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Extreme Fire Behavior

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On the Cover:

The Rabbit Creek Fire, part of the Idaho City Complex on Idaho's Boise National Forest in 1994. The fire was enormous, burning 146,400 acres (59,250 ha) in 73 days. Even larger fires burned in the interior West in 2000, one of the worst fire seasons in recent memory (see the articles in this issue by USDA Forest Service Chief Mike Dombeck). Photo: Karen Wattenmaker, USDA Forest Service, Boise National Forest, Boise, ID, 1994.

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.

Firefighter and public safety is our first priority.

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A Tribute to America's Wildland Firefighters

Mike Dombeck

In August 2000, during one of the worst fire seasons in recent decades, I traveled to fire camps in Idaho and Montana. It was a real pleasure and privilege for me to join the men and women on the fireline who are protecting our Nation—our lives, property, and wildland resources—from the ravages of wildland fire. They are truly our national heroes.

Mike Dombeck, Chief of the USDA Forest Service. Photo: Karl Perry, Forest Service, Washington Office, Washington, DC, 2000.

Shortly after its birth in 1905, the USDA Forest Service was baptized in flames. We've all heard the legends of the Big Blowup, the great 1910 fires in the northern Rockies that burned 3 million acres (1.2 million ha). Some 78 firefighters gave their lives fighting the blazes. Ed Pulaski saved his crew by holding them at gunpoint in the shelter of a mine while the firestorm raged outside, choking and blinding his terrified men. Joe Halm, just 26 years old, saved his crew by lighting an escape fire and ordering his men to lie down inside the black. After the fire passed, his firefighters dug out their tools and went right back to work.

That's the can-do spirit that helped us grow—all of us collectively, from every agency and entity in the wildland fire community—into the greatest wildland firefighting organization the world has ever known. In the 1930's, more than 50 million acres (20 million ha) might burn in a single fire season. Fifty million acres—can you imagine! That's because there was often little we could do with the limited resources we had to stop most fires before they got big.

Today, we stop 98 percent of our wildland fires during initial attack. Ninety-eight percent—what an accomplishment! Even the few large fires that escape initial attack rarely do much damage, thanks to the skill and dedication of America's wildland firefighters.

We are part of a proud tradition. It's folks like Ed Pulaski, Joe Halm, and every man and woman on the fireline today who turned the tide in the battle, who are winning the war against wildland fires.

But too often, our success has had high and tragic costs. On August 5, 1949, 13 young firefighters died in a wildland fire blowup in a dry Montana ravine known as Mann Gulch. The Mann Gulch Fire sounded a warning bell, teaching us that even our best firefighters are sometimes no match for the unpredictable fury of a wildfire. That warning bell sounded again on July 6, 1994, when 14 young firefighters died in another wildland fire blowup, this time on the slopes of a Colorado peak known as Storm King Mountain.

At Storm King Mountain, at Mann Gulch, and on countless other fires over the last hundred years, many brave men and women fought the flames and sometimes made the ultimate sacrifice. They did not do so in vain. The lessons they taught are still with us today. We owe it to them, we owe it to ourselves, to always remember our cardinal rule: Safety is our first priority. We must respect our heritage, we must honor our fallen firefighters by continuing to stress the importance of safety, communication, and strict adherence to the Ten Standard Firefighting Orders.

So let me conclude with a pledge and a plea. My pledge is this: I will do everything in my power to make sure that America's heroes on the fireline have all the resources they need to continue doing their job, both safely and well. In exchange, I ask only that you make safety your first priority. Remember: As long as no lives are at stake, there's nothing on that fireline worth dying for. ■

Mike Dombeck is the Chief of the USDA Forest Service, Washington Office, Washington, DC.

How Can We Reduce the Fire Danger in the Interior West?

Mike Dombeck

The 2000 fire season will long be remembered. By late August, more than 6 million acres (2.4 million ha) had burned nationwide, with much of the fire season left to go. On average during the preceding decade, only 3.6 million acres (1.5 million ha) had burned during the entire fire season. Nevertheless, the 2000 fire season was hardly exceptional from a historical perspective. From 1919 until 1949, more than 29 million acres (12 million ha) burned on average each year, far more than in 2000—or any other year in recent decades.

In 2000, most of the worst fires were in the interior West. Their cause? A combination of hot, dry weather; prolonged drought; bad luck; and excessive fuels buildups that accelerated fire spread.

In August 2000, I traveled with President Clinton, Secretary of Agriculture Dan Glickman, and Secretary of the Interior Bruce Babbitt to the Burgdorf Junction Fire on the Payette National Forest in Idaho. In addition, I discussed the situation and long-term prognosis with our leaders in the interagency wildland fire community in Boise, ID. Most importantly, I visited fire camps and rural areas in Idaho and Montana to talk with firefighters and community leaders, hear their insights, and listen to their concerns.

Mike Dombeck is the Chief of the USDA Forest Service, Washington Office, Washington, DC.

Fuel buildups in our western forests are the single greatest source of fire danger we face.

They taught me much about the wildland fire situation in the West. Like other Americans, they wanted to know what more we can do to protect American lives, property, and wildland resources from the extreme fire danger of recent years in the interior West.

Firefighting Priorities and Preparedness

After more than a century of wildland firefighting, the United States has the best-trained, best-equipped, most effective firefighting organization in the world. The key to our success has been nationwide cooperation. Wildland firefighting today involves many partners at multiple levels, from rural fire departments to Federal land managers.

All wildland firefighters in the United States share the same priorities:

1. Our first priority is safety. Our highest goal on the fireline is to protect the safety of our

The Cerro Grande Fire near Los Alamos, NM, in May 2000. Driven by high winds, the fire burned 47,650 acres (19,284 ha) in 33 days, destroying 235 structures and displacing some 600 families. Estimated losses reached more than $1 billion. The Cerro Grande Fire was one of the first during the 2000 fire season to draw national attention. Photo: W.R. Fortini, Jr., USDA Forest Service, Cibola National Forest, Mountainair Ranger District, Mountainair, NM, 2000.

citizens, including our firefighters themselves, from the dangers of wildland fire.
2. Our second priority is initial attack. Our forces are trained and equipped to detect fires immediately, get to them quickly, and extinguish them before they spread. On average, we suppress 98 out of 100 fires during initial attack. For the few fires that get away, we marshal all the resources needed for containment.
3. Our third priority is to protect our communities at risk, including residences, sources of drinking water, historical and archeological sites, and infrastructure (such as power lines and transfer stations).

On every fire, we strive to protect our Nation's wildland resources.

The nerve center of wildland firefighting, in close collaboration with our State partners, is the National Interagency Fire Center (NIFC) in Boise, ID. When fires get too big or too many for local or regional control, NIFC springs into action. Through NIFC, we mobilize and coordinate resources from across the United States to fight wildland fires anywhere in the Nation. During particularly severe fire seasons, NIFC calls on military or international resources under longstanding collaborative agreements.

Each winter, based on the best information and science available, we make long-range forecasts of weather conditions and the corresponding fire danger anticipated for the coming year. By February 2000, NIFC was already preparing for what we thought would likely be a severe fire season. Under our National Fire Preparedness Plan, NIFC has five preparedness levels. Each level corresponds to a certain degree of fire activity, telling us what resources we will need to meet the challenge.

Our highest goal on the fireline is to protect the safety of our citizens, including our firefighters themselves.

By August, NIFC was operating at preparedness level V, the highest level, with dozens of major fires burning in several regions at the same time and all regular firefighting resources mobilized. In the previous 10 years, we had reached level V only a few times, the last time in 1996.

Our resources were taxed, but by mobilizing our available reserves, we were able to deal with the continuing high levels of fire activity. Here's some of what we did:

- The Forest Service and the land management agencies in the U.S. Department of the Interior, including the Bureau of Indian Affairs, Bureau of Land Management, National Park Service, and U.S. Fish and Wildlife Service, directed all qualified fire personnel to be listed for fire duty, regardless of other resource priorities.
- The Forest Service issued a directive permitting all qualified former employees to enlist for fire duty.
- NIFC mobilized firefighters from Alaska and the Eastern States, where the fire season was less severe, for service in the West.
- At NIFC's request, National Guard and active-duty military units were mobilized for fire duty. Additional units were available for training if needed.

Evacuees from the Cerro Grande Fire along a highway near Los Alamos, NM. Burning in long-accumulated fuels under drought conditions, the fire forced some 18,000 people to flee their homes. Photo: W.R. Fortini, Jr., USDA Forest Service, Cibola National Forest, Mountainair Ranger District, Mountainair, NM, 2000.

The fact is that fire is an essential component in most of our western forests.

- NIFC mobilized all available C–130 military aircraft equipped with Modular Airborne Fire Fighting Systems, which turn them into airtankers.
- At NIFC's request, Canada furnished firefighting personnel and equipment under longstanding bilateral agreements. Australia and Mexico also supplied firefighting resources.

Severe Fire Weather

Why was the 2000 fire season so severe? The immediate reason was the weather. In areas of the West where the worst fires burned, the previous 10 years had been hotter than normal. In 2000, we faced drought conditions throughout much of the West. Fuels were tinder dry and highly combustible, so fires started more easily, burned more intensely, and spread far more rapidly than normal. Under these conditions, the fire season began 6 weeks earlier than normal.

Many western forests are adapted to periodic fire because they evolved in a fire-saturated climate. Worldwide, according to the fire historian Stephen J. Pyne (1982), an estimated 44,000 storms per day produce 8 million cloud-to-ground lightning strikes. One strike in 25 in the northern Rocky Mountains is capable of starting a fire. A single storm system in June 1940 started 1,488 fires in the northern Rocky Mountains; another in July 1965 ignited 536 fires in the Southwest.

Under drought conditions, a lightning strike can burn and kill forest stands in patchwork patterns that can reach for miles. In fire-adapted forests, such fires play a natural role in recycling nutrients and regenerating forests. At higher elevations in the West, severe fires occur naturally every 100 to 300 years, depending on the locality and site conditions.

A lightning strike in a western forest. The overwhelming majority of wildland fires in the West are ignited by lightning. Under drought conditions, a single storm system can start hundreds of fires. Photo: USDA Forest Service.

One of our largest fires in 2000, the Clear Creek Complex, burned more than 200,000 acres (80,000 ha) on the Salmon–Challis National Forest in Idaho. I visited the Clear Creek Complex and asked Incident Commander Joe Carvelho what we could have done to prevent the fire. Joe just shook his head and said, "After some 30 years as a wildland firefighter, I can tell you this: There's nothing anybody could have done to prevent this fire. The land was ready to burn, so it burned."

Nationwide, the past 45 years show a steady fluctuation in fire severity from year to year, with severe fire seasons alternating with lighter ones (fig. 1). When the weather is hot and dry, there are more large fires; when it is cooler and wetter, fires are fewer. The worst fire seasons in recent years include 1996 (6.7 million acres [2.7 million ha] burned) and 1988 (7.2 million acres [2.9 million ha] burned). The 2000 fire season was part of the same cyclical pattern.

Dangerous Fuel Buildups

But weather is not the whole story. It takes fuel to feed a fire, and people have profoundly altered the fuel structure in many of our western forests, especially at the lower elevations where most people live and travel. How have we changed fire patterns by tinkering with fuels? And what can we do about it?

The answers are inscribed into the history of the land. Our forest

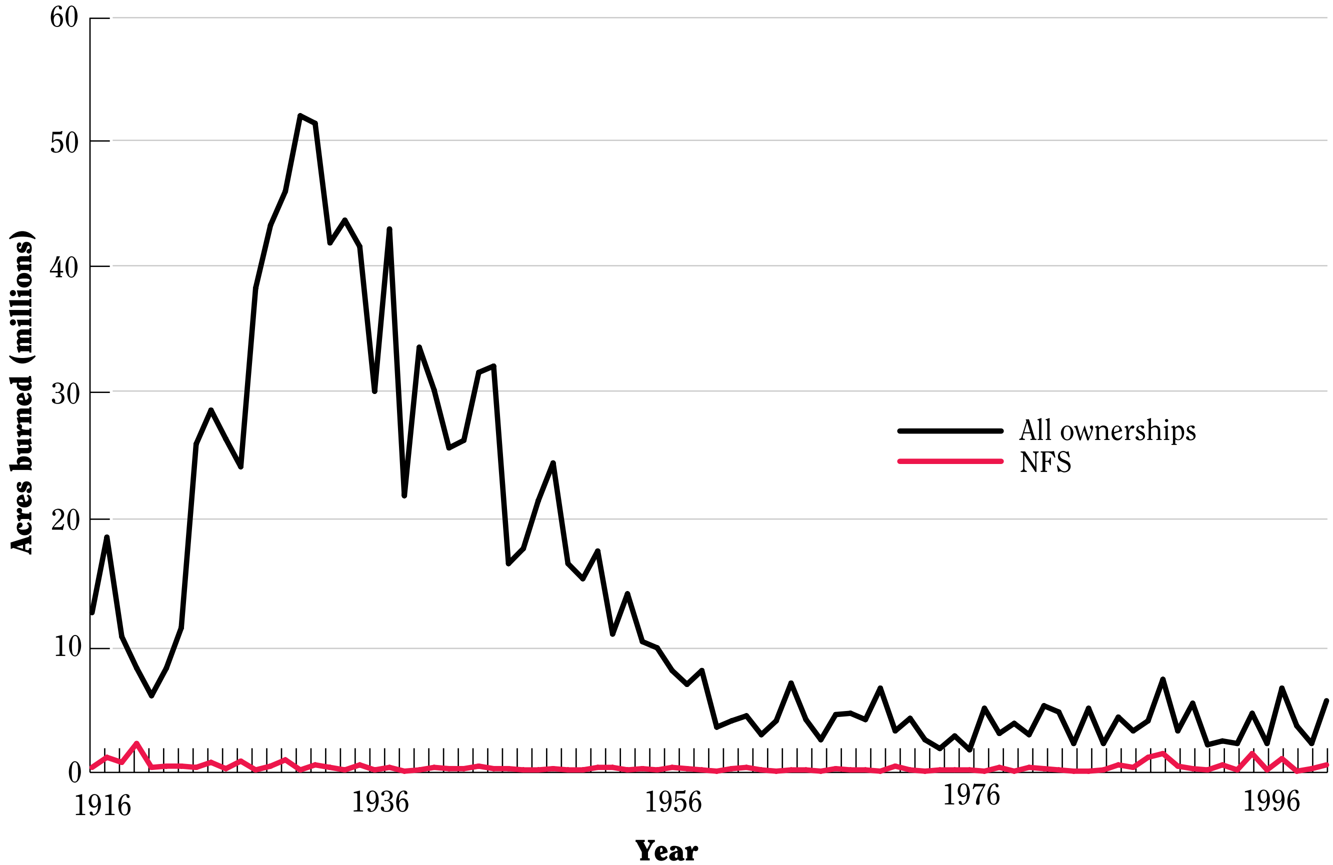

Figure 1—*Acres burned in the United States, 1916–99 (NIFC 2000; F&AM 2000). Historically, only a small fraction of acres burned nationwide have been on the National Forest System (NFS). Sharp fluctuations from year to year are due to changing weather conditions. When the weather is hot and dry, there are more large fires; when it is cooler and wetter, fires are fewer. Acres burned started sharply declining in the 1930's due to growing improvements in cooperative fire protection. Illustration: Gene Hansen Creative Services, Inc., Annapolis, MD, 2000.*

ecosystems most threatened by fire, such as ponderosa pine, once had thousands of small, low-intensity fires every few years. Most fires weren't hot enough to kill mature trees, but they did thin out the forest understories. The result was open forest with widely spaced old-growth trees.

Fire is an essential component in most of our western forests. Many forest types have been burning for as long as anyone can remember, and the number of acres scorched in 2000 was not out of the ordinary. For example, in the 1930's, 39 million acres (16 million ha) of our Nation's forests burned on average each year, many times more than burned in 2000.

Some 90 years ago, we began putting out almost every fire we could, because we thought fire bad for the land. By the 1940's, we had the resources to quickly extinguish most fires. Heavy vegetation, no longer cleared out by fire, built up in our open, lower elevation forests in the West (fig. 2). For example, the density of ponderosa pines on Arizona's Kaibab National Forest rose from 56 per acre (22 per ha) in 1881 to 851 per acre (344 per ha) in 1990 (GAO 1999). When fire now occurs, the dense fuels make the fire so intense that it can destroy entire forest stands.

In recent years, the average number of acres burned annually on our western national forests has soared. Today, 24 million acres (10 million ha) of national forests in the West are at high risk of wildland fires that could compromise ecosystem integrity and human safety. An additional 32 million acres (13 million ha) are at moderate risk. That's 56 million acres (23 million ha) at risk, or about 29 percent of the land in our National Forest System.

False Prescriptions

What's the answer? Some contend that we should just leave the land alone. After doing so much to despoil the land, who are we to tell Mother Nature what to do?

But most of the land is not in a natural state—and probably hasn't been for millennia. The land evolved with fire, often through firesticks brandished long before Columbus. We have ample evidence that American Indians used fire to clear many of our western valleys, creating the open, lower elevation forests that greeted the first European settlers (Boyd 1999; Pyne 1982; Williams 2000a, 2000b). When we excluded fire from the land, we upset an age-old balance between humans and nature.

The lush density of our western forests today is no more natural than the green of our lawns and gardens. Decades of fire exclusion have, in a sense, shaped ecosystems that *never existed before*. Today, much of our landscape is a 20th-century product of our own firefighting success. To pretend otherwise, to shut our eyes and turn away from the thing we have created, would be to abdicate our responsibility as custodians of the land, our obligation to the American people to restore the land to health.

At the other extreme, some say we should build more roads and harvest more timber. The more we cut, they contend, the less there is to burn.

We tried that, and it didn't work. In the 1980's, we harvested up to 12.7 billion board feet (30 million m^3) of timber annually from our national forests, three to four times more than we harvest today. To support the postwar timber boom, we expanded our forest road system to 380,000 miles (610,000 km), enough to circle the Earth 15 times.

Figure 2—*Forest succession in ponderosa pine in the absence of fire, near Lick Creek, Bitterroot National Forest, MT.* Top: *In 1909, management begins in an old-growth forest historically kept open by frequent low-intensity fires.* Center: *By 1948, fire exclusion has permitted understory buildups.* Bottom: *By 1979, small-diameter trees and brush form abundant fuels for fire to ladder into the canopy. A fire that would remain a harmless surface burn in 1909 would become a stand-replacing crown fire in 1979. Photos: W.J. Lubken, USDA Forest Service, 1909; USDA Forest Service, 1947; W.J. Reich, USDA Forest Service, 1979.*

All that timber we harvested, all those roads we built at taxpayer expense did nothing to stop large fires. The soaring timber harvests of the 1980's coincided with some of our worst recent fire seasons (fig. 3). In fact, the 10-year average annual number of acres burned nationwide in the 1980's (4.2 million acres [1.7 million ha]) was higher than in the 1990's (3.6 million acres [1.5 million ha]), when timber harvest was low. There is absolutely no reason to believe that more commercial timber harvest will solve our wildland fire problem.

Why? Partly because large, merchantable trees—the kind that are profitable to remove through logging—aren't the problem. What we need to remove are the small-diameter trees and brush that have sprouted in the absence of low-intensity fire. These small-diameter materials, typically of little or no commercial value, are filling our forests, fueling our worst and largest fires. Fires that historically stayed on the forest floor now use small-diameter trees as handy ladders for climbing into the forest canopy, with devastating results.

Commercial timber harvest has a firm place on our national forests to help meet our Nation's need for wood fiber. But we must not let commercial interests masquerade as forest health policy. The goal of commercial timber harvest is the cost-effective removal of commercial-grade timber, not small-diameter trees that are relatively worthless on the market. Commercial timber harvest won't solve our forest health problem because that isn't its purpose.

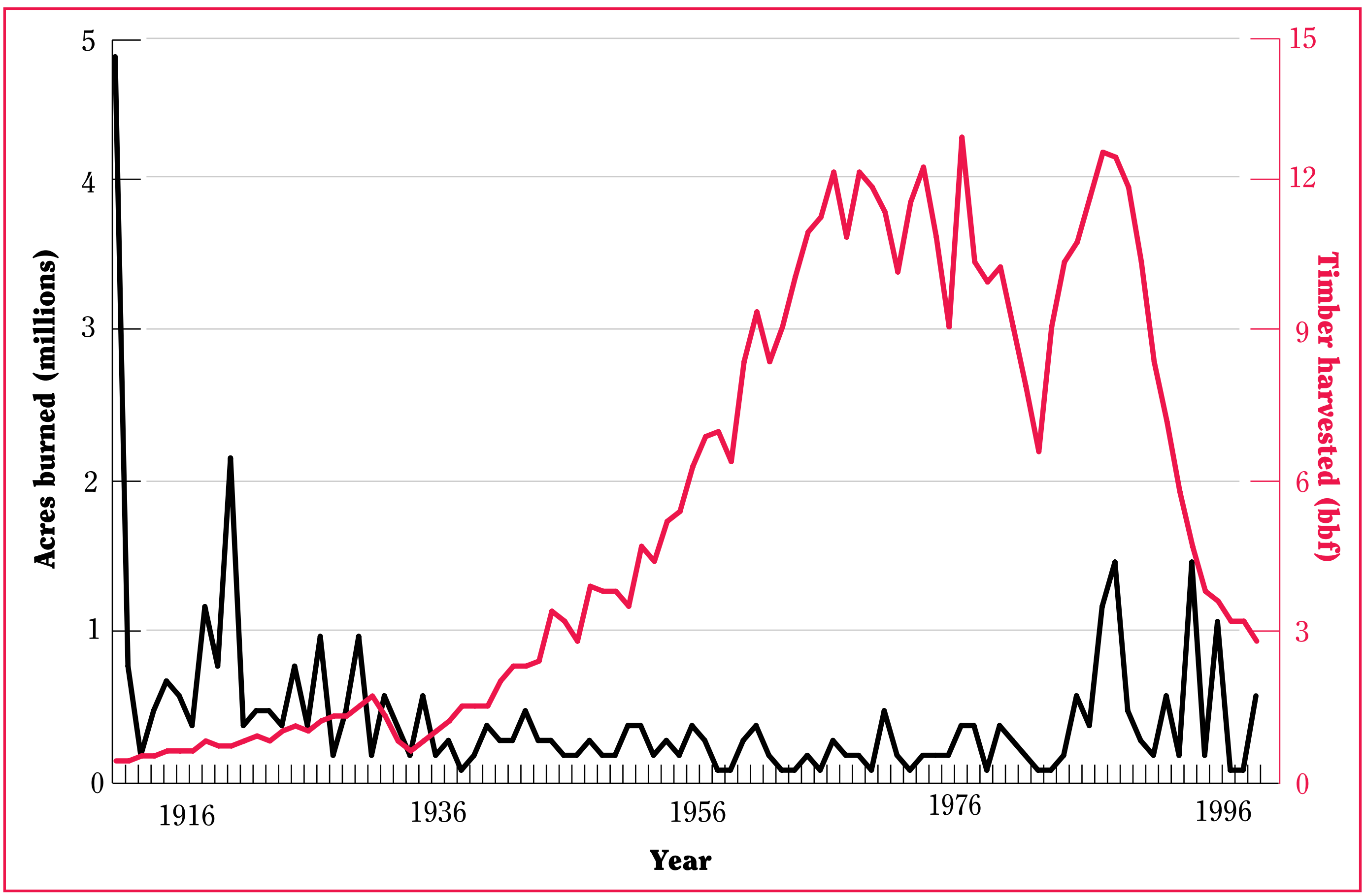

Figure 3—*Acres burned and billions of board feet (bbf) of timber harvested on the National Forest System, 1910–99 (F&AM 2000; FM 2000). There is no apparent correlation between the level of timber harvest and fire season severity. Rising harvest levels in the 1910's and 1920's corresponded to both light and severe fire seasons. A harvest decline in the 1930's did not reverse the downward trend in acres burned. From the 1940's to the 1960's, fire season severity remained relatively constant while harvest levels soared. A spike in timber harvest during the 1980's coincided with severe fire seasons in 1987 and 1988, and low harvest levels in the 1990's coincided with both light and severe fire seasons. Illustration: Gene Hansen Creative Services, Inc., Annapolis, MD, 2000.*

Does Commercial Timber Harvest Reduce Fuel Loads?

Some argue that more commercial timber harvest is needed to remove the small-diameter trees and brush that are fueling our worst wildland fires in the interior West. However, small-diameter trees and brush typically have little or no commercial value. To offset losses from their removal, a commercial operator would have to remove large, merchantable trees in the overstory. Overstory removal lets more light reach the forest floor, promoting vigorous forest regeneration. Where the overstory has been entirely removed, regeneration produces thickets of 2,000 to 10,000 small trees per acre (800–4,000 per ha) (Arno [In press]), precisely the small-diameter materials that are causing our worst fire problems. In fact, many large fires in 2000 burned in previously logged areas laced with roads. It seems unlikely that commercial timber harvest can solve our forest health problems.

In fact, the high harvest levels of the past were unsustainable. Today, Americans expect more from their national forests than just wood. They expect clean water; more than 60 million Americans get their drinking water from watersheds that originate on our national forests and grasslands. They expect healthy fish and wildlife and rich recreation opportunities. They expect to find places of beauty and serenity for solitude and spiritual renewal. Today, we harvest timber at lower, more sustainable levels—levels that will ensure not only a steady supply of wood fiber, but also all the other values and benefits that Americans expect from their forests.

The Solution: Restoring the Land to Health

Sooner or later, rivers will fill their floodplains and fire-adapted ecosystems will burn. However, we do have the ability, if not the will, to minimize the impacts of floods and fires on human beings by making thoughtful development and resource management decisions that acknowledge the realities of nature.

The key is living within the limits of the land. For that, we must look to the land and its history. If we impaired the health of the land by removing its low-intensity fire, then perhaps we can help bring the land back to health by restoring some of that fire.

The Forest Service has made a start. In the 1970's, we stopped excluding fire from the land. Today, we have a comprehensive fire management strategy that includes fire use and small-tree removal to treat excess fuels and reduce the risk of unnaturally severe fires on our national forests and grasslands.

Where it is safe, effective, and appropriate, we are restoring low-intensity fire to the land. From 1994 to 1999, we increased our annual fuels treatments by more than 300 percent, from 385,000 acres (156,000 ha) to 1,320,000 acres (534,000 ha), mostly through prescribed burning. That's still not enough.

Small-tree removal can be a tool for restoring forest health, and we are using it. Where vegetation is too thick to safely burn, we are exploring options for removing the small-diameter trees and brush that are overcrowding our forests. The trick is to find cost-effective ways to remove forest materials of little or no commercial value.

Through our Forest Products Laboratory, the Forest Service is finding new uses and markets for small-diameter timber. Our laboratory has an enviable record of working with private industry to improve wood use efficiency. For example, our innovation in recycling and efficient wood utilization helped to increase products we can generate from a single log by 40 percent.

Today, one of our top research priorities is finding ways to utilize small-diameter trees. We are making remarkable headway: We have discovered ways to use small-diameter Douglas-fir for flooring and furniture, and small-diameter red maple and ponderosa pine for building materials. In tandem with our research to make small-tree removal profitable, we are working with private industry to develop incentives for removing small-diameter trees.

Do our fuels treatments work? You bet. The 2000 fire season gave us plenty of evidence. On the Pike National Forest in Colorado, we treated a large area, then awaited the inevitable fires. Last June, the Hi Meadow Fire came roaring through the canopy, moving like a freight train. But when it hit the area we had treated, it dropped straight to the forest floor and started to crawl along the ground, burning the surface fuels and licking harmlessly at the trees. The stands we had treated were saved. On the Payette and Salmon–Challis National Forests in Idaho, I visited similar forest stands left intact after fires. The stands survived thanks to our treatments—prescribed burning and small-timber removal.

By no means, however, do we have all the answers. Forest Service Research will review and evaluate various fuels treatments to assess which are most effective under what conditions and with what limitations. Our adaptive management dictates that we continue to learn from new experience, pragmatically applying treatments when and where they are shown to work. We must avoid quick fixes and one-size-fits-all approaches.

A Comprehensive Fire Management Strategy

The Forest Service can't do it alone. Most wildland fires do not burn on national forestland. In 1999, for example, the National Forest System accounted for only about 11 percent of the acres burned nationwide. Moreover, wildland fires often cross jurisdictional boundaries. Collaboration is the key to effective wildland fire management.

> When we excluded fire from the land, we upset an age-old balance between humans and nature.

Our fire management strategy includes collaborative efforts to prevent wildland fires and to reduce fire severity by treating fuels. We are working with counties, States, and other partners nationwide, including homeowners and small woodlot owners, to reduce fuel loads and improve fire safety. Ultimately, private landowners must take responsibility for making their homes and properties firesafe by clearing away enough fuels to create a survivable space.

Through the collaborative National Wildland/Urban Interface Fire Protection Program (online at <http://www.firewise.org>), we help Americans learn how to keep themselves and their property safe from wildland fire. We furnish updates on fires and fire danger so people can plan for fire safety. For longer term planning, we offer tips on construction, landscaping, and other techniques for making homes firesafe and creating a survivable space.

Our fire management strategy includes rehabilitating burned areas. Wildland fires leave behind safety hazards, such as falling snags, and the potential for property damage and resource degradation through postfire flooding and erosion. To counter the threat, we are sending Burned Area Emer-

Forest stand successfully treated for fuels to reduce fire danger. The 1994 Cottonwood Prescribed Burn on Idaho's Boise National Forest eliminated brush and other ladder fuels that might carry a low-intensity surface fire into the canopy, destroying the stand. Photo: Karen Wattenmaker, USDA Forest Service, Boise National Forest, Boise, ID, 1994.

We must not let commercial interests masquerade as forest health policy.

gency Rehabilitation (BAER) teams to areas affected by fire. BAER teams include hydrologists, soil scientists, engineers, archeologists, and other specialists who devise rehabilitation plans. Volunteers do much of the rehabilitation work, such as removing hazards and seeding burned areas. During and after the 2000 fire season, we treated hundreds of thousands of burned acres.

A Long-Term Approach to Land Health

Fire has profoundly affected ecosystems in the past. Conversely, the absence of fire has severely affected ecosystems today, placing them at greater risk than ever. It took millennia for healthy forest ecosystems to evolve; after European settlement, it took decades to impair their health. Restoring our forests to health will take more than just a few years. It will take imaginative new approaches based on our ever-deepening understanding of the land and its history.

In the meantime, we can thank America's wildland firefighters—the best in the world—for risking their lives to keep the 2000 fire season from being far, far worse. It's worth remembering that 70 years ago, tens of millions of acres burned on average each year, up to 52 million acres (21 million ha) in a single fire season. In 2000, despite some of the worst drought conditions in memory, our firefighters succeeded in controlling almost every fire. For that, we owe a debt of gratitude to the skill and dedication of our women and men on the fireline, truly America's national heroes.

Using felled timber to control soil erosion following the 1988 Yellowstone Fires on the Gallatin National Forest, MT. Burned Area Emergency Rehabilitation teams continue to use similar techniques to rehabilitate burn sites nationwide. Photo: Ron Nichols, USDA Forest Service, 1988.

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The South Canyon Fire Revisited: Lessons in Fire Behavior

Bret W. Butler, Roberta A. Bartlette, Larry S. Bradshaw, Jack D. Cohen,
Patricia L. Andrews, Ted Putnam, Richard J. Mangan, and Hutch Brown

On July 6, 1994, 14 firefighters died in a wildfire on Storm King Mountain in western Colorado. Their deaths made the South Canyon Fire a landmark event in the annals of wildland firefighting, next to such major firefighting tragedies as the Big Blowup of 1910 and the Mann Gulch Fire of 1949.*

Within weeks after the fire, the Report of the South Canyon Fire Accident Investigation Team (USDA/USDI/USDC 1994) outlined many of the circumstances that led to disaster. More recently, John Maclean (1999) has described additional factors, such as resource use decisions in the days before the blowup.

This article summarizes a detailed study by the authors on the fire behavior associated with the South Canyon Fire (Butler et al. 1998). What fire-related factors contributed to the tragedy? And what lessons do they teach?

Bret Butler is a research mechanical engineer, Roberta Bartlette is a forester, Larry Bradshaw is a meteorologist, and Jack Cohen and Pat Andrews are research physical scientists for the USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT; Ted Putnam is an equipment specialist (retired) and Dick Mangan is the Fire and Aviation Program Leader for the Forest Service's Technology and Development Center, Missoula, MT; and Hutch Brown is the editor of Fire Management Today*, Forest Service, Washington Office, Washington, DC.*

* On the Big Blowup, see Stephen J. Pyne, "A Story To Tell," *Fire Management Today* 60(4): 6–8; on the Mann Gulch Fire, see Mike Dombeck, "The Mann Gulch Fire: They Did Not Die in Vain," and Richard C. Rothermel and Hutch Brown, "A Race That Couldn't Be Won," *Fire Management Today* 60(2): 4–9.

A Firefighting Tragedy

In the summer of 1994, Colorado suffered its worst drought in decades. Severe fire weather was certain to come. On July 2, a major storm hit the State with dry lightning strikes, igniting thousands of wildland fires.

One fire started on the flanks of Storm King Mountain near Glenwood Springs, a resort community in western Colorado. The mountain overlooks an interstate highway in a canyon carved by the Colorado River. On the morning of July 3, drivers on the highway could see a puff of smoke on a mountain spur called Main (or Hell's Gate) Ridge, where a lightning fire smoldered in a tree.

A caller reported the fire from across the river in a gulch known as South Canyon. The caller was unsure exactly where the smoke originated, so Federal officials named the fire after the caller's location.

At first, the South Canyon Fire seemed insignificant compared to much larger fires burning elsewhere. For days, fire managers and aerial observers monitored the slowly spreading fire from a distance. None thought it wise to divert thinly stretched resources from higher priority fires.

On July 5, more than 2 days after the fire's ignition, a hand crew finally reached Main Ridge. Joined by smokejumpers and hotshots, the firefighters began a concerted effort to contain the fire, now dozens of acres in size. By the afternoon of July 6, they seemed to be making headway, cutting fireline along two flanks of the fire.

Suddenly, the fire blew up. Witnesses at the helibase below Storm King Mountain watched in helpless horror as smoke billowed across the slopes, enveloping the fire shelters they could see deployed. Within minutes, 14 of the 49 people on Storm King Mountain—more than a quarter of the firefighting force—lay dead. Others, some badly burned, escaped over the ridge, while still others survived in their fire shelters. It took hours for many of the traumatized survivors to descend the mountain to safety. Meanwhile, the fire continued to rage, burning 2,115 acres (856 ha) before finally coming under control on July 11.

> Winds whipping from the west through the Colorado River Gorge were funneled up the ravine where the fire was worst, playing a key role in the blowup.

Topography

The Colorado River cuts through a series of north–south ridges on its way west through the Rocky Mountains. At Glenwood Springs, the river bisects a ridge of shale and sandstone, forming a narrow canyon at the base of Storm King Mountain, at 8,700 feet (2,700 m) the highest peak in the area. The mountain rises about 3,000 feet (900 m) above the river's north bank. Broken spurs and steep ravines reach south from the peak to the river.

Main Ridge, the site of the South Canyon Fire, starts in a saddle south of the peak and runs southwest for about 3,700 feet (1,100 m) before ending at a knob overlooking the Colorado River. From the knob, the canyon walls fall steeply about 1,100 feet (330 m) to the river below.

Though adjacent to an interstate highway, Main Ridge is difficult to approach. No roads or trails lead up from the highway. The ridge is flanked on the east and west by deep, twisting ravines running north and south, called the East and West Drainages. The first firefighters reached the fire by hiking for hours up the East Drainage.

The fire burned mostly on the west flank of Main Ridge, so the firefighters built fireline down into the West Drainage (fig. 1). They traversed steep slopes of up to 55 percent, with treacherous footing in the crumbling shale. Side spurs and draws angling from Main Ridge down into the drainage slowed travel and blocked the firefighters' view of the fire. The most prominent side spur, where many firefighters ate lunch on July 6, became known as Lunch Spot Ridge.

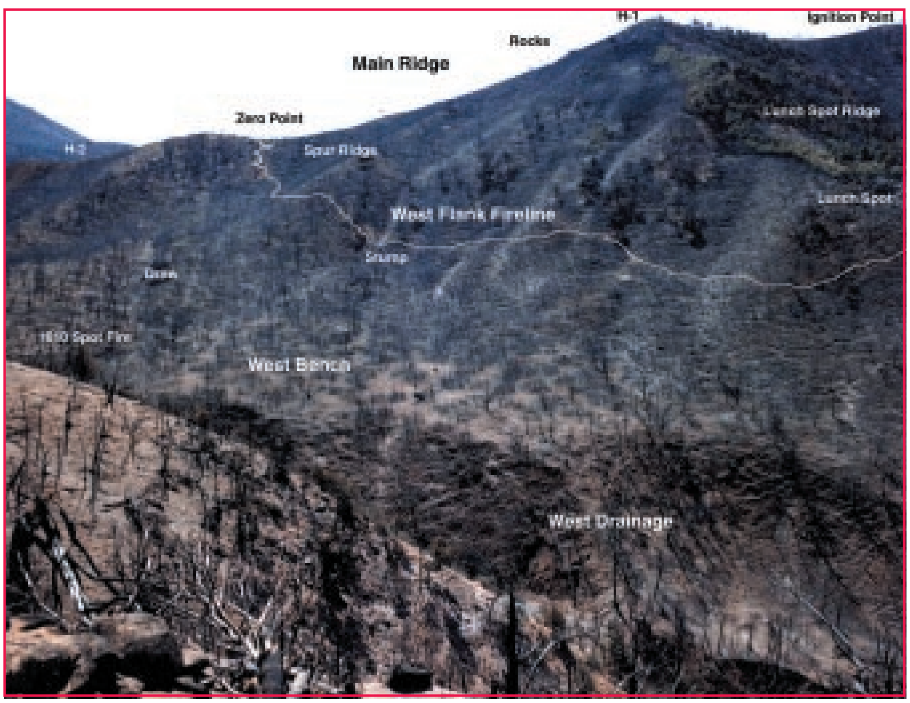


***Figure 1**—View of the South Canyon Fire site looking northeast across the West Drainage at the west flank of Main Ridge. Note the west flank fireline, helispots (H–1 and H–2), Lunch Spot Ridge, and West Bench. Illustration: USDA Forest Service, Fire Sciences Laboratory, Rocky Mountain Research Station, Missoula, MT, 1998.*

The bottom of West Drainage is especially steep, with a slope of about 80 percent. The bottom widens into a half-acre (0.2-ha) level area called the Bowl about 250 feet (80 m) upcanyon from the base of two long, vertical gullies, the Double Draws. Upcanyon from the Bowl, the steep slope flattens into an area called the West Bench.

The narrow mouth of West Drainage, facing southwest, opens onto the highway and river. Winds whipping from the west through the river gorge are funneled up the ravine. They played a key role in the blowup.

Fuels

Vegetation in the area of the fire was mixed (fig. 2). Gambel oak thickets covered north- and west-facing slopes. Gambel oak reached from Main Ridge down to the West Bench just north of Lunch Spot Ridge, the area traversed by most of the fireline on the fire's west flank. More than 50 years old, the oak formed a closed canopy 6 to 12 feet (1.8–2.4 m) tall, with leaf litter 3 to 6 inches (8–16 cm) deep and limited visibility (fig. 3). Elsewhere, except for a pocket of ponderosa pine and Douglas-fir south of the Double Draws, open pinyon–juniper forest prevailed, with a grassy herbaceous layer.

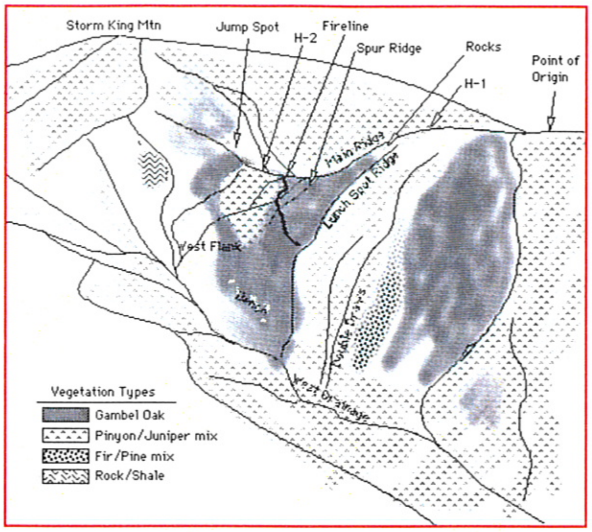


Figure 2—*Approximate distribution of vegetation in the area of the South Canyon Fire (not to scale). Gambel oak occupied north- and west-facing slopes, including most of the terrain traversed by the west flank fireline. Open pinyon–juniper forest predominated elsewhere, except for an area of ponderosa pine and Douglas-fir south of the Double Draws. Illustration: USDA Forest Service, Fire Sciences Laboratory, Rocky Mountain Research Station, Missoula, MT, 1998.*

Figure 3—*Firefighters constructing fireline on the west flank of Main Ridge on the South Canyon Fire, July 6, 1994. The heavy Gambel oak severely limited visibility and remained combustible despite partial underburning. Photo: Anthony Petrilli, USDA Forest Service, Missoula Smokejumpers, Missoula, MT, 1994.*

The vegetation was generally thickest toward the top of Main Ridge, giving way to shrubs and thick cured grasses below. The bottom of the drainage was generally covered with grass, with occasional pockets of dead brush that had rolled or washed downhill. The Bowl supported heavy live vegetation, including numerous conifers.

Due to the drought, all fuels were several weeks ahead of their summer drying trends. Fine dead fuel moisture content was about 2 to 5 percent. Live foliar moisture was probably about 125 percent in green Gambel oak and about 60 percent in underburned oak.

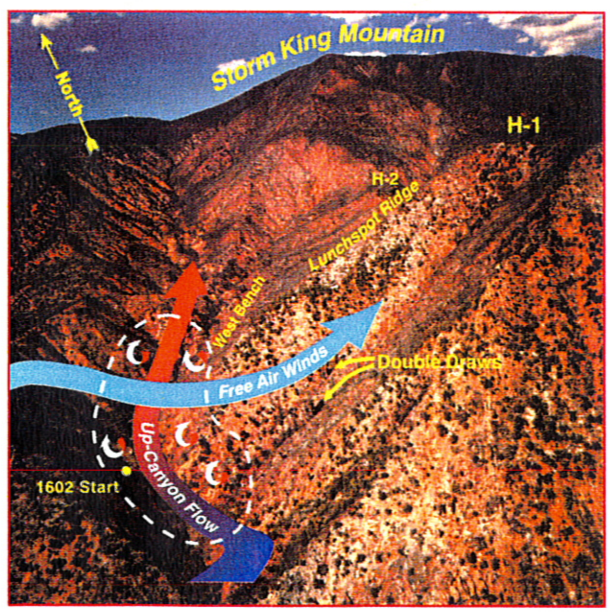
Weather

Conditions were drier and warmer than average. Precipitation levels at Glenwood Springs from October 1, 1993, to July 6, 1994, were 58 percent of normal. Temperatures were higher than usual from May through July.

On July 5, the air in western Colorado was hot and dry, with light winds from the south. A cold front building over Idaho reached Colorado early on July 6. With the approaching cold front, the relative humidity dropped from a high of 40 percent on July 5 to 29 percent on July 6, allowing the fire to remain active overnight. The cold front reached Glenwood Springs at about 3:20 p.m., bringing strong winds from the west.

Wind combined with topography to create turbulence in the West Drainage (fig. 4). The westerly winds speeded up as they pushed through the narrow Colorado River Gorge. Caught by the angle

Figure 4—*Interaction of the westerly wind flow over the ridgetops burned by the South Canyon Fire and the northerly wind flow up the West Drainage, forming a shear layer (dashed line). The shear layer generated turbulence that helped spread fire and burning embers up the West Drainage and onto the ridgetops. Illustration: USDA Forest Service, Fire Sciences Laboratory, Rocky Mountain Research Station, Missoula, MT, 1998.*



The relative humidity dropped from July 5 to July 6, allowing the fire to continue spreading downhill overnight toward the bottom of the drainage.

of Main Ridge, they swept north up the West Drainage. Rising daytime temperatures on the upper mountain slopes increased the upcanyon flow by reducing pressure at the canyon mouth, as did strong higher elevation westerly winds pouring across Main Ridge. By about 4 p.m., winds of 30 to 45 miles per hour (50–70 km/h) were rushing upslope from the mouth of West Drainage, with gusts reaching 50 miles per hour (80 km/h). Cross-cutting higher elevation winds created a shear layer and turbulence in the canyon.

Early Fire Behavior

From its point of ignition on Main Ridge (fig. 5), the fire backed slowly downhill, burning in cured grasses under juniper and pinyon and in the leaf litter under Gambel oak. Sheltered from the low to moderate winds by canopy cover, the fire torched only where ladder fuels carried it into individual trees. The fire advanced mostly north and west, making occasional upslope runs through canopy fuels. From July 2 to July 6, the fire backed downhill at a nearly constant rate.

On July 5, firefighters arrived on Main Ridge and constructed the first helispot (H–1) but failed to build effective firelines. The next morning, the firefighters built another helispot (H–2), then cut a fireline along the ridgetop between the helispots.

Next, the leaders scouted the fire by helicopter and made the fateful decision to continue fighting the fire from Main Ridge instead of evacuating the ridge and attacking the fire from the highway below. They decided to improve the ridgetop fireline while building fireline down into the West Drainage to hook around the west flank of the fire. By 3:15 p.m., 49 firefighters were on the mountain, about evenly divided between the ridgetop and west flank firelines.

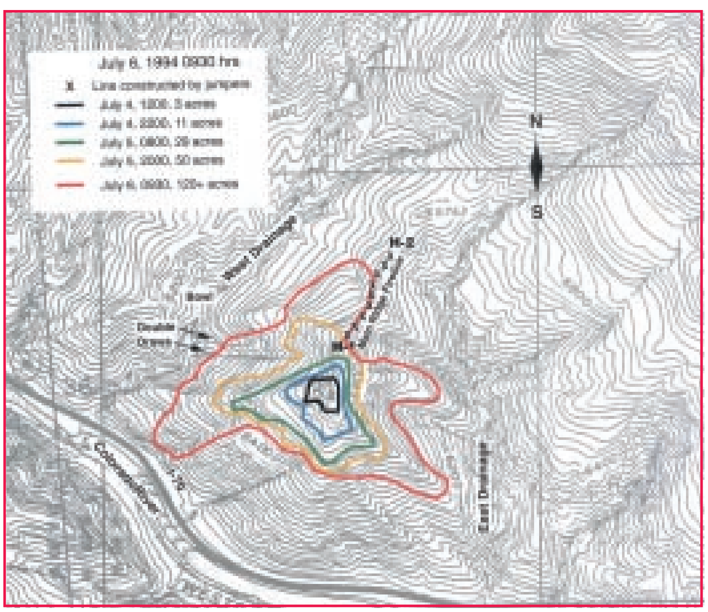


Figure 5—*South Canyon Fire perimeters from the time of ignition on July 2 through the morning of July 6, before the blowup (3 acres = 1.2 ha; 11 acres = 4.5 ha; 29 acres = 12 ha; 50 acres = 20 ha; 120 acres = 50 ha). Illustration: USDA Forest Service, Fire Sciences Laboratory, Rocky Mountain Research Station, Missoula, MT, 1998.*

During the night of July 5, low humidity kept the fire advancing at a probable rate of about 32 feet per hour (10 m/h) By midmorning on July 6, the fire had burned into the Double Draws and was about three-fourths of the way down to the bottom of the drainage. Assuming that the rate of spread remained constant during the day, the fire would have reached the bottom of the drainage by about 4 p.m.

The Blowup

At about 3:55 p.m., the fire, fed by growing winds, made three upslope canopy runs through the patch of pine and Douglas-fir south of the Double Draws. Flame lengths exceeded 100 feet (30 m). Photos show smoke rising from well below the crown fire runs, indicating that fire was reaching the bottom of the drainage.

By this time, strong westerly winds were flowing across the tops of the ridges while a strong upcanyon (southerly) wind was blowing up the bottom of the West Drainage; this combination created severe turbulence over the West Drainage. Embers from the crown fire runs and from the flames in the bottom of the drainage scattered in the turbulence, igniting spot fires up and across the canyon. By 4:02 p.m., firefighters reported spot fires actively burning on the opposite (east-facing) slope of the West Drainage.

Pushed by winds, the fire swept up the east-facing slope and upcanyon toward the Bowl in a running flame front 50 yards (45 m) wide. In the Bowl, relatively dense surface fuels pushed the fire into the crowns of the conifers there, increasing the size and height of the convection current over the fire and lofting embers high up both sides of the drainage. On the ridgetop, spot fires were multiplying across the fireline by 4:03 p.m.

By 4:04 p.m., recognizing the danger, the firefighters on the west flank were all in retreat. Those observing the fire south of Lunch Spot Ridge returned to their lunch spot, while those north of Lunch Spot Ridge began moving up the west flank fireline toward Main Ridge. At about the same time, the firefighters on the ridgetop abandoned efforts to control the spot fires spreading around them and headed toward H–1 for helicopter evacuation.

By 4:07 p.m., the fire front was rushing upcanyon in a “U” shape past the Bowl (fig. 6). Two minutes later, it burned onto the West Bench, entering the Gambel oak directly under the west flank fireline. The high winds, minimally impeded by the relatively thin canopy cover on the bench, whipped up the flames in the surface fuels and sent them into the canopy. The intense heat from the burning oak canopy, coupled with relatively low live fuel moisture levels, led to continuous combustion of live and dead vegetation as the fire raced upslope in the Gambel oak north of Lunch Spot Ridge.

Above the West Bench, the fire was more exposed to the westerly winds sweeping over Main Ridge. The flames spread upcanyon at about 3 feet per second (0.9 m/s) while making upslope runs before

> For days, the fire did not seem ominous. It backed slowly downhill in surface fuels, making occasional upslope fingered runs through unburned canopy fuels.

the winds at 6 to 9 feet per second (1.8–2.7 m/s). One run carried all the way over Main Ridge, forcing the firefighters who were moving toward H–1 to turn around and head instead for H–2.

At 4:10 p.m., a spot fire ignited on the West Bench ahead of the main fire front and began sweeping upslope below the fleeing west flank firefighters. Within minutes, it had merged with the main fire and overrun the entire west flank fireline. By 4:14 p.m., the fire was cresting on Main Ridge and threatening H–2 (fig. 7). All but two of the firefighters who were on or had reached Main Ridge dropped into the East Drainage and fled downcanyon to safety.

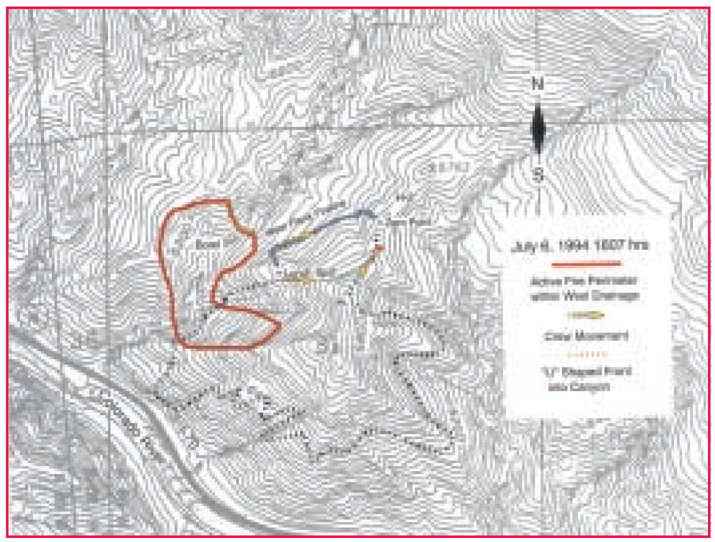


__Figure 6__—South Canyon Fire perimeter at 4:07 p.m., minutes after the blowup began. The fire had burned across the West Drainage and was advancing upcanyon in a “U” shape below the west flank fireline. Illustration: USDA Forest Service, Fire Sciences Laboratory, Rocky Mountain Research Station, Missoula, MT, 1998.

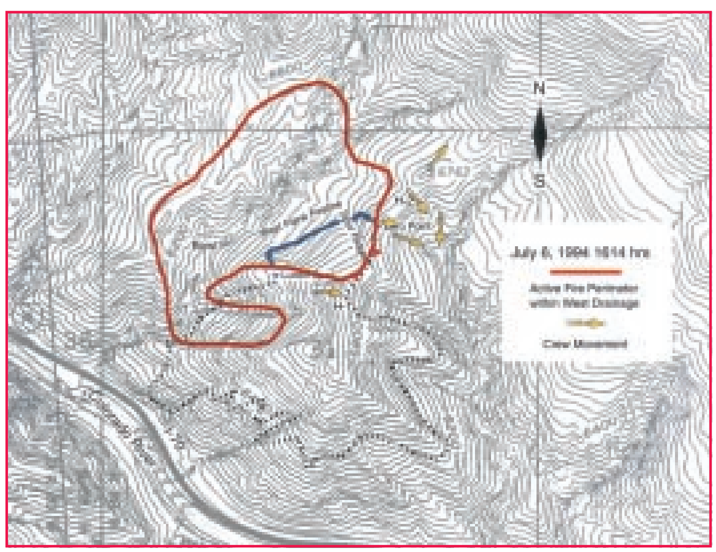


__Figure 7__—South Canyon Fire perimeter at 4:14 p.m., just after the entrapment on the west flank fireline. The fire had completely overrun the west flank fireline and was threatening H–2. Illustration: USDA Forest Service, Fire Sciences Laboratory, Rocky Mountain Research Station, Missoula, MT, 1998.

> Within minutes after the firefighters began to retreat, the fire had entirely overrun the west flank fireline, claiming the first fatalities.

The Entrapments

Before the blowup, an advance scout and a group of eight firefighters were observing the fire south of Lunch Spot Ridge. By 4:06 p.m., all nine had retreated to Lunch Spot Ridge. The scout found a safety zone on the ridge, which remained largely unburned during the blowup. The other eight moved upridge to a previously burned area of black several hundred feet below H–1. At 4:24 p.m., they deployed their fire shelters. Over the next 45 minutes, they felt the heat from three separate fire runs just south of Lunch Spot Ridge, about 500 feet (150 m) away. All survived unhurt.

The rest of the west flank firefighters were north of Lunch Spot Ridge before the blowup, widely dispersed along the fireline. All retreated back up the fireline toward Main Ridge—a distance of up to 1,880 feet (575 m) for some. Twelve firefighters who had been working on the lower portion of the fireline were caught by the fire at about 4:13 p.m. Most were in a group about 280 feet (85 m) below Main Ridge. All died within seconds of each other (see sidebar on page 20).

At 4:14 p.m., two helitack personnel watched the fire front approach them at H–2. Instead of dropping into the East Drainage with the other ridgeline firefighters, they ran up the ridge toward the mountain, perhaps trying to reach high ground for helicopter evacuation. By 4:18 p.m., a finger of the fire cut off any possibility of escape into the East Drainage. Angling toward a rock outcropping, the two died crossing a gully at about 4:23 p.m., probably from inhaling lethal hot gases funneled up the draw.

Lessons Learned

The South Canyon Fire tragically illustrates the deadly fire behavior that can occur under certain conditions of fuel, weather, and topography. Though extreme, such fire behavior is normal under the conditions that prevailed on Storm King Mountain on the afternoon of July 6. Until then, the fire was a low-intensity surface burn, with high-intensity fire behavior limited to the torching of individual trees and narrow runs within the fire's perimeter. But by 4 p.m., changing wind conditions, combined with slope and fire location, dramatically altered the fire's behavior. Within minutes, flames swept through the live fuel canopy in a continuous blazing front that caught the firefighters before they could reach their safety zone, resulting in 14 fatalities.

Several conclusions can be drawn from what happened on Storm King Mountain:

- **Topography can strongly affect local wind patterns.** In mountainous terrain, surface winds can be highly variable and subject to sudden dramatic change, especially during frontal passages. Winds should be constantly monitored all around the fire perimeter.
- **Vegetation, topography, and smoke can prevent firefighters from noticing changes in fire behavior.** Evidence suggests that the 12 firefighters overrun on the west flank fireline were caught by surprise, perhaps because they failed to realize how close the fire was getting. Lookouts positioned outside the burn area or overhead can communicate urgency and give escape directions.
- **Extreme fire behavior often occurs abruptly.** The low-intensity backing fire gave no hint of what was to come; the transition to a high-intensity fire was sudden and perhaps unexpected in the live fuels. Under certain conditions, green vegetation can support and even promote high-intensity burning. A fire's position should be constantly monitored in relation to wind, slope, and fuels; training in fire environment assessment might help firefighters anticipate potential fire behavior.
- **The longer and farther a fire burns, the more likely it is to change behavior.** Given sufficient time, a low-intensity fire can often reach a position where fuel, weather, and terrain combine to produce high-intensity fire behavior. The location of the fire perimeter should be constantly monitored.
- **The safety of an escape route is a function of its length and direction.** Escape routes should be chosen based on the potential for extreme fire behavior. Ideally, they are short and downhill.
- **Underburned Gambel oak provides no safety zone.** The blowup began in green Gambel oak but continued into the underburned areas above the west flank fireline, which offered no safety. Firefighters do not

have "one foot in the black" when working adjacent to underburned shrub vegetation.

None of the lessons from the South Canyon Fire is particularly new, and most will be readily apparent to firefighters. Perhaps the most important lesson is that the blowup was normal under the circumstances. A similar alignment of environmental factors and extreme fire behavior is not uncommon and will happen again. What was not normal is that 14 firefighters were caught in the blowup and could not escape. By learning from their experience, firefighters can help prevent a similar tragedy from occurring elsewhere.

To obtain the study summarized in this article, contact the Ogden Service Center, Publications Distribution, Rocky Mountain Research Station, 324 25th Street, Ogden, UT 84401, tel. 801-625-5437, fax 801-625-5129, or visit the center's Website at <http://www.fs.fed.us/rm/pubs/rmrs_rp9.html>.

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How Were the West Flank Firefighters Overrun?

Before reaching Main Ridge, the last survivor on the west flank fireline was knocked from his feet by a blast of hot air from the rear. Most of the twelve who died were still in line, many with their packs on. They had neither discarded their tools nor made any organized attempt to deploy their fire shelters. The dense Gambel oak and smoke in the air likely prevented them from seeing how close the fire really was. Circumstances suggest that the fire overran them with unusual rapidity, perhaps catching them by surprise; the vegetation all around them might have seemed suddenly to explode in flames. Three scenarios, perhaps in combination, might explain such fire behavior:

- **Collapsing Pocket in the Fire Front.** Toward the top of Main Ridge, northeast of the west flank fireline, the vegetation changed from Gambel oak to a pinyon–juniper mix (fig. 2). The fire could advance faster in the flashier pinyon–juniper fuels to the left of the firefighters than in the Gambel oak behind them. To their right, the fire had already reached Main Ridge. The firefighters were in a pocket, with fire burning around them on three sides. The intense energy projected from three sides might have rapidly ignited the vegetation around the firefighters, collapsing the pocket and sending a blast of hot air upslope.
- **Descending Smoke Column.** As the fire gained on the fleeing firefighters, a gust from the strong westerly winds sweeping over the West Drainage might have pushed the column of smoke and burning gases directly onto the firefighters. The embers and hot air would have quickly ignited the surrounding vegetation, and the gust of hot gases might have been experienced upslope as a blast from the rear.
- **Rapidly Spreading Fire.** The fire spread upslope much faster than the firefighters were traveling. By 4:13 p.m., as the firefighters stumbled over oak stobs up the last and steepest section of fireline below Main Ridge, their rate of travel would have fallen to 1 to 3 feet per second (0.3–0.9 m/s). They simply couldn't outrun the fire, which by this time was traveling up to 9 feet per second (2.7 m/s). The rapid rate of spread might have pushed a blast of hot air upslope.

We Still Need Smokey Bear!

Jon E. Keeley

It was gratifying to see articles in recent issues of *Fire Management Today* clarifying the role of Smokey Bear in wildland fire management strategies (Baily 1999; Brown 1999). These articles clearly spelled out Smokey's importance in reducing unplanned human-ignited wildland fires and rightly criticized attempts to detract from Smokey's campaign (Williams 1995; see also Vogl 1973).

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Fire prevention strategies aimed at reducing unplanned ignitions remain very desirable.

Why Smokey?

Continuing the Smokey campaign is essential for two reasons. First, in western coniferous forests where natural fires have been largely excluded, fire management focuses on the controlled reintroduction of fire. Therefore, fire prevention strategies aimed at reducing unplanned ignitions are still very desirable. Second, western shrublands in California's coastal ranges have experienced a massive increase in human-caused fires during the 20th century (fig. 1). Human-caused fires continue to threaten the region's natural ecosystems (Keeley et al. 1999).

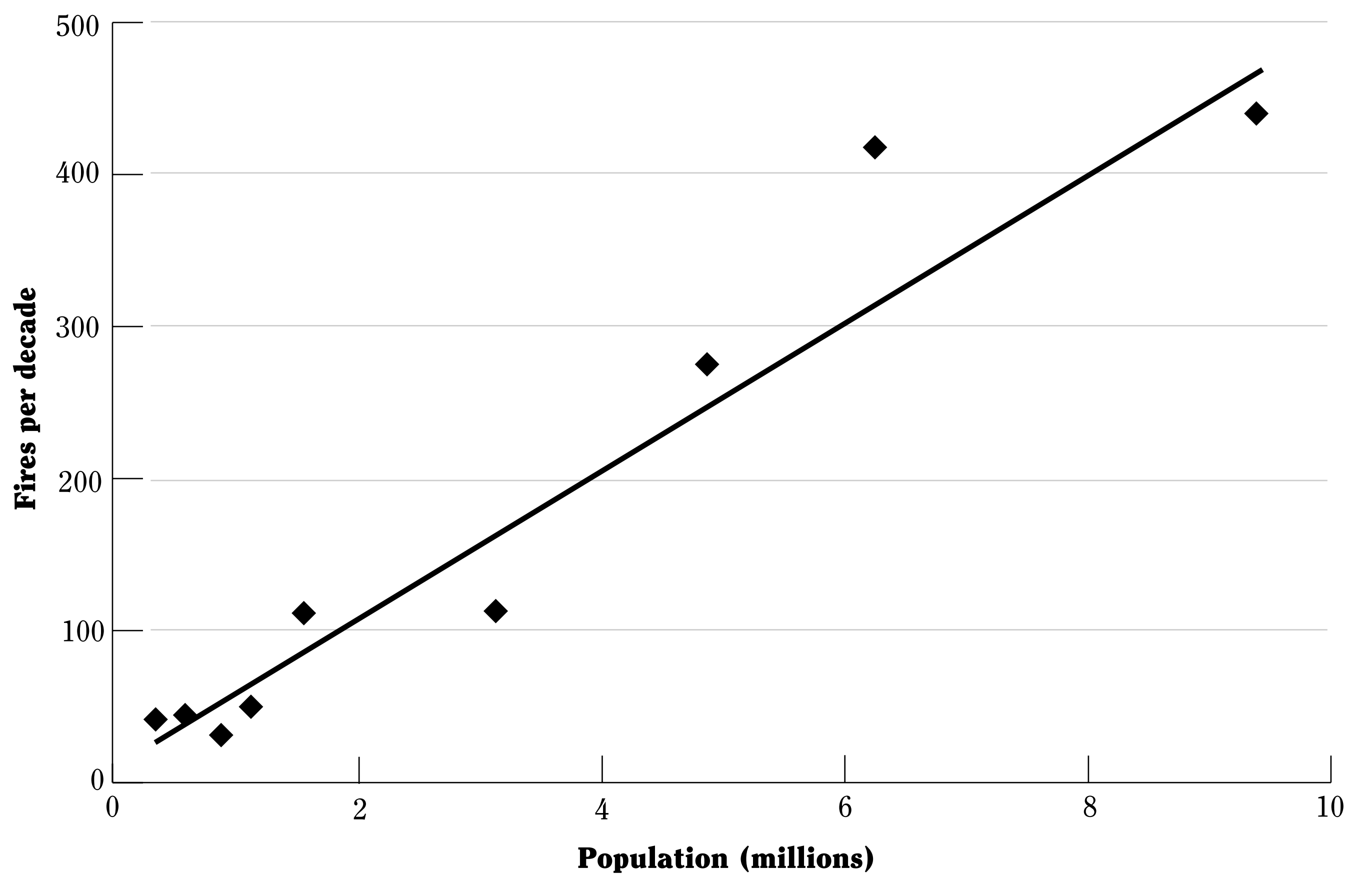

Figure 1—*Population growth and number of fires per decade in Los Angeles and Riverside Counties from 1910 to 1999 (CDF 2000). The data suggest a linear correlation ($r^2 = 0.96$, $P < 0.001$) between population density and fire frequency in the two fastest growing counties in southern California. Illustration: Jon Keeley, U.S. Geological Survey, Three Rivers, CA.*

Population growth in southern California is creating unprecedented challenges for wildland fire management.

Smokey's critics are apparently concerned that Smokey is preventing the public from perceiving the natural role of fire in coniferous forests such as ponderosa pine. There is understandable worry that public opposition might block future efforts to restore natural fire regimes.

However, it is important to note that the historical reluctance to use fire in coniferous forests originated not with the public, but with scientists and policymakers (Clar 1959). Critics such as Brown (1999) and Baily (1999) hope to combine into a single message the need for natural fire regimes and the necessity for public fire prevention. Although the resulting message might be complicated, it nonetheless represents a reality that must be dealt with. Simplistic messages are inappropriate.

Fire Danger in Southern California

Southern California's shrublands represent a situation very different from western coniferous forests, where fire exclusion has often increased fire return intervals. In southern California, the landscape is currently subject to an unnaturally high frequency of fire (Keeley et al. 1999). Major population centers sit astride fire-prone ecosystems, and human activities have vastly reduced the fire return interval. Unlike elsewhere in the West, gaining public acceptance for the natural role of fire is not a high priority. Instead, concern justly focuses on spiraling increases in population density.

Population growth in southern California, coupled with increasing access to wildland areas, creates unprecedented challenges for wildland fire management. Fire suppression crews, like Alice in Wonderland, must "run just to stay in place"; and southern California, like the Red Queen, yells, "Faster!" Now more than ever, Smokey and his message are needed.

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Now more than ever, Smokey and his message are needed in shrubland ecosystems.

Wildland Fire Communications: The Mexican Connection

Stephen M. Jenkins

On May 11, 1997, President Clinton and the leaders of 15 other nations gathered in Barbados to sign a partnership for prosperity and security in the Caribbean Basin. One of the agreements pertained to wildland fire operations and other kinds of emergency responses along the 1,933-mile (3,110-km) U.S. border with Mexico. The United States and Mexico "agreed to work toward concluding an agreement that will identify and protect radio frequencies" for firefighters in border areas.

> The United States and Mexico agreed to identify and protect special radio frequencies for wildland firefighters in border areas.

Communications Coordination

Radio interference between Mexico and the United States was almost nonexistent prior to 1975. Since then, however, both countries have developed their land mobile radio systems at an astronomical rate. As spectrum utilization increased and with no formal frequency coordination in place, collision between radio systems became inevitable—especially for incident communications, when multiple aircraft and fire suppression teams are in use.

Radio interference is especially serious during aerial operations on wildland fires. When helicopters, airtankers, and air attack planes are working close to a fire, they need a clear, uninterrupted channel of communications with ground personnel for the safety of all concerned.

For most of the past 20 years, radio frequency coordination with Mexico was limited to the local level. Since 1988, Michael Wingate, incident frequency manager for the USDA Forest Service in the Pacific Southwest Region in Sacramento, CA, and Hal Grigsby, frequency manager for the Federal Communications Commission in San Diego, CA, have worked with their counterparts in Mexico to solve interference problems along the border from San Diego to Yuma, AZ.

In 1993, during a rescue attempt on the Glenn Allen Fire in Los Angeles County, CA, Mexican radio interference limited the effectiveness of a helicopter crew trying to evacuate trapped firefighters. Two fatalities resulted, partly due to the interference. In 1994, William Jahn, Director of Telecommunications Policy for Mexico for the U.S. Department of State, and Thomas Thomison, frequency manager for the USDA, began negotiating with Mexico on a national level to protect all radio frequencies used during wildland fire suppression. Their work led to the 1997 Barbados agreement to collaborate at the national level.

The Barbados agreement quickly bore fruit. On December 17, 1998, the United States and Mexico signed a memorandum of understanding (MOU) to protect radio frequencies used in firefighting. Both countries agreed to reserve certain radio frequencies for exclusive use during firefighting and other emergency responses.

The MOU provides Mexican emergency management officials with access to emergency radio equipment in the National Incident Radio Support Cache (NIRSC) at the National Interagency Fire Center (NIFC) in Boise, ID. Along with the equipment, Mexico can obtain support from incident communications advisors during fires and other natural disasters, such as earthquakes and hurricanes.

Fire Mapping Support

The 1998 fire season in Mexico was the worst in the country's history.* On May 23, NIFC received a resource order from the Office of

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* For a discussion of wildland fire in Mexico, including the 1998 fire season, see Dante Arturo Rodríguez-Trejo, "A Look at Wildland Fires in Mexico" *(Fire Management Notes* 59(3): 15–23).

Foreign Disaster Assistance, in conjunction with the U.S. Department of State, to assist firefighting efforts in Chiapas, a State in southern Mexico. The request was for:

- An aircraft equipped with an infrared line scanner for mapping wildland fires,
- A flight crew,
- An infrared equipment operator, and
- Infrared interpreters (see sidebar below).

NIFC's premier fire-mapping aircraft, the Sabreliner jet, was already deployed in Canada, so NIFC sent the King Air 200 to Mexico. On May 23, a fire-mapping unit landed in Tuxtla Gutiérrez, Chiapas, its operational base in Mexico. After several days of mapping fires in Chiapas, a request came from neighboring Guatemala to map fires burning there. The unit flew to Flores, Guatemala, where it operated for several days. After returning to Tuxtla and mapping in Chiapas for several more days, the unit flew back to the United States on June 4.

On June 8, another request came from the U.S. Department of State to map fires in Chiapas. This time, NIFC sent the Sabreliner jet. The fire mapping unit started work on June 10, again operating out of Tuxtla, and returned to the United States on June 14.

In 1998, U.S. units mapped a total of 30 to 40 fires in Mexico and 4 fires in Guatemala. Through international agreements, U.S. aircraft had been used to map fires in Canada for more than 20 years. But this was the first time U.S. aircraft had been used to map fires south of the border.

What Is Infrared Fire Mapping?

On most fires, smoke obscures the view from the ground and even from the air. Observers often cannot tell where the fire is actively burning, what direction it is taking, and whether it is spotting. Without good information on the fire's perimeter and behavior, incident commanders have difficulty placing resources safely and effectively on a fire.

That's where infrared technology comes in. Specially equipped aircraft based at the National Interagency Fire Center in Boise, ID, fly over a fire and use infrared photography to map the fire through the smoke. The imagery is transmitted to an infrared interpreter in fire camp, who translates the information to standard maps for use by incident management teams in planning and directing the attack.

Radio Equipment Used on a Fire: Some Basics

Starter system: A starter system is the initial equipment delivered to an incident management team on a fire. The system includes:

- 3 tactical radio kits,
- 1 command repeater,
- 3 remote kits,
- 1 ground-to-air radio kit,
- 1 logistics radio kit, and
- 1 logistics repeater.

Tactical radio kit: A tactical radio kit contains 16 VHF radios used by firefighters to communicate with each other on the ground.

Repeater: A repeater is a relay needed for radio communication over mountains or long distances (where radios are not in line of sight).

Remote kit: A remote kit permits installation of a remote base to connect the incident command post with widely scattered incident locations, such as spike camps and helibases.

Logistics radio kit: A logistics radio kit contains 16 UHF radios used by incident support personnel for planning, logistics, finance/administration, and other functions.

UHF link kit: A UHF link kit is used on very large fires to link multiple command repeaters over an area too large to be covered by a single repeater. It links UHF frequencies to VHF frequencies.

Radio interference is especially serious during aerial operations on wildland fires.

Equipment Transfer

In May 1998, in response to the worsening fire situation, the NIRCS transferred telecommunications equipment to Mexico's Ministry for Environment, Natural Resources, and Fishery (SEMARNAP), the country's main Federal firefighting organization. The equipment included:

- Three starter systems,
- Twenty tactical radio kits with MT–2000 radios, and
- Additional repeaters and UHF link kits.

The U.S. Department of State reimbursed the NIRSC for the equipment.

On May 24, NIFC dispatched four communications specialists to install, operate, and manage the transferred radio equipment in Mexico. The unit operated in two teams to help the Mexican government establish tactical ground and air communications in the States of Chiapas and Oaxaca.

Interagency Teams Go South

Since 1997, when Mexico and the United States signed an agreement to coordinate communications on wildland fires and other emergencies, the National Interagency Fire Center (NIFC) in Boise, ID, has dispatched several teams to support wildland fire suppression in Mexico.

In May 1998 and again in June 1998, at the request of the Mexican government, NIFC sent aircraft to map 30 to 40 wildland fires in the Mexican States of Chiapas and Oaxaca using infrared equipment. The team in May included:

- A flight crew—Lamont Humber and E.J. Kral, pilots for NIFC, Boise, ID;
- An infrared-equipment operator—Tom Gough, an electronics technician for NIFC, Boise, ID; and
- Two infrared interpreters—Bob Bewley, a geographic information systems coordinator for the USDI Bureau of Land Management in Santa Fe, NM; and Larry Miller, a timber management officer for the Forest Service, National Forests in Mississippi, Jackson, MS.

The team in June was the same, except that Mike Cavaille, a chief pilot for NIFC in Boise, ID, replaced Lamont Humber on the flight crew.

In May 1998, NIFC transferred incident communications equipment to Mexico and sent a team of experts to coordinate its use. Team members included:

- Team Leader Frank McCarthy, a fire captain for the Los Angeles County Fire Department, Los Angeles, CA;
- Marco Muñoz, a communications specialist for the Forest Service, Malheur National Forest, John Day, OR; and
- Al Karnowski and José López, electronics technicians for NIFC, Boise, ID.

After 24 days, the team was replaced by a second group, including:

- Team Leader Jim Jordan, a fire captain for the Los Angeles County Fire Department, Los Angeles, CA;
- Victor Salazar, an electronics technician for NIFC, Boise, ID; and
- Carlos Rosas and Bob Fisher, communications specialists, respectively, for the Alaska Fire Service, Fairbanks, AK, and the Forest Service, Black Hills National Forest, Custer, SD.

In May 1999, NIFC sent a team to Mexico to evaluate caching procedures and inventory control of the communications equipment donated to Mexico. The team included:

- Team Leader Mark Barbo, a coordinator for NIFC, Boise, ID;
- Steve Warden, a warehouse supervisor for the Alaska Fire Service, Fairbanks, AK; and
- Royce Shearing and John Moulder, communications specialists for NIFC, Boise, ID.

On June 14, after a 24-day assignment, the initial group was replaced by a second unit. When the fires were finally extinguished, the equipment was returned to Chiapas and stored in a warehouse for future incidents.

Training Support

In May 1999, another team arrived in Mexico to evaluate caching procedures and inventory control of the communications equipment and other fire suppression apparatus donated to Mexico. The team's mission was to assist in developing operations and training plans for incident communications in Mexico.

SEMARNAP asked for help in setting up its own training course for communications technicians. The team recommended a "train-the-trainer" approach. SEMARNAP selected four students to attend the interagency Communications Technician course (S–258) at NIFC. The training took place on October 4–8, 1999 (see sidebar on page 27), giving the students the skills needed to establish communications coverage on an incident using portable, low-power radio equipment.

After the course, the students immediately put their new skills to the test. On October 8, they were assigned to the Kirk Fire on California's Los Padres National Forest. Carlos Rosas from the Alaska Fire Service supervised the detail. During their 5 days on the fire, the Mexican detailers did what any communications technicians would do on an incident. They flew in helicopters to mountaintop repeater sites to change batteries, even repairing one malfunctioning site. They also visited several helibases, repairing an air-to-ground radio system and helping to rehabilitate a demobilized campsite. Most importantly, they got to see firsthand the organization and operation of suppression efforts on a project fire in the United States.

The Glenn Allen Fire tragedy drew national attention to the problem of cross-border radio interference.

On October 13, the Mexican delegation returned to NIFC and spent 2 more days learning how to program and set up a remote automated weather station.

All training was conducted in Spanish using course materials translated from the English. The Mexican students took home working copies of all materials to use in conducting their own training. In November 1999, they began their own incident communications training in Mexico.

Collaboration Benefits

What began more than 20 years ago, based on local collaboration between a few individuals on both sides of the border, has blossomed into a formal bilateral agreement. Both Mexico and the United States benefit. The donated radio equipment not only helps Mexico better manage wildland fires in States such as Chiapas, it will also facilitate joint fire operations across the Mexico–United States border. Moreover, for fire suppression personnel to effectively use the NIRSC radio equipment, the

Student Isidro García Alvarez installing an antenna system for a command repeater. In 1999, four students from Mexico took the interagency Communications Technician course at the National Interagency Fire Center in Boise, ID. Photo: Stephen M. Jenkins, National Interagency Fire Center, Boise, ID, 1999.

frequencies must be protected. The likelihood of future interference in border areas such as San Diego County, CA, is now greatly reduced.

The agreement with Mexico is similar to one the United States has with its neighbor to the north, Canada. Through these agreements to provide mutual support in case of emergencies such as wildland fires and natural disasters, North America is tied together more closely than ever. For more information on fire mapping and radio communications on wildland fires, contact Steve Jenkins, Operations Manager, National Incident Communications/Infrared Operations, National Interagency Fire Center, 3833 S. Development Avenue, Boise, ID 83705, 208-387-5485 (voice), 208-387-5560 (fax). ■

Students from Mexico at a helibase on the 1999 Kirk Fire, Los Padres National Forest, CA. From left to right are Carlos Escobar Villagrán, Miguel Angel Calderón, a helitack foreman from the California Department of Forestry and Fire Protection, Isidro García Alvarez, and Juan Arturo Raygoza Martínez. After taking the interagency Communications Technician course, the students applied their new skills on the Kirk Fire. Photo: Stephen M. Jenkins, National Interagency Fire Center, Boise, ID, 1999.

Training Course Gives Students New Communications Skills

On October 4–8, 1999, four students chosen by Mexico's Federal wildland fire management agency (SEMARNAP—the Ministry for Environment, Natural Resources, and Fishery) completed the interagency Communications Technician course (S–258) at the National Interagency Fire Center (NIFC) in Boise, ID. The students included:

- Juan Arturo Raygoza Martínez, an information officer for SEMARNAP, Mexico City;
- Isidro García Alvarez, Chief of the National Forest Fire Control Center, Mexico City;
- Miguel Angel Calderón, an information officer for SEMARNAP, Mexico City; and
- Carlos Escobar Villagrán, Chief of the Program of Forest Protection, Tuxtla Gutiérrez, Chiapas.

José López from Arizona's Kaibab National Forest, Williams, AZ, worked with Rhonda Toronto and Shannon Tippett, both from NIFC, to translate the S–258 course materials into Spanish. The trainers were:

- Tony Martinez, a communications specialist for the USDA Forest Service, Shasta–Trinity National Forest, Redding, CA;
- Marco Muñoz, a communications specialist for the Forest Service, Malheur National Forest, John Day, OR;
- Carlos Rosas, a communications specialist for the Alaska Fire Service, Fairbanks, AK;
- Victor Salazar, an electronics technician for NIFC, Boise, ID;
- Shannon Tippett, an electronics technician for NIFC, Boise, ID; and
- Rhonda Toronto, a program training manager (electronics) for NIFC, Boise, ID.

Given in Spanish, the training covered everything pertaining to the incident communications equipment in the National Incident Radio Support Cache at NIFC. Topics ranged from system design to equipment issue, setup, troubleshooting, rehabilitation, inventory, and tracking. The students took home sets of training materials. Sponsored by SEMARNAP, in November 1999 they became trainers themselves in safe and effective incident communications in Mexico.

Simulating Nocturnal Smoke Movement

Gary L. Achtemeier

The continued supply of our Nation's paper and other wood products increasingly depends on wood fiber produced from forests in the Southern United States. Approximately 200 million acres (81 million ha) of forest are within 13 Southern States—roughly south of the Ohio River and from Texas east. Although these States represent only 24 percent of the U.S. land area, 40 percent of the Nation's forests lie within this region. Southern forests are dynamic ecosystems that, under good land stewardship practices, can continue to supply the Nation with many goods and services (SRFRR 1996).

Southern land managers understand that prescribed fire is the most economical way to reduce fuels; remove nutrient-competing species; and lower the danger of wildland fire, which can destroy commercial fiber and threaten urban areas. Additionally, threatened and endangered species influence management of some Southern forests. For instance, because many threatened plant and animal species are fire dependent—they rely on fire for reproduction and elimination of competing species—managers consider prescriptions that help ensure the continued survival of these species.

Gary Achtemeier is the team leader for the Smoke Management Team, USDA Forest Service, Southern Research Station, Athens, GA.

> Prescribed fire is the most inexpensive way to reduce fuels, remove nutrient-competing species, and control the threat of wildland fire.

Problem: Smoke-Choked Highways

Land managers use prescribed fire to treat 6 to 8 million acres (2–3 million ha) of forest and agricultural lands in the Southern United States each year. This practice occasionally compromises air quality and visibility (fig. 1). The number of highway accidents related to smoke, sometimes in combination with fog, is increasing in direct proportion to the number of people driving on our Nation's extensive road network. Multiple-car pileups, many physical injuries, extensive property damage, and fatalities are associated with visibility reductions due to smoke or smoke and fog on roadways.

Many serious accidents occur at night or near sunrise as smoke trapped in stream valleys and basins drifts across roadways. Mobley (1989) conducted a comprehensive study on smoke-related highway incidents in the South from 1979 to 1988. He found that visibility reduction due to smoke or a combination of smoke and fog was related to 28 fatalities, more

Figure 1—*Smoke from smoldering embers following a prescribed fire in a Southern forest. The fire front is visible in the distant background. When smoldering continues after sunset, smoke can become trapped in the shallow, cold layers of the ground air and then be carried by local winds across roadways, creating visibility hazards for transportation. Photo: USDA Forest Service, Southern Research Station, Athens, GA.*

than 60 serious injuries, many minor injuries, and litigation expenses into the millions of dollars. On May 8, 2000, near Interstate 10 in southeastern Mississippi, a mixture of fog and smoke from a small wildland fire was tied to a predawn accident that killed five and injured 24 (Twilley 2000).

Solution: Modeling Nocturnal Smoke Movement

Simulating smoke movement at night is a complex, time-dependent problem. Wind shifts can transport smoke to different locations at various times during the night. Land management personnel charged with alerting the appropriate authorities to pending transportation hazards must know where and when smoke will arrive. Wind observations from nearby weather stations are often unreliable because of the local nature of night winds. Furthermore, weather stations report windspeeds that are less than 2 miles per hour (1 m/s) as calm. However, a windspeed of 2 miles per hour (1 m/s) blowing for 10 hours at night can move smoke 20 miles (32 km) from its origination point—potentially affecting roadway visibility at many locations and at great distances.

The Smoke Management Team at the USDA Forest Service's Southern Research Station in Athens, GA, developed a smoke movement and dispersion model that departs from proven techniques, such as Gaussian plume models like VSMOKE (Lavdas 1996). Planned Burn—Piedmont (PB-Piedmont), version 1.2–95, designed to model smoke movement when winds are light and highly variable, is a wind model and a particle generation model. The model addresses the problem of complex terrain with ridge/valley height differences of less than 330 feet (100 m) where smoke plumes diverge and split into neighboring valleys. This type of terrain characterizes the Piedmont of the Southeast and topographically similar areas of the United States. PB-Piedmont models smoke movement as a mixture of independent particles—similar to smoke actually flowing downwind from a burn site.

Smoke trapped inside a valley gradually "bleeds" away as the valley ventilates. The team designed the smoke model so that particles could periodically "birth"—increasing the number of particles and allowing the model to simulate the "bleedoff" of smoke.

Related Smoke Simulation Model

The Smoke Management Team used the Slow Nocturnal Air Flow (SNAF) model to help develop PB-Piedmont. SNAF simulates minuscule pressure forces that could drive winds as slow as 4 inches per second (10 cm/s) (Achtemeier 1991) over ridges and valleys with height differences of less than 330 feet (100 m). In 1991, a prototype of SNAF was completed and satisfactorily tested against wind data collected with instruments that measured windspeeds as slow as 4 inches per second (10 cm/s) (Achtemeier 1993a, 1993b).

We linked the smoke model—research version "Pregnant Bubbles" (Achtemeier 1996)—to the Slow Nocturnal Air Flow model (see sidebar) and tested it in an accident case in Georgia in which smoke played a role. The model successfully placed smoke at the accident site and at another site at the same times that smoke was actually observed (Achtemeier 1993c, 1993d; Achtemeier and Paul 1994).

Developing PB-Piedmont

Initial results encouraged the Smoke Management Team to go with an operational version. However, the available computer technology did not meet the model's requirements. Desktop computers were too slow and lacked sufficient memory, and the methods to transfer data to the computers were still under development. Due to the prevailing climate, development of the operational version experienced the following complications (fortunately, now mostly solved):

- Because privately owned forests are prevalent in the South, the model had to be user friendly to encourage private landholder use. *Solution*—Forest managers on the Oconee National Forest, Eatonton, GA, received the new smoke model for beta testing in the spring of 1997. Their comments, and conversion to Windows 95, helped the team make the model more user friendly.
- The model had to run quickly on computers with limited processing speeds and memory storage capabilities. *Solution*—Computer technology today exceeds model requirements.

Single Particles in Smoke-Filled Rooms

The ventilation of a smoke-filled room illustrates the smoke dispersion problem. Smoke does not immediately vacate a room; rather, it thins out as fresh air gradually mixes with and replaces the smoky air. If a single particle in the smoke model represented the smoke within the room, the room would be either completely smoke filled or completely smoke free, depending on whether the particle remained within or departed from the room. PB-Piedmont simulates smoke dispersion by periodically increasing the number of smoke particles represented in the model.

Visibility reduction through smoke from prescribed fires has been linked to traffic fatalities and injuries, leading to costly litigation.

- PB-Piedmont requires spatial mathematical relationships among weather data captured at many stations surrounding burn sites throughout the South. *Solution*—The model receives, decodes, and processes large amounts of weather data, which are now accessible through the World Wide Web.
- The model simulates a time-dependent process of smoke movement. Because smoke locations are constantly changing, PB-Piedmont must display results graphically while calculations are ongoing. The team did not want to stop the model after every time step to enter the results into a commercial graphics package. Also, we did not want to require users to purchase expensive graphics software to run the model. *Solution*—In 1996, we developed model-compatible graphics software, which, in 1997, we linked with the model.
- PB-Piedmont requires detailed elevation data to model the slope and valley currents that carry trapped smoke. At the time of development, the USDI U.S. Geological Survey (USGS) had not digitized large areas of the southeastern Piedmont into 98-feet (30-m) resolution digital elevation maps. *Solution*—A mechanism to easily link and transfer these data to the model is under development.

Continued beta testing at the Oconee National Forest revealed that the most serious ongoing problem was linking the USGS digitized elevation data to PB-Piedmont. Although the Smoke Management Team had provided the elevation data for the Oconee National Forest, smoke knows no boundaries, and the lack of elevation data for surrounding private lands degraded model performance.

In 1998, fire managers at the regional office of the Forest Service's Southern Region in Atlanta, GA, asked the Smoke Management Team to provide sufficient elevation data on a CD-ROM so that they could run the model. The team is acquiring, quality checking, and reformatting 98-feet (30-m) digital elevation model data for more than 20,000 USGS 7.5-minute quads. We named the CD-ROM version of the model PB-Piedmont—"PB" stands for both Pregnant Bubbles (the research version) and Planned Burn (the operational version). We released PB-Piedmont for Georgia in November 1999 and the South Carolina version in December 1999. Versions for Alabama and Mississippi were available in mid-2000. Elevation data processing is occurring for Louisiana, Texas, and North Carolina—other Southern States will soon follow. Comments supplied by South Carolina users will help the team further simplify the user interface for PB-Piedmont. Additionally, a World Wide Website will soon allow users easy access to new, improved versions of PB-Piedmont.

Validating PB-Piedmont

Tests with PB-Piedmont show that the combination of large-scale wind systems with weak drainage winds that form over terrain typical of the southeastern Piedmont can create complex plume structures. To validate PB-Piedmont, we needed to compare the modeled smoke plumes with observed smoke plumes. The only way to observe an entire smoke plume moving along the ground at night is from the air. Since smoke scatters headlights from vehicles and creates visibility hazards, we believe it was possible that moonlight scattered by smoke would be visible from the air above the plume.

To test this idea, the Smoke Management Team conducted a project at the Oakmulgee Wildlife

Management Area on the Talladega National Forest in western Alabama. Mounting a Xybion* intensified, multispectral video camera with an infrared cutoff filter in a Beechcraft King Air aircraft, we flew the aircraft over test smoke plumes. We selected this site because it contained terrain typical for the Piedmont, provided a safe environment, and had no light sources that could contaminate the video imagery or damage light-sensitive equipment.

Because maximum moonlight was needed to permit data collection, we restricted field operations to clear skies and nearly calm winds during three 8-night windows timed to coincide with the full moon in January, February, and March 1997. Only four nights—one in January, one in February, and two in March—met both the lunar and the meteorological criteria.

Smoke behavior during the night of March 20, 1997, provided the most severe test of PB-Piedmont (Achtemeier 1998; Achtemeier et al. 1998). Because the forecast called for winds to decrease to nearly calm, we expected that rapid cooling in the basin would entrap smoke and that drainage and valley flows would favor slow movement of smoke downvalley to the northeast. Beginning at 9:45 p.m. central standard time, Forest Service ground personnel burned 50 bales of hay soaked in diesel fuel. They also detonated 60 smoke bombs that had a burn lifetime of approximately 2 minutes each. The fire began along a road next to a stream basin that flowed to the northeast. Aircraft overflights at approximately 5,000 feet (1,500 m) commenced at 9:48 p.m. and continued at 7-minute intervals for 2 hours. Video images from the Xybion camera were stored in Super Vertical Helical Scan (SVHS) format for future analysis.

Figure 2 shows actual smoke movement relative to the surrounding elevations. Elevations range from 330 feet (100 m) in the bottomlands to about 490 feet (150 m) along the ridgetops, with a few high points near 560 feet (170 m). Elevations greater than 445 feet (135 m) are shaded dark green to better identify the drainage basin. Elevations in the strip from 430 to 445 feet (130–135 m) are shaded light green to identify a gap in the ridge enclosing the southern end of the valley that is 33 feet (10 m) deep. Smoke generated at the burn site (fig. 2a) did not move down the valley as expected. Instead, the smoke moved southwest up the valley along the natural extension of the stream (fig. 2b). The plume then split around a protruding ridge (fig. 2c), flowing up a side valley and crossing the ridge through the shallow gap at the southern end of the valley. Smoke diversion through the side valley continued throughout the remainder of the burn (fig. 2d).

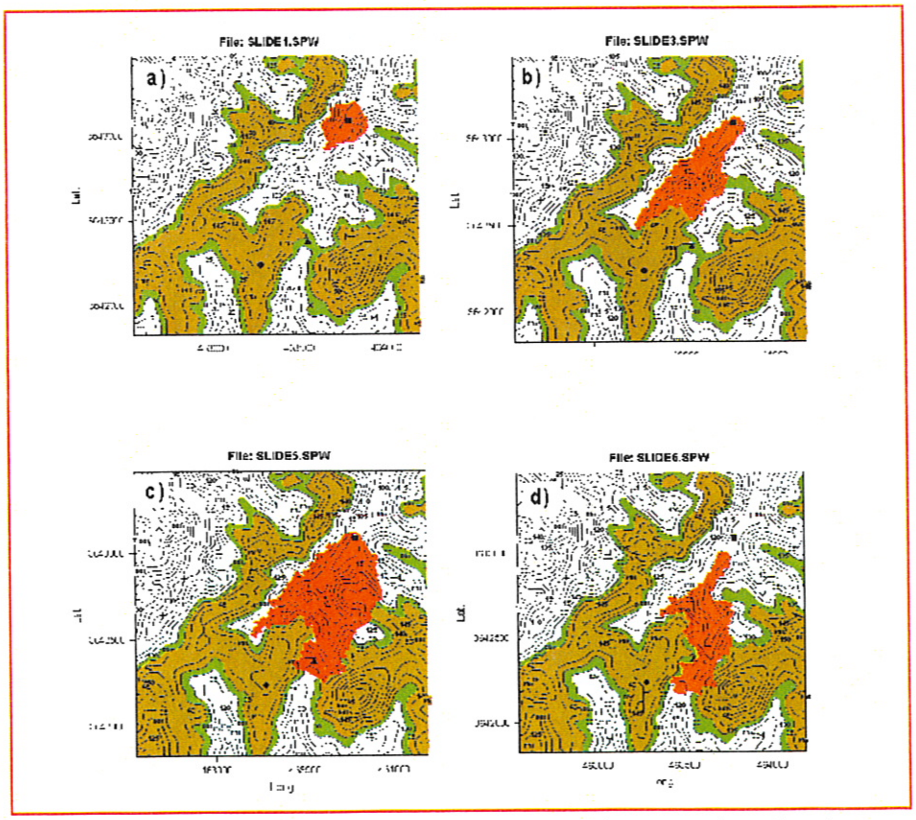

Figure 2—*Image analysis of smoke movement relative to the surrounding elevations, as extracted from video imagery during the night of March 20, 1997. (a) Plume shortly after ignition at 9:47 p.m. central standard time. (b) Plume drifting up the valley along the road at 10:02 p.m. (c) Plume diverting into the adjacent valley at 10:58 p.m. (d) Plume dissipating at 11:51 p.m. Black dots identify the burn site; red identifies the smoke plume; dark green identifies elevations above 445 feet (135 m); light green identifies elevations between 430 and 445 feet (130–135 m). Illustration: Smoke Management Team, USDA Forest Service, Southern Research Station, Athens, GA, 2000.*

*The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement of any product or service by the U.S. Department of Agriculture. Individual authors are responsible for the technical accuracy of the material presented in *Fire Management Today*.

The PB-Piedmont model simulates the problem of complex terrain where smoke plumes diverge and split into neighboring valleys.

Figure 3 shows smoke movement modeled by PB-Piedmont for the same times as in figure 2. From the point of ignition (fig. 3a), model smoke moves up the valley (fig. 3b), divides around the protruding ridge (fig. 3c), turns up the side valley, and crosses the ridge through the gap at the southern end of the valley (fig. 3d). PB-Piedmont results were nearly identical to the observed smoke movement, with the exception that PB-Piedmont later showed some smoke drifting down the valley (fig. 3d). No smoke was actually observed downvalley from the burn site.

PB-Piedmont Can Help Land Managers

The current version of PB-Piedmont (1.2–95) helps managers monitor where residual smoke from a prescribed burn, if present, might be going. PB-Piedmont provides numerical "eyes" to "see" smoke at night. The model's predictive time is about 30 minutes, which is usually long enough to make decisions about posting roadway signs, diverting traffic, or alerting law enforcement to possible visibility hazards. The model does not predict smoke concentrations, because residual smoke emissions are usually unknown.

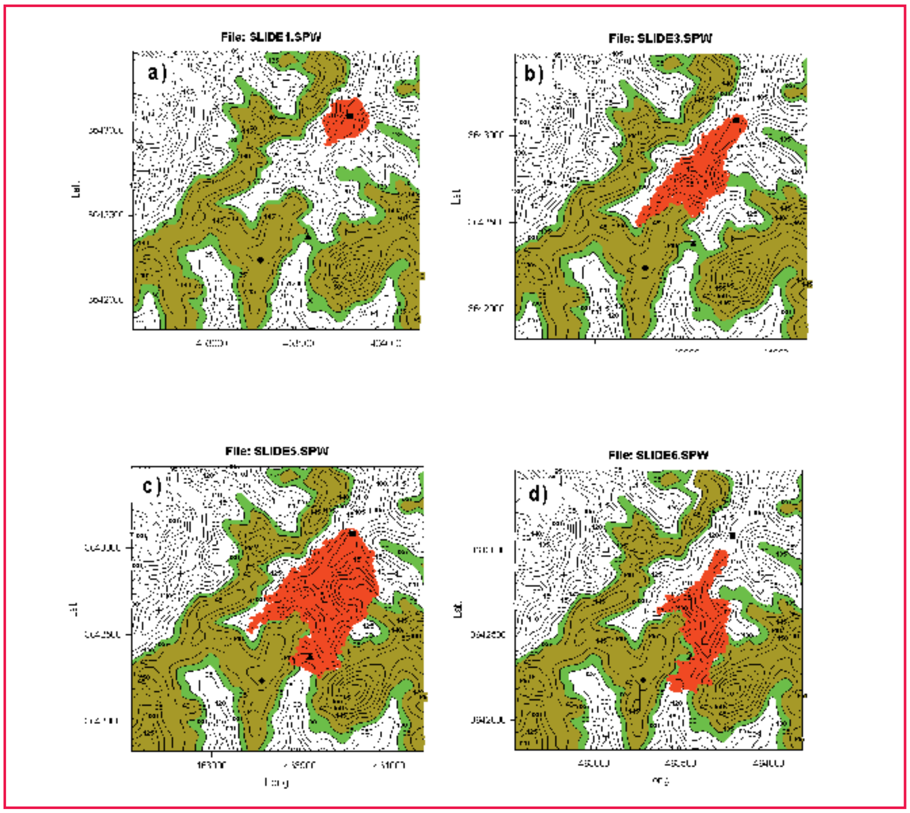

Figure 3—*Simulated smoke movement generated by the model PB-Piedmont for the night of March 20, 1997. (a) Plume shortly after ignition at 9:47 p.m. central standard time. (b) Plume drifting up the valley along the road at 10:02 p.m. (c) Plume diverting into the adjacent valley at 10:58 p.m. (d) Plume dissipating at 11:51 p.m. Red dots identify the burn site; white identifies the smoke plume; green identifies terrain at the lowest elevation, 330 feet (100 m); dark orange identifies terrain at the highest elevation, 490 feet (149 m). Illustration: Smoke Management Team, USDA Forest Service, Southern Research Station, Athens, GA, 2000.*

A future version of PB-Piedmont will link with models developed by the U.S. Department of Commerce, National Center for Environmental Prediction, that predict weather 48 hours into the future. When forecast data become routinely available for PB-Piedmont users, land managers might have enough information to make before-event decisions about whether to burn.

The Smoke Management Team is developing two sister models. PB-Coastal Plain will incorporate land use data and land/water information, along with small variations in elevation, to model smoke movement over the lower Coastal Plain. PB-Mountains will simulate smoke over the mountainous areas of the South.

Acknowledgements

The Smoke Management Team gratefully acknowledges the Forest Service's Remote Sensing Applications Center for loan of the Xybion intensified multispectral camera; the USDA Forest Service, Southern Region, Fire and Aviation Management for use of aircraft; Ken Forbus, Tim Giddens, Pat Outcalt, and Wayne Adkins (ret.) of the Southern Research Station's Smoke Management Team for technical and electronic contributions to the project; and ground crews on the Talladega National Forest, Oakmulgee Ranger District, Centreville, AL, for helping the project succeed.

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Fireline Humor From 1931

Gerald W. Williams

This bit of 1930's humor is from an old newsletter (*Six Twenty Six*, volume 15(4)) published by the USDA Forest Service's Pacific Northwest Region.

Jerry Williams is a historical analyst for the USDA Forest Service, Washington Office, Washington, DC.

HOW TO EXTINGUISH A FOREST FIRE

1. Throw patent cigarette lighter into midst of fire. There is a natural antipathy between fire and cigarette lighters. Flames will die out at once.

2. Spread luncheon cloth on grass, produce plate of sandwiches and announce in loud voice that it looks like a nice day for a picnic. Rain will pour down immediately, destroying forest fire and sandwiches.

3. Walk nonchalantly through fire and complain about feeling chilly. Flames will become discouraged and quit.

4. Whistle "Dixie" and start marching toward near-est river. Stirring music will cause flames to strut along behind you. Wade across river. Forest fire will try to follow you and will get its ardor dampened.

5. Borrow fire-eaters from [a circus] side-show and yell, "Free lunch – go to it, boys!" Flames will disappear rapidly.

(Clipped, D. J. Stoner)

Are Helibuckets Scooping More Than Just Water?

Justin Jimenez and Timothy A. Burton

> Fire management tactics might affect threatened, endangered, and sensitive fish species more adversely than the ecological impacts of the fire itself.

Natural resource managers are concerned that fire management activities—implemented over a broad range of habitats—might adversely affect threatened, endangered, and sensitive (TES) fish species. Every fire season, helicopters plunge attached buckets into rivers, streams, lakes, and ponds, and then travel to remote areas where they release their water loads onto wildland fires that are often inaccessible to ground-based firefighters. Although helibucket dipping is an effective fire management tool, any fish accidentally captured and transported in these buckets are doomed.

The USDI U.S. Fish and Wildlife Service and the U.S. Department of Commerce, National Marine Fisheries Service, require that State and Federal agencies evaluate the potential impacts of fire suppression activities on TES species. Land managers at the Boise National Forest (NF) decided to investigate whether helibucket dipping into small, high-elevation lakes and ponds could result in the capture and removal of TES fish species (see sidebar).

The Experiment: Where It Happened

During fire suppression, helicopters dip buckets into lakes, rivers, and streams that are preferably within 5 minutes flying time from the fire. A suitable dip site ensures operator safety and has sufficient water depth and surface area. Pilots typically dip at least 148 feet (45 m) from shore into the deepest part of the water body, but they may dip into shallower areas if they believe the location is safe. In our test, we attempted to sample typical helicopter dipping sites, as well as areas where we observed fish or where we thought they would be in high densities.

On the Boise NF at 7,000 feet (2,100 m), we selected three mountain lakes that, although they are not home to any TES fish species, are typical habitat for bull trout (*Salvelinus confluentus*) and cutthroat trout (*Oncorhynchus clarki*)—both considered at-risk fishes. We chose these lakes to avoid any potential impact to TES species. Bull Trout Lake is roughly 99 acres (40 ha), Martin Lake is approximately 10 acres (4 ha), and an unnamed "pothole" lake is about 0.5 acre (0.2 ha) in size. Martin Lake and the pothole lake do not have tributaries. However, Spring Creek, a small salmonid spawning stream, flows into Bull Trout Lake; and Warm Spring Creek, a larger salmonid spawning stream, flows out of this lake.

Brook trout (*S. fontinalis*) are the primary residents of Bull Trout Lake, and rainbow trout (*O. mykiss)* live in Martin Lake and the pothole lake (Allen 1999). In July and August 1999, the Idaho Department of Fish and Game stocked Bull Trout Lake with about 4,000 hatchery rainbow trout—8 to 12 inches (20–30 cm) long.

Protecting Threatened, Endangered, and Sensitive (TES) Species

Our study sites on Idaho's Boise National Forest primarily contained brook trout (nonnative in the West) and hatchery-raised rainbow trout—non-TES fish species. We assumed that non-TES salmonids would be at least as vulnerable to capture as TES salmonids, and that wild native fish would not likely show lower avoidance behavior than stocked fish. We used non-TES species as surrogates for TES salmonids to determine the potential for the capture of TES species in lakes by helibucket dipping.

Justin Jimenez and Tim Burton are fisheries biologists for the USDA Forest Service, Boise National Forest, Boise, ID.

Martin Lake became home for approximately 2,600 hatchery rainbow trout, and more than 500 of them took up residence in the pothole lake (Alsager 1999). Although all age classes of fish were in Bull Trout Lake, only the stocked hatchery rainbow trout resided in Martin Lake and the pothole lake.

Fish appear to avoid helibuckets dipped into small, high-elevation lakes and ponds because of helicopter rotor wash and the shadow of the helicopter.

How We Did It

Before the helicopter dipping tests, we snorkeled to survey fish presence, distribution, and species composition and abundance. Snorkel surveys identified fish near the inlet to Bull Trout Lake that were feeding throughout the water column. However, species identification and counts were difficult because the fish were wary of the snorkeler. The snorkeler did observe approximately 50 brook trout juveniles and fry in the inlet channels upstream of their entrance to the lake. Additionally, just before the dipping test, two recreational anglers caught two or three rainbow trout near the inlet of Bull Trout Lake.

We saw few fish feeding from the surface in Martin Lake. As in Bull Trout Lake, species identification and counts were difficult because fish fled from the snorkeler and hid in aquatic plants. We also snorkeled the pothole lake, which at the time contained approximately 200 of the hatchery rainbow trout 8 to 10 inches (20–25 cm) long. From the shore, we easily saw an abundance of fish in the pothole lake because its maximum depth is approximately 3 feet (1 m)—average depth is approximately 1.3 feet (0.4 m).

Boise NF district and forest fisheries biologists, the forest fuels planner, and members of the Lucky Peak Helitack Crew put the test into action on September 21, 1999, from 10 a.m. to 3 p.m. We used a type 2 helicopter (Bell 212) with a 1,300-quart (1,230-L) 4-foot by 4-foot (1.2-m by 1.2-m) bucket attached by a 98-foot (30-m) long line. We also tested a short line 15 feet (4.6 m) long. To allow dragging and capturing of water from the surface, we weighted the bucket on one side. After dipping, the helicopter pilot released the water from the bottom of the bucket into a 5,944-quart (5,625-L) storage tank near the inlet to Bull Trout Lake (fig. 1).

Figure 1—*A 5,944-quart (5,625-L) fold-a-tank storage facility near the inlet to Bull Trout Lake, Boise National Forest, ID. After dipping the helibucket into small, high-elevation lakes, the pilot released the water into the tank. Researchers then searched the water for captured fish during a study on the potential removal of threatened, endangered, and sensitive fish species through helibucket dipping. Photo: Justin Jimenez, USDA Forest Service, Boise National Forest, Boise, ID, 1999.*

In Bull Trout Lake, we dipped the bucket three times within 98 feet (30 m) of the inlet, three times within 30 feet (9 m) of the inlet, three times near the lake center, and three times within 98 feet (30 m) of the outlet. We tested use of the short line and its associated rotor wash in the last dip near the inlet of Bull Trout Lake (fig. 2). In Martin Lake, we dipped the bucket three times at various locations, including the center and just off the shore. At the pothole lake, we dipped the bucket three times where we could see the most fish.

What Happened

We did not capture any fish in the helibucket during any of the tests. However, we found midges in the mud and algae from the helibucket dipping near the outlet of Bull Trout Lake, and we captured flatworms at Martin Lake. We did not see any water surface disturbance from rotor wash when using the long line. However, we observed water surface disturbance from rotor wash when using the short line (fig. 2).

In all three lakes, fish appeared to avoid the helibucket, dispersing to prevent capture. Where the short line was used, rotor wash seemed to frighten the fish and make them disperse. Where the pilot used the long line and rotor wash was minimal, we think that the shadow of the helicopter and the sight of the bucket dropping caused the fish to disperse. In the pothole lake, the helicopter pilot deliberately tried to capture fish that he saw from the air. However, as the bucket approached the water surface, the fish scattered to avoid the bucket. During the last dip into the pothole lake, the pilot tried three times to capture fish by dragging the bucket toward a corner of the lake; still, he was unsuccessful.

Lessons Learned

During this experiment, we did not capture any fish, and we observed fish avoidance and dispersal behaviors. Although the sample size, location, and fish species limited our experiment, we concluded that there is little potential of capturing salmonids in lakes, reservoirs, and ponds by helibucket dipping. However, flow conditions in rivers and streams could affect the potential drift of fish into buckets or the ability of fish to disperse. Therefore, we do not recommend extrapolation of the results to rivers and streams; instead, we encourage similar experiments in rivers and streams.

Figure 2—*Helibucket dipping with a short line and dip tank. Note the rotor wash. Researchers on the Boise National Forest believe that fish avoid helibucket dipping from a short line probably because of rotor wash. Photo: Justin Jimenez, USDA Forest Service, Boise National Forest, Boise, ID, 1999.*

Literature Cited

Allen, D.B. 1999. Bull Trout Lake area creel surveys. Nampa, ID: Idaho Department of Fish and Game.

Alsager, R.D. 1999. Personal communication. Hatcheries manager, Idaho Department of Fish and Game, Nampa, ID. ■

Indiana Man Recognized for 42 Years of Volunteer Service

Teena Ligman

One of the USDA Forest Service's national volunteer awards for 1999 went to Herbert Dale Harrell, who spent much of his life as a Forest Service fire warden protecting Indiana's Hoosier National Forest from wildland fire.

When Harrell saw a smoke, he'd drop what he was doing and race to the fire to put it out.

Devotion to Fire Protection

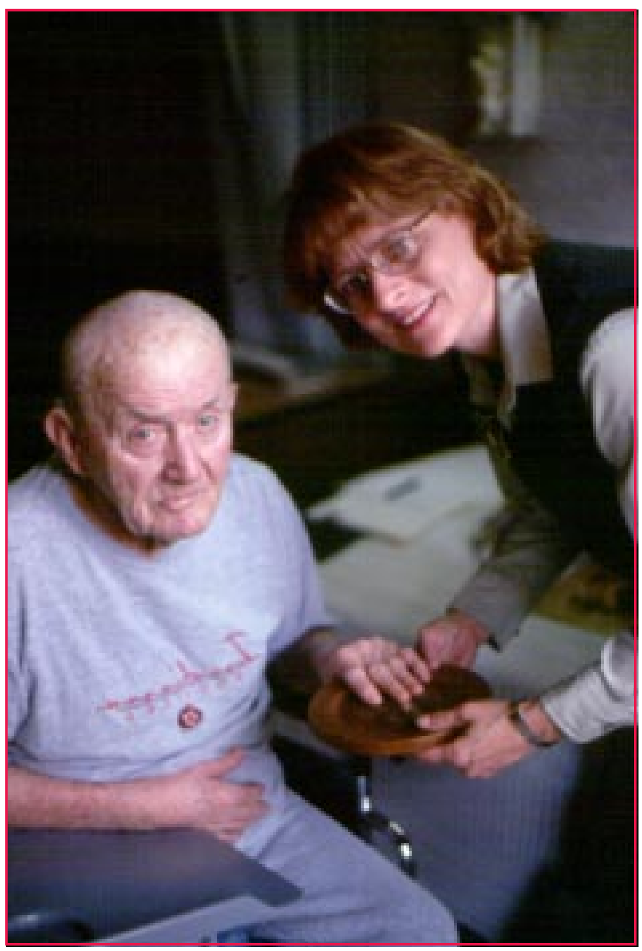
Harrell served as fire warden from 1956 to 1998. His home, with its sign and red fire cache, was a well-known landmark in Heltonville, IN, projecting a positive image for the Forest Service in the local community. With 42 years of service, Harrell was one of the longest serving fire wardens in the history of the Forest Service. He vigilantly trained and organized firefighters and passed on his passion for protecting the forest from fire.

Harrell, now 78, farmed and worked 33 years as a rural mail carrier for the U.S. Post Office. But his first interest was always the Hoosier National Forest and wildland firefighting. "If he saw a smoke," laughed his wife Violet, "he'd drop what he was doing and run to put it out."

The Forest Service chose community leaders to be fire wardens, people their neighbors would respect. Wardens also had to understand maps and be willing to put in long hours without pay during fire season. Harrell was an obvious choice. Violet Harrell remembers her husband spending hours inventorying and maintaining his fire cache, keeping the tools sharp and in good condition, and filling the canteens with fresh water.

Schoolboy Firefighters

One of a fire warden's jobs was to recruit firefighters. Harrell's primary source was the local school. If a fire was reported during the schoolday, Harrell would phone Heltonville School, load up the tools, and pick up as many boys as he could haul to the fire. In the 1950's and 1960's, most of the boys in junior and senior high school were trained in firefighting. They were routinely released from school to help.



Dale Harrell, a USDA Forest Service fire warden on Indiana's Hoosier National Forest from 1956 to 1998, receives a volunteer award for his lifetime of service on the Hoosier National Forest. Presenting the award is Verna Molina, a public affairs specialist for the Forest Service, Hoosier National Forest, Bedford, IN. Photo: Teena Ligman, USDA Forest Service, Hoosier National Forest, Bedford, IN, 1999.

Teena Ligman is a public affairs specialist for the USDA Forest Service, Hoosier National Forest, Bedford, IN.

Even if the call came at night, Harrell was always ready. “Dale would jump out of bed,” recalled his wife, “and maybe fight fire all night, then hurry home in the morning and go run his mail route.” She said Harrell always had rolls of maps around, and when he heard there was a fire, he’d spread them out and decide whom to call for help and what routes the firefighters should take. Often, he worked closely with the lookouts in the towers as well.

As a fire warden, Harrell was responsible for issuing local burning permits. He taught his neighbors to wait for the right weather conditions before starting a fire and to prepare firelines and take other safety measures. His efforts undoubtedly helped reduce accidental fires in his area.

One of Harrell’s main contributions was to help change the way local people think about fire. Area residents formerly burned the woods each spring to control pests such as snakes and ticks and to improve forage for cattle. Some people used arson to protest government policies. To counter arson, Harrell worked to instill a respect for the forest in his neighbors. He practiced good land use ethics and taught that wildland fires can do lasting damage to wildlife and trees.

A Lifetime of Accomplishment

In 1998, Harrell had a stroke and gave up his job as fire warden. His wife kept the fire warden sign. She treasures the memories it represents.

Today, Harrell suffers from Alzheimer’s disease and lives in a nursing home. When family, neighbors, and retired Forest Service employees visit and mention his days as a fire warden, Harrell’s eyes seem to brighten. If he could, Harrell would undoubtedly still be on fire watch. The Hoosier National Forest is a better place for his many years of service. ■

Fire Wardens: A Proud Tradition

Drawing on an old American tradition, the early Forest Service relied on volunteers to watch over many of our national forests and protect them from wildland fire. Fire wardens were chosen from among the citizens of rural communities. A sign with the words “National Forest Warden” was posted in front of the warden’s home. Each warden was trained in firefighting and granted the authority to issue burning permits. Wardens acted as local spokespersons for the national forest and were responsible for maintaining a cache of fire tools. Today, the fire warden system is part of the system of rural fire districts and cooperative fire protection.

A Forest Service fire warden (left) examines a flapper, a tool used to fight grass fires, on the Hoosier National Forest in 1937. The man with him holds a broom rake, used for leaf fires. On the right is a fire cache, a tall red metal bin. Each fire cache held enough tools and water for a 10-man fire crew. Photo: USDA Forest Service, 1937.

Reader Comments on Wildland Fire Terminology

Editor's note: Occasionally, Fire Management Today *publishes comments from readers on topics of special interest. To have your comments considered for publication, contact the managing editor, Hutch Brown, at USDA Forest Service, 2CEN Yates, P.O. Box 96090, Washington, DC 20090-6090, tel. 202-205-1028, fax 202-205-0885, e-mail: hutchbrown@fs.fed.us.*

***

May 1, 1998

Once again, the Winter 1998 issue of *Fire Management Notes* [now *Fire Management Today*] contained incorrect wildland fire terminology. The National Interagency Incident Management System was adopted by all Federal land management agencies in 1985. I would submit that 13 years is ample time for authors and editors to eliminate Large Fire Organization terminology from articles published in *Fire Management Notes*.

Richard T. Gale
Deputy Chief Ranger, Fire, Aviation and Emergency Management
National Park Service

This comment, received more than 2 years ago, reminded us of our obligation at Fire Management Today *to promote the use of a common wildland fire terminology. Over the years,* Fire Management Today *has published several terminology updates, most recently in the spring 2000 issue.**

***

July 12, 2000

I must comment on the use of the term "wildland fire" as opposed to the term "wildfire."* There is a very fundamental definition of "wildfire" that is recognized in the field. A wildfire is any fire that is not a planned or controlled burn or that is out of control, regardless of cause or vegetative cover type. A wildfire might be burning on wildland, cropland, or pastureland or in a rural/urban setting, whereas a wildland fire is a fire burning only on wildland. "Wildland fire" is a far more limiting term than "wildfire." The fire management community should consider these aspects when deciding which term is more appropriate.

Brian L. Garvey
Area Forest Supervisor/Law Enforcement Coordinator
Minnesota Department of Natural Resources, Division of Forestry

In 1997, the National Wildfire Coordinating Group (NWCG) adopted the term "wildland fire" to describe nonstructural fires on wildlands, except for prescribed fires, and redefined "wildfire" to mean an unwanted wildland fire. The 1997 NWCG definitions leave room for wildland fire managers to use both "wildland fire" and "wildfire."

***

June 22, 2000

I question the term "wildland fire use."* A prescribed fire is actually a wildland fire use, yet by the most recent definitions, "wildland fire use" applies only to natural fires (i.e., fires caused by lightning). Instead of "wildland fire use," why don't we simply use the term "natural fire"? Thus, we would have three types of wildland fire: natural fire, prescribed fire, and wildfire (never liked this term, either).

Rick D. Stratton
Fire Effects Researcher, Rocky Mountain Research Station
USDA Forest Service

* *See Hutch Brown, "Wildland Fire Terminology Update,"* Fire Management Today *60(2): 40–46.*

Websites on Fire*

National Fire Protection Association (NFPA)

Established in 1896, NFPA is dedicated to protecting people and their property from the devastating effects of fire. Every building, process, service, design, and installation today is affected by codes and standards developed through NFPA's true consensus system. The NFPA Website includes a homepage—updated daily—that highlights current developments and research; sections focusing on NFPA's primary mission of developing and advocating scientifically based consensus codes and standards; research, training, and education to reduce the worldwide burden of fire and other hazards; and an NFPA online catalog featuring more than 600 fire safety products and services, including online seminar registration.

Found at **<http://www.nfpa.org>**

National Wildfire Suppression Association (NWSA)

Formed in 1990, NWSA is a voluntary national association of independent contractors who provide engines, crews, dozers, tenders, food services, and other resources for all types of incident needs.

The NWSA Website features information about NWSA's training program for wildland fire suppression resources to meet or exceed all standards in the National Wildfire Coordinating Group's Wildland Fire Qualification Subsystem Guide (PMS 310–1). Site visitors can request the NWSA newsletter *Fireline*, link to dozens of different fire-related sites, and read about upcoming events.

Found at **<http://www.nwsa.net>**

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* 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 editor, Hutch Brown, at USDA Forest Service, Office of Communication, P.O. Box 96090, Washington, DC 20040-6090, tel. 202-205-1028, fax 202-205-0885, e-mail: hutchbrown@fs.fed.us.

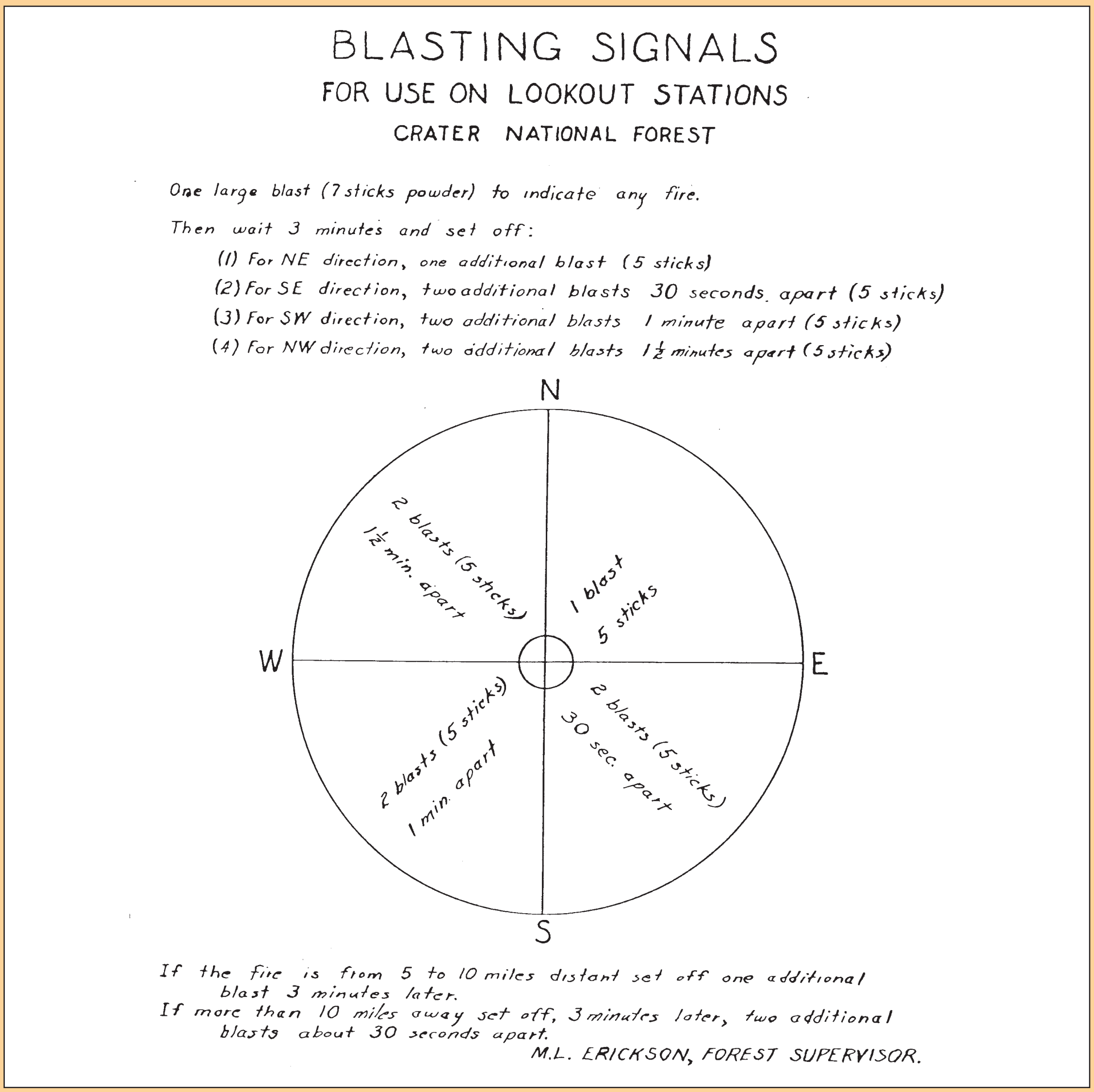
Lookouts of Yesteryear Used Blasting Signals

Gerald W. Williams

In the days before lookout stations had telecommunications, how did they let district rangers know when they detected a wildland fire? One imaginative way was to use dynamite blasts. As figure 1 shows, forest supervisors developed methods for using blasts to signal not only the presence of a fire, but also its approximate location.

Lookouts also used other signaling systems, such as mirrors or even flags. Most were almost worthless in wind, rain, or fog and low clouds. Perhaps the most common reason why such systems failed was that the receiving station was simply not paying attention. Only with the advent of telephones and (later) radios would getting fire detection messages from mountaintops to ranger stations become truly effective. ■

Jerry Williams is a historical analyst for the USDA Forest Service, Washington Office, Washington, DC.


BLASTING SIGNALS

FOR USE ON LOOKOUT STATIONS

CRATER NATIONAL FOREST

One large blast (7 sticks powder) to indicate any fire.

Then wait 3 minutes and set off:

(1) For NE direction, one additional blast (5 sticks)

(2) For SE direction, two additional blasts 30 seconds apart (5 sticks)

(3) For SW direction, two additional blasts 1 minute apart (5 sticks)

(4) For NW direction, two additional blasts 1½ minutes apart (5 sticks)

If the fire is from 5 to 10 miles distant set off one additional blast 3 minutes later.

If more than 10 miles away set off, 3 minutes later, two additional blasts about 30 seconds apart.

M.L. ERICKSON, FOREST SUPERVISOR.

Figure 1—*Directive from the 1910's on Oregon's Crater National Forest (now the Rogue River National Forest) instructing lookout stations on how to use dynamite blasts to signal the presence of wildland fires. Such signaling methods were common before the days of telecommunications. First, a single large blast near a lookout station would signal the detection of a smoke. Then smaller blasts at timed intervals would signal the direction of the fire from the lookout station as well as its approximate distance.*

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Guidelines for Contributors

Editorial Policy
Fire Management Today (*FMT*) is an international quarterly magazine for the wildland fire community. *FMT* welcomes unsolicited manuscripts from readers on any subject related to fire management. Because space is a consideration, long manuscripts might be abridged by the editor, subject to approval by the author; *FMT* does print short pieces of interest to readers.

Submission Guidelines
Submit manuscripts to either the general manager or the managing editor at:

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Attn: April J. Baily, F&AM Staff
P.O. Box 96090
Washington, DC 20090-6090
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Internet e-mail: abaily@fs.fed.us

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If you have questions about a submission, please contact the managing editor, Hutch Brown.

Paper Copy. Type or word-process the manuscript on white paper (double-spaced) on one side. Include the complete name(s), title(s), affiliation(s), and address(es) of the author(s), as well as telephone and fax numbers and e-mail information. If the same or a similar manuscript is being submitted elsewhere, include that information also. Authors who are affiliated should submit a camera-ready logo for their agency, institution, or organization.

Style. Authors are responsible for using wildland fire terminology that conforms to the latest standards set by the National Wildfire Coordinating Group under the National Interagency Incident Management System. *FMT* uses the spelling, capitalization, hyphenation, and other styles recommended in the *United States Government Printing Office Style Manual*. Authors should use the U.S. system of weight and measure, with equivalent values in the metric system. Try to keep titles concise and descriptive; subheadings and bulleted material are useful and help readability. As a general rule of clear writing, use the active voice (e.g., write, "Fire managers know…" and not, "It is known…"). Provide spellouts for all abbreviations. Consult recent issues (on the World Wide Web at <http://www.fs.fed.us/fire/planning/firenote.htm>) for placement of the author's name, title, agency affiliation, and location, as well as for style of paragraph headings and references.

Tables. Tables should be logical and understandable without reading the text. Include tables at the end of the manuscript.

Photos and Illustrations. Figures, illustrations, overhead transparencies (originals are preferable), and clear photographs (color slides or glossy color prints are preferable) are often essential to the understanding of articles. Clearly label all photos and illustrations (figure 1, 2, 3, etc.; photograph A, B, C, etc.). At the end of the manuscript, include clear, thorough figure and photo captions labeled in the same way as the corresponding material (figure 1, 2, 3; photograph A, B, C; etc.). Captions should make photos and illustrations understandable without reading the text. For photos, indicate the name and affiliation of the photographer and the year the photo was taken.

Electronic Files. Please label all disks carefully with name(s) of file(s) and system(s) used. If the manuscript is word-processed, please submit a 3-1/2 inch, IBM-compatible disk together with the paper copy (see above) as an electronic file in one of these formats: WordPerfect 5.1 for DOS; WordPerfect 7.0 or earlier for Windows 95; Microsoft Word 6.0 or earlier for Windows 95; Rich Text format; or ASCII. Digital photos may be submitted but must be at least 300 dpi and accompanied by a high-resolution (preferably laser) printout for editorial review and quality control during the printing process. Do not embed illustrations (such as maps, charts, and graphs) in the electronic file for the manuscript. Instead, submit each illustration at 1,200 dpi in a separate file using a standard interchange format such as EPS, TIFF, or JPEG (EPS format is preferable, 256K colors), accompanied by a high-resolution (preferably laser) printout. For charts and graphs, include the data needed to reconstruct them.

Release Authorization. Non-Federal Government authors must sign a release to allow their work to be in the public domain and on the World Wide Web. In addition, all photos and illustrations require a written release by the photographer or illustrator. The author, photo, and illustration release forms are available from General Manager April Baily.

Contributors Wanted

We need your fire-related articles and photographs for *Fire Management Today*! Feature articles should be up to about 2,000 words in length. We also need short items of up to 200 words. Subjects of articles published in *Fire Management Today* include:

- Aviation
- Communication
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- Education
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- Fire behavior
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- Fire use (including prescribed fire)
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- Planning (including budgeting)
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- Training
- Weather
- Wildland–urban interface

To help prepare your submission, see "Guidelines for Contributors" in this issue.

Photo Contest for 2001

Fire Management Today invites you to submit your best fire-related photos to be judged in our annual competition. Winners in each category will receive awards (first place—camera equipment worth $300 and a 16- by 20-inch framed copy of your photo; second place—an 11- by 14-inch framed copy of your photo; third place—an 8- by 10-inch framed copy of your photo). Winning photos will appear in a future issue of *Fire Management Today*. All contestants will receive a CD–ROM with all of the photos not eliminated from competition.

Categories

- Wildland fire
- Prescribed fire
- Wildland-urban interface fire
- Aerial resources
- Ground resources
- Miscellaneous (fire effects; fire weather; fire-dependent communities or species; etc.)

Rules

- The contest is open to everyone. You may submit an unlimited number of entries from any place or time; but for each photo, you must indicate only one competition category.
- Each photo must be an ***original color slide***. We are not responsible for photos lost or damaged, and photos submitted will not be returned (so make a duplicate before submission).
- You must own the rights to the photo, and the photo must not have been published prior to submission.
- For every photo you submit, you must give a detailed caption (including, for example, name, location, and date of the fire; names of any people and/or their job descriptions; and descriptions of any vegetation and/or wildlife).
- You must complete and sign a statement granting rights to use your photo(s) to the USDA Forest Service (see sample statement below). Include your full name, agency or institutional affiliation (if any), address, and telephone number.
- Photos are judged by a photography professional whose decision is final.
- Photos will be eliminated from competition if they lack detailed captions; have date stamps; show unsafe firefighting practices (unless that is their express purpose); or are of low technical quality (for example, have soft focus or show camera movement). (Duplicates—including most overlays and other composites—have soft focus and will be eliminated.)
- Photos are judged by a photography professional whose decision is final

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March 2, 2001

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Washington, DC 20090-6090

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(You may copy and use this statement. It ***must be signed.***)

Enclosed is/are __________ (*number*) slide(s) for publication by the USDA Forest Service. For each slide submitted, the contest category is indicated and a detailed caption is enclosed. I have the authority to give permission to the Forest Service to publish the enclosed photograph(s) and am aware that, if used, it or they will be in the public domain and appear on the World Wide Web.

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