a gravel road w/30 mailboxes and mobile home park just past the parking area. Proceed down the gravel road to the second house on the left… signs will be in place.*

Lodging: Lots of camping space available on site. Many motels and restaurants in Redmond, 6 miles south.

See Ya There!

Along the way, he excelled as a district fire management officer and forest-level fire ecologist for the Forest Service. Then the National Park Service wooed this mathematics graduate over to their side of the wildland fire equation. In the late 1990s, Gleason retired his Forest Service badge to become a wildland fire specialist and deputy fire management officer for the National Park Service's Rocky Mountain Region.

But the core of Paul Gleason's legendary wildland fire expertise came from his two decades of hotshot firefighting. Beginning in 1979, Paul devoted 12 years as superintendent of the Zigzag Interagency Hotshot Crew in the Forest Service's Pacific Northwest Region.

The Gleason Complex, appropriately based on a fire camp theme, was for the most part a gathering of people who had battled fire alongside Paul on his hotshot crew. It was his third public memorial. In March, two others were held: in southern California—near the site of the 1966 fatality Loop Fire, in which Paul lost 12 of his fellow firefighters—and west of Denver at the foot of the Rocky Mountain Front Range.

National Contributions

Gleason is widely recognized for his various contributions to the national wildland fire service. Chief among these are:

- Developing the LCES (lookouts, communications, escape routes, and safety zones) concept that has become a foundation for wildland firefighter safety;
- Helping to pioneer the wildland firefighter professional tree falling program; and
- Relentlessly pursuing the development of improved fire behavior training.

At the 2001 National Hotshot Workshop—before anyone knew cancer had ignited deep inside him—Gleason was given the Golden Pulaski Lifetime Achievement Award for his "longevity, leadership, versatility, and hard work" in dedicating his life to wildland fire management.

"Paul lives and breathes fire," explained Mike Hilbruner, the national applied fire ecologist for the Forest Service, at the presentation ceremony. "His years with the hotshot program, together with his Forest Service and [National] Park Service work in fire ecology, exhibit an outstanding versatility."

"Now," Hilbruner continued, "he is expanding his diversity of experience by becoming a university instructor—helping to prepare the next generation of fire managers and fire researchers."

Legend in the Fire Community

On Paul Gleason, from Michael Thoele's book Fire Line—Summer Battles of the West:*

"At forty-four, though he would not have claimed it for himself, he ranked as one of the lesser fire gods. A Pacific Northwest hotshot crew boss, he was something of a legend in his own time, a tough, aggressive, intellectual firefighter who was the stuff of stories told in fire camps from Alaska to New Mexico. In the world of Western wildfire, only two or three hotshot bosses were seen as his equal. …

"He had marched through all the ranks in the infantry of forest fire. He had paid his dues and earned his spurs. He was known as a man who quoted Chinese philosophers, read books on the art of warfare, and, in the off-seasons, was a rock climber who took on the big walls all over the West."

* Golden, CO: Fulcrum Publishing, 1995.

If you were to pick the most important character trait for an effective leader, what would that be?

Paul Gleason: It would be mindfulness. That ability to take in your surroundings and sort out the important stuff, to be aware, to be vigilant.

Gleason Forte: Teaching

Teaching was always one of this expert firefighter's prime fortes. In the last decade of Paul's life, myriad students came into contact with him, either directly or indirectly, through fire behavior courses S–290 to S–590. Paul literally "wrote the book" for all or parts of these national courses.

A Gleason Complex attendee remembered how much he enjoyed Gleason's fire critiques—his classroom dissections of incidents handled by his crew after they were over—almost as much as the actual firefighting under Paul.

There is no question that Paul's aggressive, heads-up actions saved severely burned firefighter Geoffrey Hatch's life on the 1990 fatality Dude Fire. A popular misconception is that this experience planted the seed for Gleason's LCES brainchild. The tragic impact of singlehandedly finding the six dead firefighters on the Dude Fire no doubt convinced Gleason of LCES's value. But this promoter of firefighter safety had been driving around with "LCES" on his pickup's custom license plates for the prior 4 years.

As a tribute to Paul's penchant for teaching—and learning—"The Paul Gleason Wildland Fire Scholarship Fund" has been established at Colorado State University to help support undergraduate students pursuing studies in wildland fire science. "This will help continue the work Paul was so dedicated to doing," explains his wife Karen Miranda Gleason.

Supporting Women on Fireline

Often overlooked in Paul's lengthy wildland fire legacy is his promotion and support of women on the fireline. One of the first women in the Nation to penetrate the historic all-male hotshot ranks—on the Zigzag Hotshot Crew in 1976—confided recently that she couldn't have survived and endured without Paul Gleason's encouragement and optimism.

A true teacher, he could instill in others not only his wildland fire savvy, but also his self-assurance and wily determination to try to understand and overcome all obstacles.

Indeed, as early as 1983, the iconoclastic Gleason had hired 7 women on his 20-person hotshot crew. By 1985, often to the bewilderment of other hotshot crews at the time, his lead pulaski was—watch out, fellas—a woman.

Gleason Trademark: Strength

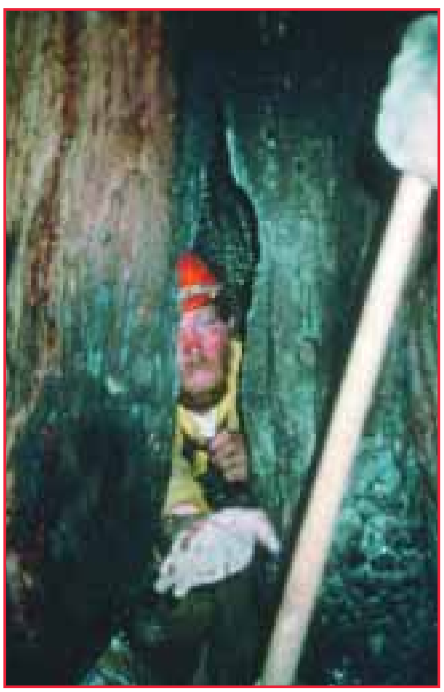
Gleason's sometimes seemingly unbridled physical strength, prowess, and resilience were another of this man's vibrant trademarks. "In 1978, I remember seeing Gleason do 45 good pullups," remarked a Gleason Complex attendee. In addition to being a luminary in the world of wildland fire, Paul was also a nationally recognized rock climber. He and his brother Phil claimed several first ascents of western precipices.

A memorial stone for Paul is being placed near the entryway to the Japanese Gardens in Portland, OR. It is a special vantage point from which the majestic, glaciated faces of Mount Hood, Mount Adams,

What makes you want to follow someone?
Paul Gleason: Confidence, knowing for certain that the person making the call has your safety foremost in their mind. And knowing that the job you are about to take on is the right thing to do, that it makes sense.

Mount St. Helens, and Mount Rainier—all climbed by Gleason (he summited Rainier at age 16)—can be viewed.

"Paul loves to challenge himself mentally and physically," Mike Hilbruner said at the Golden Pulaski award ceremony in 2001. "Those who have worked with Paul have seen him fall back into cutting order [dig fireline with the crew] whenever he could—without compromising his crew's safety. As superintendent, he didn't have to do that. But it's typical Gleason—demonstrating an around-the-clock, assertive, hands-on ground-pounder work ethic."



Paul Gleason reaching out for a fire tool to extinguish a hotspot inside a snag. Photo: John Gale, USDA Forest Service, LaGrande Hotshots, LaGrande, OR, 1987.

Trickster, Too

Paul's underlying, often irreverent and mischievous humor—yes, he had a good dose of trickster in his soul, too—was also celebrated at the Gleason Complex. But the Gleason traits recollected most by this part of his "fire family" were his remarkable tenacity and grit.

Paul was diagnosed with colon and liver cancer last spring. Next came 6 months of intensive chemotherapy. At the Gleason Complex, the people who helped take care of Paul as his body and energy slowly atrophied—but never his positive spirit—all marveled at this man's willpower and courage.

Paul Gleason was never afraid of death; he never gave up his hope to continue living.

Tough Loss to Absorb

To the incredulity and sorrow of the national—even international—wildland fire community, Paul Gleason died on the morning of February 27, 2003. He was 57 years old.

"I remain astonished at how vividly Paul lives on in our talk, his nonstop wisdom, and his sense for the beauties of more action and less talk," recalls Dr. Karl E. Weick, Rensis Likert Distinguished University Professor of Organizational Behavior and Psychology at the University of Michigan Business School. Weick is internationally renowned for his research on safety and decisionmaking in many environments, including wildland fire.

"Paul Gleason made a big impact on my life, despite a mere handful of contacts," said Dr. Weick. "I can only wonder in awe at the even greater impact he may have had on those who shared much longer, more intimate moments with him. I know that the whole [wildland fire] community must find this a tough loss to absorb."

Dr. Marty Alexander, a senior fire behavior research officer with the Canadian Forest Service in Edmonton, Alberta, ranks Gleason with a handful of "historic fire figures" in the last century in North America and Australia. "Unfortunately, Paul's time was far too short," Alexander laments. "But he definitely has had an effect on my outlook on wildland fire."

The Awesome Power of Fire

On December 12, 2002, Paul Gleason's wife Karen Miranda Gleason sent an e-mail to friends and family commenting on Paul's deteriorating condition:

Many of you have known Paul as a supervisor, a teacher and trainer, or just a great example of a positive person and firefighter who has lived life to the fullest in many interesting circumstances. … But when people refer to Paul as "a great role model," "an amazing person," even "a hero of sorts in the fire community," he doesn't understand this very well. He doesn't think he is special—just an ordinary guy who always wanted to do a good job. …

Paul has become more introspective now, spending much time in spiritual practices of Buddhism, which he finds comforting, focusing on the tenets of patience and compassion. Like a forest returning over time after a burn and the cycles of nature, so does Paul believe now in rebirth of all living beings. …

In short, now, without much ability to fight the fire, he is becoming the wise old master sitting on the rock in a purple robe after climbing to the top of the mountain, watching the awesome power of fire burning the landscape, which he will become part of one day.

Paul Lives On

In 2001, at age 55, under the mandatory Federal firefighter series retirement rules, Paul was required to retire. Still ablaze with enthusiasm and desire to pursue his wildland fire vocation, he wasn't about to downshift gears. So he sprinted directly into his fire sciences teaching post at the university level. He also hit the open road as a wildland fire science consultant. One of his first stops was Switzerland.

"Why would such a legendary fire person as Paul find time to come to a place where wildland fires definitely do not head the list of natural hazards?" asks Britta Allgöwer, senior research scientist and project leader in the Department of Geography at the University of Zurich. "Maybe that's just it," answers Allgöwer, who hired Gleason to come to her country to evaluate the fuel load and help in her quest to develop an ecosystem management strategy for the Swiss National Park. "Paul was genuinely interested in *everything* that concerns fire. He literally and truly lived fire."

Professor Allgöwer recalls how the pony-tailed Gleason "fell in love" with the Swiss National Park's forests. A portion of this Switzerland sojourn—in which Paul's wife Karen was able to join him—included pursuing his hands-on zeal for mountaineering. "Paul loved to explore everything around him," confirms Allgöwer. "And he also loved to explore his limits. Like trying to solo a 30-foot-high [9-m] 5.9 [difficult] climb late in the day all by himself—without being sure whether or not he could 'do the last couple of moves'—as he confessed to me later!"

"To work with Paul was a revelation," says Allgöwer. "Although the great wildland fire expert, he never superimposed his reasoning and opinions to his surroundings here. Together, ideas and hypotheses were formulated and passionately debated."

What do you consider your strengths to be?
Paul Gleason: [Pause.] Probably endurance. And more specifically, enduring adversity and using that experience to make something good come out of it.

Paul Gleason rock climbing at one of his favorite spots near Mt. Hood, OR. Photo: Jeff Hunt, Breckenridge, CO, 1982.

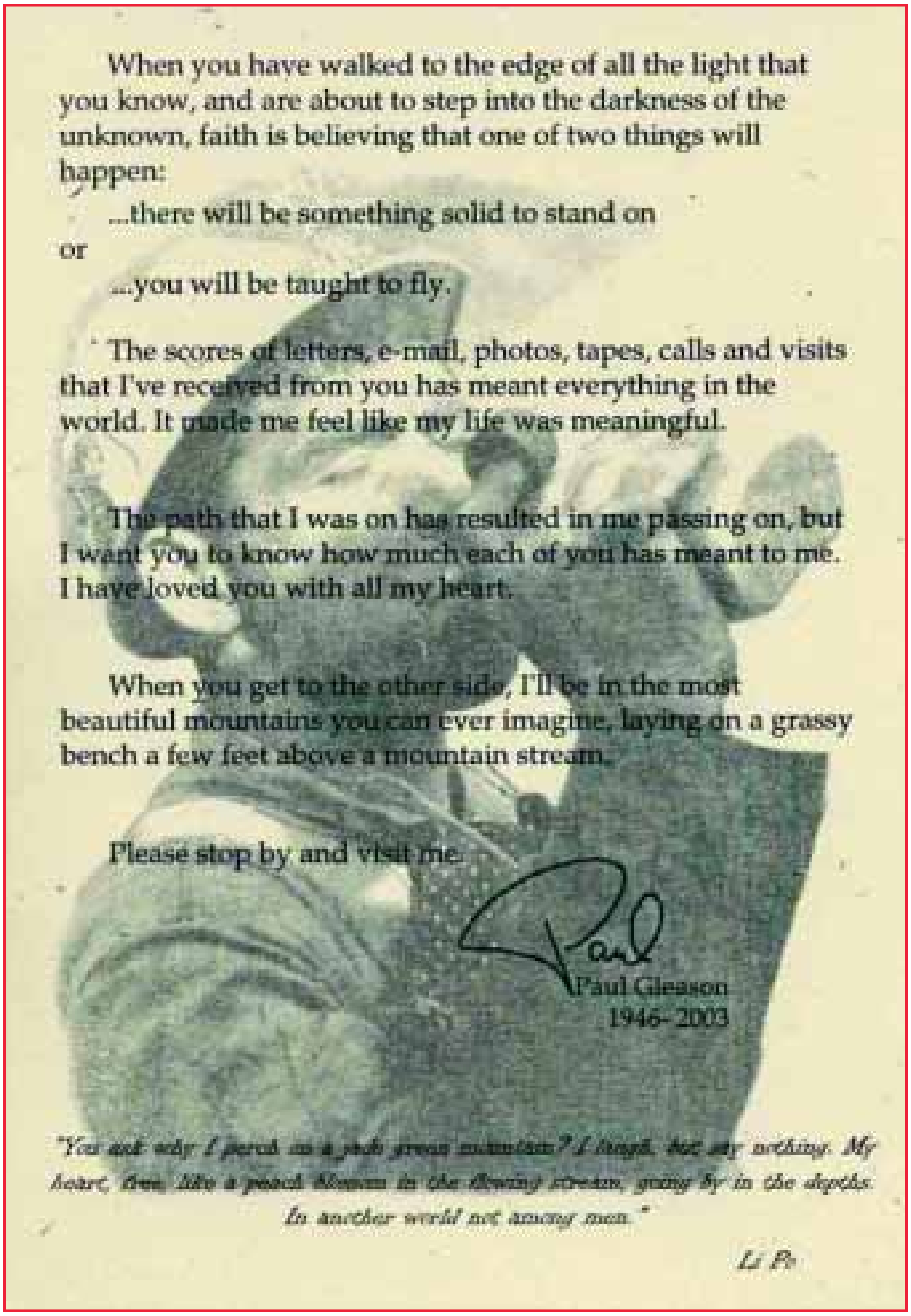
"Paul lives on," Allgöwer insists. "Whenever his name is mentioned, I always notice a warm glance in people's eyes—even more so, now."

Class and Grace

"Clearly, Paul was suffering beyond what any human is prepared to endure," said friend Merrill Kaufmann, a research plant physiologist for the Forest Service's Rocky Mountain Research Station, on the severity of Paul's aggressive, fatal cancer.

"Though, I can truly say that Paul lived through his recent illness with the same class and grace we have always known of him." ■

The class and grace for which Paul was known shone through in his written words of farewell to his friends:



When you have walked to the edge of all the light that you know, and are about to step into the darkness of the unknown, faith is believing that one of two things will happen:

...there will be something solid to stand on

or

...you will be taught to fly.

The scores of letters, e-mail, photos, tapes, calls and visits that I've received from you has meant everything in the world. It made me feel like my life was meaningful.

The path that I was on has resulted in me passing on, but I want you to know how much each of you has meant to me. I have loved you with all my heart.

When you get to the other side, I'll be in the most beautiful mountains you can ever imagine, laying on a grassy bench a few feet above a mountain stream.

Please stop by and visit me.

Paul

Paul Gleason
1946–2003

"You ask why I perch on a jade green mountain? I laugh, but say nothing. My heart, free, like a peach blossom in the flowing stream, going by in the depths. In another world not among men."

Li Po

Interview With Paul Gleason*

Jim Cook and Angela Tom

Paul Gleason's career as a firefighter spanned parts of five decades. He started as an 18-year-old crew member on a southern California hotshot crew and culminated his career as a professor of wildland fire science at Colorado State University.

During his career, Paul Gleason was front and center on three well-known fires of the modern era—the Loop Fire in 1966, the Dude Fire in 1990, and the Cerro Grande Fire in 2000.

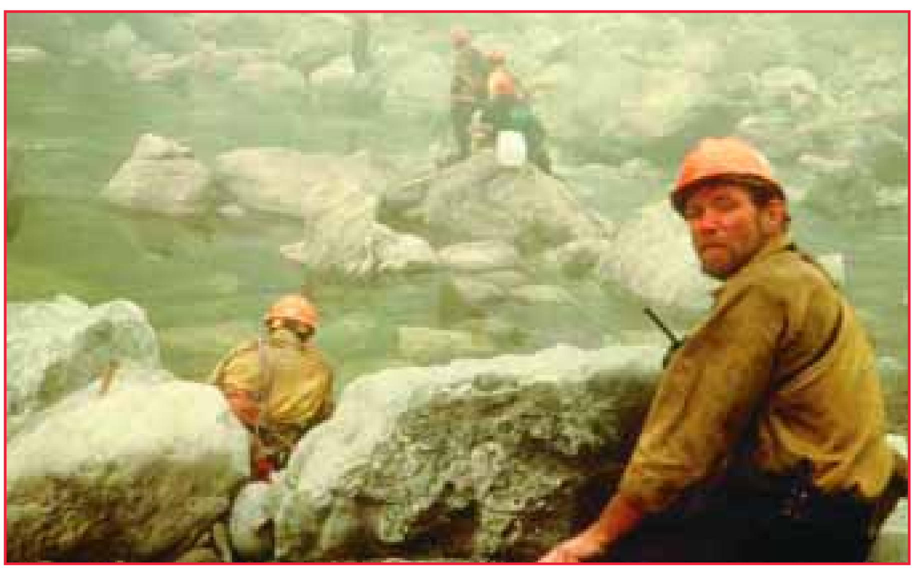
Paul grew up in southern California, the son of a traveling evangelist preacher. He became an accomplished rock climber in his teens and continued to climb throughout his entire life. In 1964, he got his first job as a firefighter on the Angeles National Forest, CA. He continued to work there on the Dalton Hotshot Crew through 1970, with the exception of a 1-year stint in the U.S. Army. From 1971 to 1973, he went to college and earned a degree in mathematics.

During this time, he also traveled and climbed extensively. He returned to work as a firefighter in 1974 as the assistant foreman for a 20-person regional reinforcement crew on the Okanogan National Forest, OR. Then, in 1977, he took the job as the assistant superintendent of the Zigzag Interagency Hotshot Crew on the Mount Hood National Forest, OR, moving up to superintendent in 1979. He remained in that role until 1992. He then transferred to the Arapaho–Roosevelt National Forest as a district fire management officer and eventually became the forest's fire ecologist.

Paul's next move was to another fire agency in 1999 as the deputy fire management officer for the Rocky Mountain Region of the National Park Service. In 2001, mandatory retirement at age 55 took Paul away from the Federal fire service and into academia. For the next 2 years, Paul was adjunct professor for the wildland fire science program at Colorado State University. He remained in this role until he lost his battle with cancer in 2003.

During his career, Paul Gleason was front and center on three well-known fires of the modern era—the Loop Fire in 1966, the Dude Fire in 1990, and the Cerro Grande Fire in 2000. His role on these three touchstone fires gave rise to his passion for firefighter safety and the "student-of-fire" philosophy that he crusaded for. He was a leader of firefighters and a leader for the wildland fire service.

Paul's contributions are far reaching. He teamed up with D. Douglas Dent to pioneer the professional tree falling program for wildland



Paul Gleason ensuring that his crew members safely cross the Illinois River on the Siskiyou National Forest in Oregon during the 1987 Silver Fire. Gleason crossed last. Photo: John Gale, USDA Forest Service, LaGrande Hotshots, LaGrande, OR, 1987.

Jim Cook is the training projects coordinator for fire operations safety for the USDA Forest Service, National Interagency Fire Center, Boise, ID; and Angie Tom is a 10-year seasonal wildland firefighter now serving on the Midewin Interagency Hotshot Crew based on the Midewin National Tallgrass Prairie, Wilmington, IL.

* Reprinted from the Website (http://fireleadersip.gov) of the Wildland Fire Leadership Team, chartered by the National Wildfire Coordinating Group's Training Working Team. The interview was conducted in Denver, CO, on February 26, 2003.

firefighters. He developed the "lookouts, communications, escape routes, safety zones" concept that has become the modern foundation of firefighter safety (Gleason 1992). He was very involved in the development of fire behavior training, with a focus on taking the scientific aspects of extreme fire behavior and making them understandable concepts for every firefighter. He reached outside the fire service and collaborated with experts, such as Dr. Karl Weick, who were doing research in the realm of decision-making and high-reliability organizations.

In the final tally, Paul was always a "student of fire"—a role model for others. To the very end of his life, he engaged in teaching and learning about fire. The opportunity to ask Paul the following questions about leadership came the day before he died and at his insistence.

Cook/Tom: *What makes you want to follow someone?*
Gleason: Confidence, knowing for certain that the person making the call has your safety foremost in their mind. And knowing that the job you are about to take on is the right thing to do, that it makes sense.

Cook/Tom: *Who do you think is a leadership role model and why?*
Gleason: Chuck Hartley, who was the superintendent when I first went to work on the Dalton Hotshots. Why … because he instilled that confidence. When I worked for Chuck, I never doubted for a minute that our safety was always the first thing in his mind. Plus, Chuck ran the crew in a way that allowed us to have a sense of confidence in ourselves and in our own capabilities as well.

Formal Publications by Paul Gleason*

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* Compiled by the issue coordinators, Martin E. Alexander and David A. Thomas.

Gleason teamed up with D. Douglas Dent to pioneer the professional tree-falling program for wildland firefighters.

Cook/Tom: *If you were to pick the most important character trait for an effective leader, what would that be?*
Gleason: That's a hard one to answer. [Pause.] But if there has to be one, it would be mindfulness. That ability to take in your surroundings and sort out the important stuff, to be aware, to be vigilant. Then take all that information, put it together, and see if it makes sense to you. Another part of that mindfulness concept is the ability to relate to all types of people and see what they can contribute.

Cook/Tom: *Are leaders born or made … explain?*
Gleason: I think they are born, and I know we might disagree on this some. Certainly, many important leadership skills can be developed, but I feel that trait of mindfulness is an innate capability that someone either has or doesn't have.

Cook/Tom: *Regarding leadership, what quote comes to mind?*
Gleason: "Those are my people. Wherever they go I must follow, for I am their leader."

Cook/Tom: *Thinking back to your youth, what influences helped you become a leader?*
Gleason: My father traveled for his work, frequently with the whole family. In our travels we camped out a lot and I think that was a big part of why I have always been drawn to the outdoors. Growing up in southern California, I remember many summers and falls where the hills around the Los Angeles area would be on fire and especially the memory of long strands of fire moving across the hills at night. I think I knew I wanted to be a firefighter by the time I was in 5th grade. Climbing was another big influence on me. I remember one time my brother Phil and I did a climb late in the fall and we weren't able to finish the whole climb before dark. So we had to spend the night up there suspended in our slings with just the stuff we had on us, which wasn't much. Man, it got cold when the sun went down, I think it was in November.

Cook/Tom: *What do you consider your strengths to be?*
Gleason: Let me think about that for a minute. [Pause.] Probably endurance, and more specifically enduring adversity and using that experience to make something good come out of it.

Paul Gleason (left), with Merrill Kaufmann, a research forest ecologist for the USDA Forest Service, Rocky Mountain Research Station, standing on the site of the Snowtop Fire a day after the fire. On July 10, 1993, the fire burned to within 4-1/2 feet (1.4 m) of Kaufmann's cabin in Colorado. Gleason was at the cabin during the fire and helped protect it. The cabin survived because Kaufmann had covered it with a metal roof, thinned the surrounding trees, and removed nearby fuels. Photo: Evelyn Kaufmann, 1993.

Cook/Tom: *How about your weaknesses?*
Gleason: I didn't know I had any! [Laughs. Pause.] My biggest weakness is patience, wanting to see things happen too quickly or get changes in place right away. Not having the patience to let things develop. Sometimes I'm that way with the people I work closely with. My expectations of their time and commitment could be unrealistic on occasion.

Cook/Tom: *Since you started in 1964, what are the biggest improvements you have witnessed in the wildland fire service?*
Gleason: I think that would have to be the increased focus on firefighter safety.

Cook/Tom: *What do you consider the worst changes you have seen in the wildland fire service?*
Gleason: Lack of aggressiveness on the fireline. This might sound like a contradiction to the last answer, but I don't think so. What I mean here is that there seems to be a lot of indecisiveness on selecting a strategy and getting with it to make it happen.

Gleason was very involved in fire behavior training, with a focus on making the scientific aspects of extreme fire behavior understandable for every firefighter.

Cook/Tom: *Describe a few of the toughest decisions or dilemmas you have faced.*
Gleason: The first thing that comes to mind is the Dude Fire … and especially the decision to leave the subdivision and go down into Walk Moore Canyon. I passed a number of people coming up the line in a hurry as I was going down. I talked to a couple of the other hotshot superintendents. Everyone thought there was no way that anyone working in the bottom of that canyon could make it out alive. Even so, a few of us continued on down into the canyon. We met Hatch and then began to find the others on the Perryville Crew … but that's a whole other story.

Cook/Tom: *What helped to guide you in that decision?*
Gleason: [Pause.] I don't know exactly why I did that, but it just seemed like the right thing to do. I just knew I would have to live with my decision. It's like the Cerro Grande thing. That was another tough situation. We made our decisions in good faith and using our best judgment based on what we knew. I remember how difficult it was to go to talk to the people in Los Alamos and tell them who I was, what we did, why we did it. But I have to live with those decisions because at that time it was my responsibility.

Cook/Tom: *Do you think a legacy is important and, if so, what do want your legacy to be?*
Gleason: If you choose to lead others you will have a legacy. But that legacy will be determined by those that follow you. [Pause.] I suppose I would want my legacy to be that firefighters begin to realize the importance of being a student of fire and that I was able to help make that happen.

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In the final tally, Paul was always a "student of fire"—a role model for others.

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