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Learning to Live With Fire

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On the Cover:

Llamas graze calmly in a field as a wildfire draws dangerously close to a home on the Deer Creek Ranch outside Selma, OR. For a discussion of the challenges inherent in living with fire, see the articles by Dale Bosworth and Jerry Williams beginning on page 4. Photo: Thomas Iraci, USDA Forest Service, Pacific Northwest Region, Portland, OR, 2002.

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.

Contents

Short Features

Living With Fire Isn't So Simple*

Dale Bosworth

Would that it were so simple. Some would have us believe that if we just stop fighting fire, everything will be fine (Stahl 2004). Never mind the people who will lose their homes—they supposedly deserve it. Never mind the habitat loss for plants and animals—nature supposedly knows best. Just look, they say, at how the American Indians lived with fire.

Working With Fire

Indeed, let's look. Near Seeley Lake, MT, where the spruce–fir forest naturally supports fires that are large but rare, researchers found a site where fires historically were far more frequent than nature would explain (Barrett 2004). Indians using the site had burned the surrounding woods for centuries, perhaps to keep big fires from wiping out their camps in a drought. The USDA Forest Service has done something similar at Seeley Lake by thinning to protect the local community.

Apparently, these Indians did not believe that nature knows best. In fact, Indians nationwide used fire and other technologies to shape ecosystems to their liking (Boyd 1999; Pyne 1982; Whitney 1994; Stewart 2002; Williams 2002, 2003). Does that mean they were at war with nature? No. They worked with nature for self-protection and resource diversity. Many ecosystems flourished as a result, such as longleaf pine in the South (Bonnicksen 2000).

> A policy of allowing all fires to burn would be just as flawed as the old policy of putting them all out.

At the Forest Service, we learned the lesson long ago and ended the war against fire. Today, we work with fire to promote resource diversity and restore fire-adapted ecosystems. We stress homeowner fire safety programs, but we also protect the surrounding landscape.

We do that because a home is more than just a house. Your home is the community you belong to. It's the surrounding landscape with every-

The Hayman Fire in Colorado burning dangerously close to several homes near Woodland Park on June 18, 2002. Photo: Cindy Nowack, Fremont–Winema National Forest, Klamath Ranger District, Klamath Falls, OR, 2002.

Dale Bosworth is the Chief of the USDA Forest Service, Washington, DC.

* The article appeared as a guest editorial in *Wildland Firefighter* 8:2 (February 2004): 7, 9.

thing it gives you, such as scenic beauty and clean water from your municipal watershed. If you've saved your house in a community devastated by fire—in a landscape blackened by fire—you've still lost your home.

Reconciling such needs in the context of fire-adapted forests and grasslands is central to our fire management today. Sometimes that means using fire in the woods; sometimes it means suppressing it. Through prescribed and wildland fire use, the Forest Service actually burns more acres on national forest land than we suppress.

Managing Risks

Do we burn enough? Maybe not, but it's not as simple as that. A policy of allowing all fires to burn would be just as flawed as the old policy of putting them all out. Three things keep us from using fire more:

- The forests that need fire the most, such as ponderosa pine in the West, are often in no condition to burn. They are too overcrowded with vegetation. Under such conditions, simply letting fires go could have catastrophic results for communities and ecosystems alike.
- Prolonged drought in many parts of the country contributes to the problem. When fire danger indexes are extreme, we usually decide to suppress fires that we might otherwise use to restore ecosystems. Our fire management plans never say, "Use fire no matter what."
- We use fire only within acceptable limits of social, economic, and ecological risk. For example, if a fire would severely damage soils or destroy habitat for endangered species, we suppress it. Our policy is to use fire where we can and suppress fire where we must.

> Our policy is to use fire where we can and suppress fire where we must.

The risks are compounded by the growing wildland/urban interface. Picture an island in a sea of gasoline. If you touch a match 10 or 20 miles (16–32 km) out, it might seem like a long way away, but the fire will still burn the island. Many forest communities are like that

If you've saved your house in a community devastated by fire, you've still lost your home. This mobile home park was almost totally destroyed by the Rodeo–Chediski Fire on the Apache–Sitgreaves National Forest in Arizona. Photo: Thomas Iraci, USDA Forest Service, Pacific Northwest Region, Portland, OR, 2002.

today. Surrounded by overgrown forests, they are in a veritable sea of fuels. Remote fires can easily roar out of the backcountry, like Cerro Grande did in 2002. That same year, Hayman made a 16-mile (26-km) run in a single day. Fire managers must weigh such risks before deciding to use fire in the backcountry.

The Right Kind of Fire

Our aim is to restore the *right* kind of fire to the land. Often, that means first thinning overgrown forests, then waiting for the right weather conditions before igniting a burn. If we can restore healthy landscape conditions, then we can better control the results of a fire—yes, even in a drought. We've shown it again and again (see "Success Stories" on the World Wide Web at <http://www.fireplan.gov/content/home/>).

Our first priority, of course, is firefighter and public safety, but letting nature take its own course would not enhance human safety. Instead, it would heighten the lethal risk from huge fires like Biscuit in 2002 or Cedar in 2003. The best way to reduce the risk is to take some of the heat out of the ecosystem *before* these fires get started.

That will take some work. Nationwide, hundreds of millions of acres are at risk from wildland fires that could compromise human safety and ecosystem integrity (Schmidt and others 2002). Not every acre can be treated, nor should it be; strategically placed treatments will protect and restore most values at risk. Still, the needed treatments will be expensive. The question for Americans is this: Do we as a Nation want to pay sooner for treatments, or later—and vastly more—in human lives, suppression costs, and damage to homes, communities, and wildland resources?

No Easy Answers

There are no easy answers. Managing wildland fires is as complex as the ecosystems that Americans have entrusted to our care as public land managers. Decades ago, we moved beyond simplistic solutions when we dropped the old policy of fire exclusion. We cannot afford to go back now: A simple policy of not fighting fires is simply not an option.

For our policy to be sustainable, we must face today's fire environment in all of its social, economic, and ecological complexity. That means continuing to suppress fire where we must and using fire where we can while creating new fire use opportunities through ecological restoration. It's the best way to keep our firefighters safe, our ecosystems healthy, and our fellow Americans well served.

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A Changing Fire Environment: The Task Ahead*

Jerry Williams

Wildland fire management today is a high-stakes business. At no time in our history have greater areas been at more risk from wildland fires that could compromise human safety and ecosystem integrity. Some 132 million acres of national forest land alone are classified at high or moderate risk (Schmidt and others 2002) (see the sidebar on page 8). More than 2 billion acres (800 million ha) of State, private, and other Federal lands are similarly classified at risk.

The results are palpable. In the past few years, we've witnessed record-setting wildfires, such as the October 2003 fires in southern California, the worst in California history. In a matter of weeks, 14 major fires burned 750,043 acres (300,017 ha), cost 24 lives, and destroyed 3,710 homes (CDF/USDA FS 2004). Utilities and other basic infrastructure were destroyed, and damage to private property exceeded $2 billion. The disruption to lives, communities, and economies can scarcely be imagined.

Afterwards, the Governor of California appointed a commission to examine the causes and make recommendations to avoid similar losses in the future. I was named to that commission.

Jerry Williams is the National Director of Fire and Aviation Management for the USDA Forest Service, Washington, DC.

* The article is based on a presentation by the author at the National Interagency Fuels Workshop on February 4, 2004, in Albuquerque, NM.

View of the 2002 Hayman Fire, the largest in Colorado history to date. Photo: Steven Smith, Colorado Springs Fire Department, Colorado Springs, CO, 2002.

> We can improve preparedness and suppression, but until we better manage fuel buildups and growth in the wildland/urban interface, the gains will be marginal.

Two Schools of Thought

Why have wildfires gotten so large, destructive, and dangerous? Why, in an era when fire protection is better than ever, are wildfires setting records for suppression costs, natural resource and private property losses, and environmental damages? Two schools of thought emerged on the commission:

- Some contended that fire protection just isn't good enough. They maintained that faster attack, more reliance on military assets, better coordination and communications, and improved preparedness can keep fires from getting so big and dangerous.
- Others, including me, see the problem in broader terms. Yes, we can improve preparedness, coordination, command, and cooperation, but until we better manage fuel buildups and growth in the wildland/urban interface, the gains will be marginal at best. The condition of forests and grasslands, especially across much of the West, predisposes many areas to large, damaging wildfires. Unconstrained growth in the wildland/urban interface only exacerbates the problem.

Of the 10,000 wildfires that the USDA Forest Service suppresses each year on average, only about 100—1 percent—account for more than 95 percent of the acres burned and nearly 85 percent of total suppression expenditures. The fire siege of 2003 was a prime example, and it occurred in a State with the best fire protection in the Nation. Next to the Forest Service, California arguably fields the largest wildland fire service in the world. The California Department of Forestry and Fire Protection, the Federal agencies, and the county and local authorities collectively spend more than $3.5 billion annually on fire protection in southern California. Yet even moderate Santa Ana wind conditions in October 2003 drove fires that burned more acres and caused more damage than ever before in the region.

When one of the biggest and best fire services in the world is not big enough, it would appear that getting more, bigger, and better fire protection is not the solution. Instead, we need to focus on what causes the huge fires we're getting. I am convinced that the key is "taking some heat out of the ecosystem" by reducing fuel loadings.

Fire Regimes and Condition Classes

Schmidt and others (2002) published national maps reflecting coarse-scale data on the condition of vegetation and fuels. The purpose was to help land managers answer three basic questions:

1. How do current vegetation and fuels differ from those that existed historically?
2. Where are fuel accumulations higher than they were historically?
3. On a coarse scale, what areas are highest priority for treatment?

Mapping was by fire regime and condition class, as defined by the USDA Forest Service (2000). In brief:

- Fire regimes I and II have short fire return intervals (0–35 years) and, respectively, low and stand-replacement fire severity.
- Fire regimes III and IV have moderately long fire return intervals (35–100+ years) and, respectively, mixed and stand-replacement fire severity.
- Fire regime V has very long fire return intervals (greater than 200 years) and stand-replacement fire severity.
- In condition class 1, fire regimes are within their historical range, and the risk of losing key ecosystem components is low.
- In condition classes 2 and 3, fire regimes have been, respectively, moderately and severely altered from their historical range, and the risk of losing key ecosystem components is, respectively, moderate and severe.

Schmidt and others (2002) found that almost 132 million acres (53 million ha) of national forest land across all fire regimes were in condition classes 2 and 3. Of these lands, the Forest Service has identified fire regimes I and II as highest priority for treatment, or about 73 million acres (29 million ha).

Difficult Fire Environment

Land stewardship is a core value for the Forest Service's Fire and Aviation Management staff. Eighty years ago, a Forest Service employee in the Southwest began shaping a powerful new concept he later called a land ethic. Writing in the *Journal of Forestry*, Aldo Leopold (1924) observed changes in the forests due to overgrazing and fire exclusion. His observations were in ponderosa pine—what today we call fire regime I (see the sidebar).

> We need fire protection programs that are ecologically appropriate, socially acceptable, and economically feasible.

The same observations were later made in other long-needle pine ecosystems (Carle 2002)—by Harold Weaver in Oregon, Harold Biswell in California, Herbert Stoddard in the Southern States, M.L. Heinselmann in the Lake States, and, more recently, Stephen Arno and others in the Rocky Mountains. It's time for us now, as stewards of the land, to act on these observations.

We work in a difficult environment. Volatile fuel conditions dominate entire landscapes. Public expectations for protection have never been higher, yet "naturalness" values and public concern about forest appearance are equally important. Even though risk is high, political tolerance for "mistakes" is low. We need fire protection programs that are ecologically appropriate, socially acceptable, and economically feasible.

A difficult fire environment. Telltale snags attest to the dense pine fuels that fed the 2002 Rodeo–Chediski Fire on its run through a trailer park in Overgaard, AZ. Photo: Tom Schafer, Show Low, AZ, 2002.

Focus on Our Objective

In this context, it is important to focus on our objective. Our stewardship objective is to restore and maintain resilient, diverse, and functioning fire-adapted ecosystems. By definition, fire-prone forests and grasslands in this condition are safer, more sustainable, healthier, and more productive. We prescribe-burn, thin trees, and harvest timber as the means to an end: healthy, resilient fire-adapted ecosystems.

But we must not confuse means with ends. On principle, we don't undertake treatment activities just to get "black acres," to meet a thinning target, or to move logs. We undertake these activities, *first and foremost*, to improve the condition of the forest. We still meet targets and furnish wood products, but the reason that we burn, thin, or harvest is, *first and foremost*, to restore and maintain resilient, diverse, and functioning fire-adapted forests. We do these things because they are the right means to our end.

> Our goal is to restore the *right kind* of fire, consistent with the ecological dynamics of the particular forest type.

Principles and Practices

In fiscal year 1995 (FY1995), the Forest Service treated less than 600,000 acres (240,000 ha) for hazardous fuels (USDA Forest Service 1999). By FY2001, with the help of the National Fire Plan, the Forest Service and U.S. Department of the Interior together were treating more than 2 million acres (800,000 ha) (NFP 2004). Soon, with the help of new authorities in the Healthy Forests Restoration Act (see the sidebar), we might be jointly treating some 4 million acres (1.6 million ha) per year. That's a big jump, and it should prompt us to revisit the way we do business.

We need a new set of principles and practices:

1. ***Establish and use fire danger and stand condition risk thresholds to govern the use of fire.*** Remember, our goal isn't simply to put fire back into the forest. Our goal is to restore the right kind of fire, consistent with the ecological dynamics of the particular forest type. In many places, we need to mechanically treat before burning in order to mitigate the risks of fire use, even if it costs more money. Don't let pressures to reduce treatment costs put you on a pathway to disaster. Establish limits of prescribed fire use based on established risk thresholds, and stick to them!
2. ***Adopt a national coordination system that mobilizes for fire use opportunities like we mobilize for wildfire threats.*** Burning windows open and close, and opportunities to use fire can quickly fade away. When a unit has the opportunity to burn, it should not be limited by the resources at hand; it should get all the resources it needs to capitalize on the window of opportunity. If we do anything less, we will likely fall short in the job ahead.
3. ***Plan for contingencies.*** If burning windows are closed in one part of the country but open in another, we need to have coordination and budget systems in place to rapidly move targets and dollars. With windows of opportunity as narrow as they are, we need to be quick on our feet at these treatment scales.
4. ***Don't let more trouble pile on.*** Ironically, we manage much of the land that is in condition class 3 (see the sidebar on page 8)—

for example, dense ponderosa pine—precisely for that condition. Especially in dry forest types, look for opportunities to amend land and resource management plans where the risk of losing the desired resource condition exceeds the probability of sustaining it.

5. ***Do treatments first where we have willing partners and wanting publics.*** We need to avoid the high costs that come with "going it alone."

Favorable Conditions

You've worked hard, and we've come a long way. Today, there is broader recognition than ever that the wildfire problem in this country will be won or lost on the fuels front. There is a deeper public understanding of the ecological dynamics of fire-prone ecosystems and a growing public awareness that restoring fire-adapted ecosystems to something more like their historical condition is key to their long-term health and resilience—and to public safety. Congress is with us—our budget for hazardous fuels reduction in FY2005 showed a healthy bump.

Of course, we still have a way to go. There are places where we could use more people and benefit from more money. Sometimes, competing values will confound us and regulatory controls will slow us down. But despite the challenges ahead, we need to "gut up" and deliver!

Make no mistake. Now that the Healthy Forests Restoration Act has passed, people are watching to see whether the Federal agencies can move promise into practice. They are watching to see whether we can demonstrate, by way of what we leave on the land, that we are the careful stewards we say we are. They are watching to see, given the higher funding we have gotten in an era of tight budgets and increased accountability, whether we can do what we say we will do.

The conditions for success are favorable. Broad segments of our publics support the task before us. So do the Administration and Congress. I don't know that there has ever been a better alignment of policies, budgets, and support for the work ahead.

Let's get it done!

Evening ignition on the Blue Sky prescribed burn unit, Hart Mountain National Wildlife Refuge, OR. Through such treatments, Federal agencies must prove their worth as public land stewards. Photo: John Wood, U.S. Fish and Wildlife Service, Klamath Basin National Wildlife Refuge Complex, Tulelake, CA, 2002.

When a unit has the opportunity to burn, it should get all the resources it needs to capitalize on the window of opportunity.

Healthy Forests Restoration Act, Title I

In August 2002, prompted by record-breaking fires in Arizona, Colorado, New Mexico, and Oregon, the President announced the Healthy Forests Initiative. It included a call for legislation "to further accomplish more timely, efficient, and effective implementation of forest health projects" (CEQ 2002).

In December 2003, prompted by record-breaking fires in southern California, a bipartisan majority in Congress passed the Healthy Forests Restoration Act. Title I contains perhaps the most far-reaching legislation affecting Federal forest management since the 1970s.

Title I limits requirements for environmental analysis and streamlines procedures for administrative appeals on projects for reducing hazardous fuels. However, the projects must be on Federal land in an area that:

- Is in or near the wildland/urban interface;
- Affects a municipal watershed and is in—
  - Condition class 3, or
  - Condition class 2, fire regimes I–III;*
- Has ecosystems or resources threatened by—
  - Blowdown or other storm damage, or
  - An insect or disease infestation; or
- Contains habitat for threatened and endangered species.

Priority is given to projects designed to protect communities and municipal watersheds.

* For brief descriptions, see the sidebar on page 8.

Now that the Healthy Forests Restoration Act has passed, people are watching to see whether the Federal agencies can move promise into practice.

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Got Clearance?

Jon P. Agner

Less is more. That's the philosophy behind *Got Clearance?*, a dramatic new approach to a billboard campaign on Firewise landscaping.

We came up with the idea in 2002 while leading a Cooperative Wildland Fire Prevention/Education Team in the Pacific Northwest. The following year, extreme fire danger prevailed in the Northern Rockies, where I was working on the Lolo National Forest. I was asked to form another Fire Prevention/ Education Team, this time in the Southwest Montana Zone.

I immediately dug out the old plans for *Got Clearance?* In accordance with our philosophy of "less is more," we thought we could best drive home the point about Firewise landscaping with as few words as possible. We came up with two billboard designs (figs. 1 and 2).

We also developed a 60-second television public service announcement featuring the University of Montana mascot, Monte the Grizzly Bear. Monte prepares defensible space around a home in the wildland/urban interface using a slapstick routine—comedy underpinned with a serious message.

In addition, we saw an opportunity to tie our campaign into local advertising for lawn-related tools and equipment. We worked with local hardware stores to get them to adopt the *Got Clearance?* theme.

Figure 1—*An urgent point is driven home with a punch. Photo: Jon Agner, USDA Forest Service, Lolo National Forest, Missoula, MT, 2003.*

Figure 2—*Surviving a fire with good defensible space—a big message in a few words. Photo: Jon Agner, USDA Forest Service, Lolo National Forest, Missoula, MT, 2003.*

Jon Agner is the acting fire prevention officer for the USDA Forest Service, Lolo National Forest, Missoula, MT.

For more information, contact Jon Agner, Lolo National Forest, 406-677-3935 (tel.), jagner@fs.fed.us (e-mail). ■

Testing for Deck Material Flammability

Jim Wheeler

Efforts to reduce fire danger in the wildland/urban interface (WUI) are finally getting the attention they deserve. National and State funding is addressing a century of ecosystem degradation. Local communities are practicing preventive maintenance through fuels reduction and ecosystem stewardship programs. One area, however, is still in need of attention—outdoor deck material.

Most deck material is tested for flame spread rates but not necessarily for ignition potential or energy production.

Why Worry About Decks?

Flagstaff, AZ, is a national leader in firewise construction in the WUI. Subdivision developers must perform forest stewardship (thinning) across the entire site, use class-A roofs, limit combustible exterior siding, and install NFPA 13D sprinkler systems. Such built-in protection systems mitigate the indoor and outdoor fire threat, but they don't address the potential combustibility of deck materials.

Although most deck materials are tested for flame spread rates, the Flagstaff fire authorities couldn't tell from the material safety data sheets whether they are also tested for other effects commonly found in wildland fires, such as ignition potential or energy production. Perhaps manufacturers were not exposing their deck materials to roof tests, such as the burning brand or flying brand tests.

Jim Wheeler is the assistant fire chief and fire marshal with the Flagstaff Fire Department, AZ.

In March 2002, fire marshals from Flagstaff, Prescott, and Payson, AZ, met to discuss the issue of deck flammability. We believed that if decks ignited during a wildland fire, the fire could reach proportions that would break windows and doors, igniting structures with otherwise firewise construction. We decided to conduct an ad hoc test of different deck materials to gain a better understanding of how they perform in a wildfire.

The Decks

Through donations from local lumber and home improvement businesses, we acquired enough material to construct six decks. The deck material included wood products as well as four commonly found types of composite materials. We made one deck from all five test materials combined, one from wood products alone, and four from the composite materials.

The decks were 4 feet (1.2 m) square on 2- by 10-inch (5- × 25-cm) frames. The frames were set on 8- by 8- by 16-inch (20- × 20- × 40-cm) cement blocks stacked 2 feet (0.6 m) high. A fiber-cement siding product was used at the base on two sides to simulate a typical house stemwall (fig. 1). All deck

Figure 1—*Typical deck test array. Different products were constructed on wooden frames and placed on cement blocks with a simulated fiber-cement stemwall attached. Photo: Jim Wheeler, Flagstaff Fire Department, Flagstaff, AZ, 2002.*

materials were untreated, and no stain or other flammable liquids were applied.

The Tests

Burning Ember Test. One test involved only the deck made from all five materials combined. We placed hot embers on the deck to simulate ember fallout in advance of a fire front. All of the materials charred slightly. Some quickly self-extinguished, whereas others smoldered for more than 30 minutes without ignition. All embers eventually cooled and self-extinguished (fig. 2).

Surface Fire Test. The other test involved the five decks made from different materials. We placed 2 inches (5 cm) of pine needles under the decks to fuel the kind of running surface fire commonly found in Arizona's WUI. A ventilation fan provided a constant wind of 5 to 8 miles (8–13 km) per hour. We lit the pine needles and waited to see whether the deck material would ignite and how severe the resulting fire would be.

The surface fire ignited all decks tested, but the materials behaved differently after the surface fire exhausted its pine needle fuels and went out. The wood deck was the slowest to ignite, and it self-extinguished relatively quickly (fig. 3). Most of the composite materials ignited easily and resulted in high to extreme fire severity (fig. 4).

But Trex,* a material made from plastic and wood, performed well. Trex was more difficult to ignite

*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.*

If decks ignite during a wildland fire, the fire could reach proportions that would break windows and doors, igniting structures with otherwise firewise construction.

Figure 2—*Burning ember test. Hot embers failed to ignite any of the various materials used to build the deck. Photo: Jim Wheeler, Flagstaff Fire Department, Flagstaff, AZ, 2002.*

Figure 3—*Wood deck test. The wood deck performed well and resisted ignition from the simulated surface fire. However, no stains or varnishes had been applied to its surface before the test. Photo: Jim Wheeler, Flagstaff Fire Department, Flagstaff, AZ, 2002.*

than the other composites and ultimately self-extinguished (fig. 5). Trex's fire resistance appeared to result from its density. The composites that performed poorly were less dense.

Clear the Decks

We did not test for deck flammability with an accumulation of debris (such as pine needles) on the deck surface. Our burning ember test involved a clear deck surface. Other testing is being done nationally on ember ignition of debris accumulation on decks.

Moreover, our tests weren't strictly scientific. They were designed to demonstrate certain conditions and provide quick results. It is therefore difficult to draw firm conclusions about any of the materials we tested.

Figure 4—*Composite deck test. The test fire easily ignited the composite materials, which burned with high severity. Photo: Jim Wheeler, Flagstaff Fire Department, Flagstaff, AZ, 2002.*

Figure 5—*Trex deck test. Trex was difficult to ignite and self-extinguished when the test fire ran out of pine needle surface fuels. Photo: Jim Wheeler, Flagstaff Fire Department, Flagstaff, AZ, 2002.*

However, we did gain enough information to better understand the combustibility of the various deck materials tested, which will help us to institute local policy to better serve the community. Based on the tests, we made three important findings:

- Manufacturers and testing labs should use standard fire tests to determine the specific characteristics of products and materials used in the WUI.
- Although it is impossible to achieve 100-percent certainty when dealing with wildland fire, by reducing fire risks and hazards we can improve the chance of a positive outcome.
- Our surface fire tests resulted in more destructive fires than the burning ember test. If homeowners keep vegetation and debris from accumulating under their decks, they can considerably reduce the risk of surface fire ignition, especially in a wildland area.

The Flagstaff Fire Department has adopted a new fire prevention regulation permitting the use of wood and Trex decks in the WUI. We are also open to testing new and different materials, should someone want to build with a material not analyzed in this test.

For additional information, contact Jim Wheeler or Paul Summerfelt at the Flagstaff Fire Department, 211 W. Aspen Ave., Flagstaff, AZ 86001, 928-779-7688 (tel.). ■

Is Florida's Prescribed Fire Program Something To Get Choked Up About?

Bruce Harvey and Susan Fitzgerald

The National Forests in Florida burn an average of 125,000 acres (51,000 ha) of national forest land annually in one of the largest prescribed fire programs in the Nation. During the 1990s, the Florida Department of Environmental Protection, Division of Air Resource Management, began researching the impact of prescribed burning on air quality, particularly the amount and type of particulate matter produced.

In 1993, the Division of Air Resource Management conducted two onsite monitoring studies in cooperation with the National Forests in Florida. Small portable air monitors were placed in the immediate area of the burns and up to 0.5 mile (0.9 km) downwind to monitor particulate with a diameter size of 10 microns or less (PM_{10}) (see the sidebar on page 18). The data were used to determine whether the USDA Forest Service's prescribed fire program was affecting neighboring air quality.

Test Equipment

In 1996, the National Forests in Florida purchased two Teom* 1400A PM_{10} air monitors to sample the air every hour (fig. 1). We placed one air monitor in the Apalachicola National Forest's Wakulla Work Center in Leon County and the other on the Ocala National Forest in Lake County, near Ocala, FL.

Wildfires posed more of a health hazard than prescribed fires, especially for those with respiratory problems.

The Forest Service and the Florida Division of Air Resource Management developed a cooperators' agreement for managing the air monitors. The agreement allowed the Division to add the monitors to its statewide network to include more of Florida's airsheds in its monitoring program. The Division agreed to maintain the air monitors and to provide the Forest Service with the data produced.

Test Results

Results evaluated here are only for the monitor at the Wakulla Work Center, which started providing valid data in August 1996. We examined data only for prescribed fires and wildfires within a 5-mile (9-km) radius of the monitor, unless the data showed a significant spike for an incident beyond the 5-mile (9-km) radius.

The monitor recorded all PM_{10} impacts, not just smoke. However, its rural location helped to ensure that urban and industrial sources of particulates did not significantly affect the readings.

Prescribed fire on the Apalachicola National Forest, Wakulla District, Crawfordville, FL 1996.

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Tables 1 and 2 show, in abbreviated format, the highest hourly PM_{10} values for prescribed fires and wildfires from 1996 to 2000.

Data Analysis

The data showed that the amount of smoke particulates produced can vary greatly from burn to burn, depending on placement of air monitors, fuel loads, and meteorological conditions. High concentrations of particulates were found in the immediate area of a prescribed burn. Particulate concentrations

Figure 1—*Teom 1400A PM_{10} air monitor used on the Apalachichola National Forest, Wakulla Work Center. Photo: Bruce Harvey, USDA Forest Service, Crawfordville, FL, 1996.*

Table 1—*Hourly readings for particulate matter (PM_{10}) associated with wildland fires, Wakulla Work Center, 1996–2000.*

Fire type	*Number of incidents*	*Acres burned*	*Highest hourly reading (µg/m³)* [a]	*Comments*
		1996		
Prescribed	9	11,087	135	Winds toward monitor.
Wildfire	1	5	63	Winds toward monitor.
		1997		
Prescribed	6	5,046	175	Winds toward monitor. Reading resulted from a 3,600-acre (1,460-ha) prescribed fire by aerial ignition.
Wildfire	1	15	45	Winds away from monitor.
		1998		
Prescribed	8	9,944	135	Winds toward monitor.
Wildfire	2	19,603	1,156	Winds toward monitor. Reading resulted from a 19,600-acre (7,930-ha) wildfire 7 miles (11 km) south of the monitor.
		1999		
Prescribed	8	9,784	92	Reading resulted from a burn adjacent to monitor.
Wildfire	5	6,666	503	Reading resulted from a wildland fire within 1.5 miles (2.4 km).
		2000		
Prescribed	3	3,583	28	Winds away from monitor.
Wildfire	5	6,716	311	Winds toward monitor. Reading resulted from a 6,600-acre (2,700-ha) wildfire 22 miles (35 km) southwest of the air monitor.

a. Highest hourly reading, not the 24-hr standard (mean).

diminished rapidly as the distance from a burn increased due to dispersion and plume rise.

Data analysis confirmed what fire managers already knew: Prescribed fires are conducted when weather and fuel conditions allow managers to control both the fire and the smoke, whereas wildfires often burn under severe fire conditions and poor smoke management conditions.

> Neither prescribed fires or wildfires exceeded the 24-hour standard of 150 micrograms per cubic meter.

Although the Wakulla Work Center air monitor recorded prescribed fires that might have affected human health, high hourly readings were brief, and the monitor showed no high readings the following day. By contrast, wildfires had high hourly readings for several consecutive days, posing more of a health hazard, especially for those with respiratory problems. However, neither prescribed fires nor wildfires exceeded the 24-hour standard of 150 micrograms per cubic meter during the 5-year study period from 1996 to 2000.

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Table 2—*Summary of hourly readings for particulate matter (PM_{10}) associated with wildland fires, Wakulla Work Center, 1996–2000.*

Fire type	*Number of incidents*	*Acres burned*	*Highest hourly reading (µg/m³)*
Prescribed	34	39,444	175
Wildfire	14	33,002	1,156

Clean Air Standards

The standards set by the U.S. Environmental Protection Agency (EPA) under the Clean Air Act to protect human health are known as National Ambient Air Quality Standards (NAAQSs). The PM_{10} standard is for particulate matter with a diameter size of 10 microns or less. The NAAQS for PM_{10} is:

- An annual mean value of 50 micrograms per cubic meter; and
- A 24-hour value of 150 micrograms per cubic meter, not to be exceeded more than once per year over a 3-year period.

The NAAQSs were revised by EPA in July 1997 to include a standard for particulate matter with a diameter size of 2.5 microns or less ($PM_{2.5}$). The data evaluated here are for the PM_{10} standard only.

Acknowledgments

The authors wish to thank Joe Ferguson, fire staff officer, National Forests in Florida, for his comments and encouragement; and Evelyn Libby for her technical expertise. ■

A Tribute to Engine 805

Sara Patterson

We finally said goodbye to old Engine 805. For almost 30 years, she just kept on going, dousing wind-fanned flames even when they seemed unstoppable. But Engine 805 will fight no more. Disaster couldn't stop her, but retirement did.

A Firefighter Is Born

In 1974, Engine 805 was born in an International Truck Corporation assembly plant in Chicago, IL. She was painted the shade of green favored by the USDA Forest Service, because her first employer was the Lake George Ranger District on the Ocala National Forest in Florida.

Engine 805 worked hard, but her big weighty body was not suited to Florida's sandy conditions. Fortunately, Joseph Rice, the fire management officer on the New Castle Ranger District in southwestern Virginia, appreciated her talent. He took Engine 805 to her new mountain home on the Jefferson National Forest, where she saved countless fields and farms from flames.

Others also called on her services. In 1988, she fought fires that threatened to engulf the thirsty forests of Kentucky. A year later, she tirelessly helped with cleanup after Hurricane Hugo ripped through the Frances Marion National Forest in South Carolina. In 1998, she battled multiple fires raging in her own backyard in what became the Castle Complex Fire.

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Engine 805 and Smokey Bear, two warriors in the fight against wildfires. Photo: Tracy Bayne, New Castle Record, New Castle, VA, 2002.

A Star Is Born

In 2002, Engine 805 was finally retired from firefighting assignments, but that didn't end her career. She hit the entertainment circuit, making numerous parade appearances with celebrities such as Smokey Bear.

Sometimes her caretaker and "manager" Steve Elmore, a recreation technician on the New Castle Ranger District, would start her mighty pump and shoot a stream of water skyward. Squealing schoolchildren would race through her spray and climb behind her big steering wheel, pretending to be firefighters.

In 2003, on a hot August night, Engine 805 made her final gleaming appearance. It was Smokey Bear Night at a ballpark in Salem, VA. With her large compartments neatly displaying racked nozzles and hoses, Engine 805 let happy children climb onto her sideboards and imagine being behind her wheel, peering into her interior for the very last time.

Goodbye

Engine 805 is no longer Federal property. At an auction in March 2004, a private individual purchased her for $3,400. Although in beautiful condition and quite functional, Engine 805 was no longer cost-effective to maintain.

Old Engine 805, we thank you for serving and saving our national forests and for helping a new generation understand the importance of fire safety. ■

"The Air Was Fire": Fire Behavior at Peshtigo in 1871

Hutch Brown

On October 8, 1871, as myth would have it, Mrs. O'Leary's cow knocked over a lantern, starting the great Chicago Fire. On the same day, as fate would have it, wildland fires swept through parts of Michigan and Wisconsin, forming "a regional complex that splashed across 2,400 square miles [6,200 km^2] and engulfed even Chicago" (Pyne 1999). Though separated by up to hundreds of miles, the fires were connected by the same general conditions—"drought, human carelessness, and a change in wind" (Wells 1968). In particular, the same "conducive synoptic situation" (Haines and Kuehnast 1970) set off great fires in urban and rural landscapes alike.

The area burned was far greater in Michigan than in Wisconsin—about 2.5 million acres (1 million ha) compared to 1.28 million acres (512,000 ha) (Haines and Sando 1969). However, most fatalities occurred in and around the town of Peshtigo, WI, which gave the fires their collective name. Estimates of the number of dead are generally more than a thousand (Gess and Lutz 2002; Haines and Kuehnast 1970; Peshtigo Historical Museum n.d.; Pyne 1982; Wells 1968), but the region had so many new settlers and itinerant workers that the true number will probably never be known. Initially obscured by the Chicago Fire, the Peshtigo Fire is now widely regarded as the greatest tragedy fire in U.S. history (see the sidebar on page 22).

Survivors left rich accounts of extreme and unusual fire behavior. Franklin B. Hough captured some of them in his momentous *Report on Forestry* (1882), a summary of forest conditions chartered by the U.S. Congress. Hough reprinted or summarized reports on the Peshtigo Fire by Father Peter Pernin (1874), C.D. Robinson (1872), and others. Pernin's eyewitness account was reprinted in 1971 and, with a foreword by Stephen J. Pyne, again in 1999.

> "It will be a long time before those woods, more relentless than the waters, give up their dead."
> –C.D. Robinson, 1872

These stories help to illuminate the nature of extreme fire behavior (see the sidebar below). Of course, eyewitness accounts such as Pernin's "are prone to hindsight bias" (Alexander and Thomas 2003)—a bias that probably entered contemporary news accounts and investigative reports, including Robinson's (1872). Still, such accounts are a useful, colorful point of departure for examining what happened in and around the town of Peshtigo on that fateful October night.

"Majestic Wilderness"

Peshtigo (pronounced PESH-ti-go) lies in northeastern Wisconsin about 6 miles (10 km) northwest of Green Bay, an arm of Lake Michigan (fig. 1). It straddles the Peshtigo River, which transported the area's rich timber resources when logging began there in earnest following the American Civil War (1861–65). Initially built around a sawmill, the town soon acquired an immense woodenware factory employing some 800 people (Peshtigo Historical Museum n.d.). By 1871, Peshtigo was a thriving community of about 1,700 inhabitants.

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What Is Extreme Fire Behavior?*

"Extreme" implies a level of fire behavior characteristics that ordinarily precludes methods of direct control action. One or more of the following is usually involved: high rate of spread, prolific crowning and/or spotting, presence of fire whirls, strong convection column. Predictability is difficult because such fires often exercise some degree of influence on their environment and behave erratically, sometimes dangerously.

* From National Wildfire Coordinating Group, *Glossary of Wildland Fire Terminology* (PMS 205, NFES 1832; Boise, ID: National Interagency Fire Center, November 1996).

Just before the blowup, fire behavior was deceptively benign.

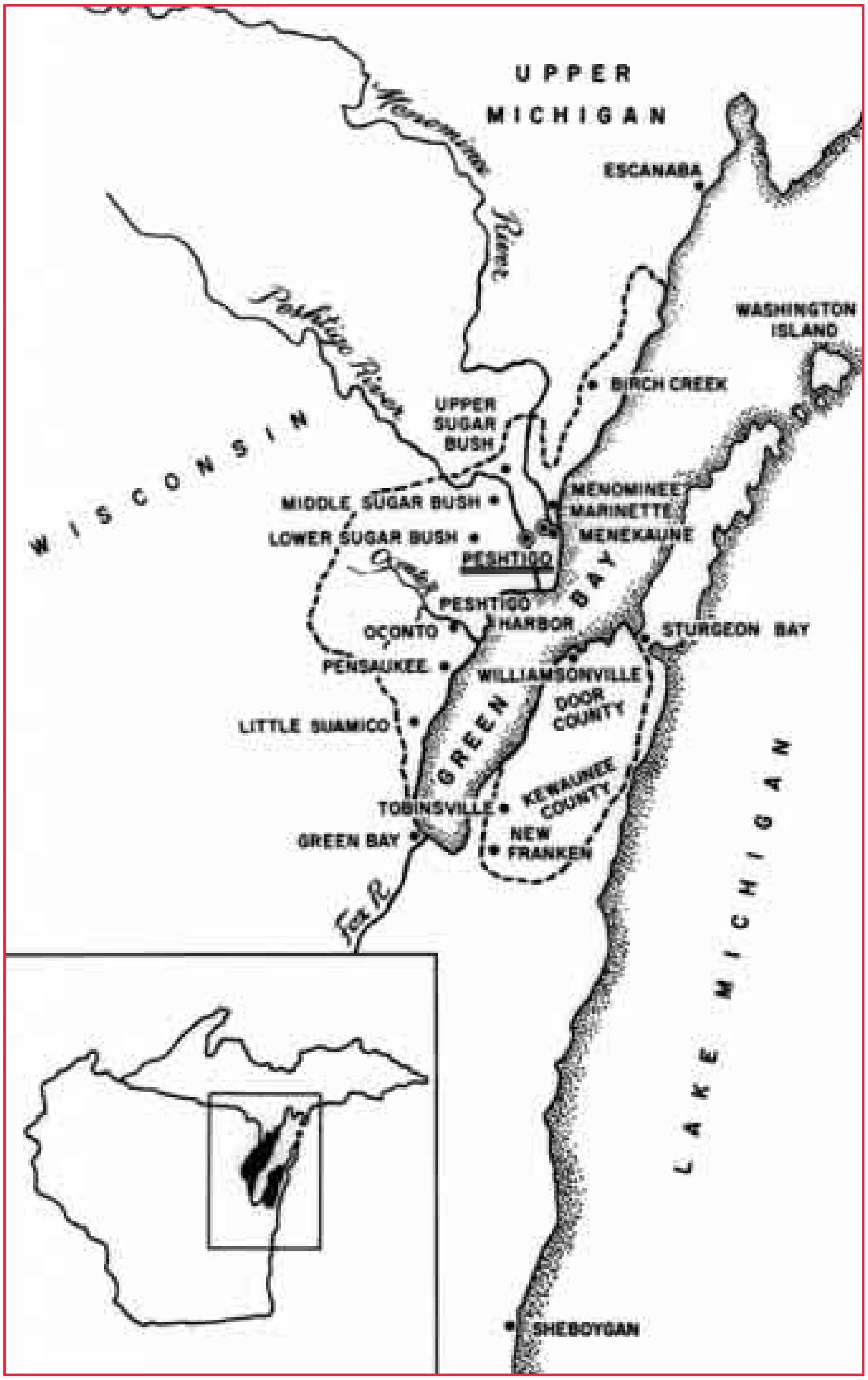

Figure 1—*Peshtigo and some of the other communities affected by the wildland fires of 1871. The fire perimeters shown encompass about 1.28 million acres (512,000 ha) in Wisconsin and Upper Michigan. Not shown are the far greater areas burned in Lower Michigan. Illustration: Courtesy of the Wisconsin Historical Society, image number 6783; from Wells (1968).*

Peshtigo was not the only settlement in the area. It was connected by rail to a port at the mouth of the Peshtigo River 6 miles (10 km) to the southeast. The woods to the north and west held smaller settlements and scattered farms, collectively known as the Sugar Bushes (for the forest's sugar maple component). Together with the twin towns of Marinette and Menominee, about 6 miles (10 km) to the northeast, Peshtigo and its outlying farms and settlements formed a booming frontier community. Investments by Chicago magnate William B. Ogden were fueling rapid development, and Peshtigo was soon to be connected by rail to Chicago.

Yet most of the surrounding forest was still virgin timber. Pernin (1999) described Peshtigo's surroundings as "a rude and majestic wilderness—woods, everywhere woods." The rolling landscape held "the cedar and the spruce" (northern whitecedar and white and black spruce), "evergreens" (red, jack, and eastern white pine), and "all kinds of hard wood, the oak, maple, beech, ash, elm, and birch." It was a mixture typical of the Great North Woods, broken in places by "prairies and openings" (Robinson 1872).

According to Pernin (1999), cedar and spruces prevailed in wet areas, pines on sandy slopes, and hardwoods wherever the land was "dry and rich." Historical fire return intervals varied greatly among these forest types. Surface fires were rare in conifer bogs but relatively frequent in the pine forests of the Great Lakes (Bonnicksen 2002; FEIS n.d.). In both forest types, stand replacement fires occurred at intervals of 100 to 200 years (50 years in jack pine). By contrast, fire rarely touched the northern hardwood forests of the Great Lakes, where intervals between surface fires typically “exceeded the lifespan of individual trees [several hundred years]” (FEIS n.d.). Where fire-intolerant trees such as maple and beech dominated, thousands of years might have passed between stand replacement fires (Bonnicksen 2002). In such forests, extreme drought would seem to have been necessary for a crown fire in presettlement times.

The drought was mild compared to the times leading up to other historically great fires in the Midwest.

Extreme Drought?

Such a drought occurred in 1871, according to contemporary sources often cited in later accounts (Gess and Lutz 2002; Wells 1968). For months, showers across the Upper Midwest were reportedly few and brief. By October, many streams and wells had run dry. Even rich organic bottomland soil was so desiccated that it was burnable “to the depth of a foot or more” (Robinson 1872). The early October air was “hot and dry,” suggesting low relative humidity.

However, such accounts are open to question. Descriptions such as “hot and dry,” for example, are both subjective and relative. Later investigators used U.S. Army Signal Service*

* Originally, the Signal Service was the Federal entity responsible for collecting weather data. In 1891, it was superseded by the U.S. Weather Bureau, predecessor of today’s National Weather Service in the U.S. Department of Commerce’s National Oceanic and Atmospheric Administration.

Forgotten Fire?

The wildland fires of 1871 in the Upper Midwest burned through farms and towns across millions of acres, yet they got little immediate attention. In Wisconsin, telegraph lines to the North Woods were down, and the news was slow to get out. When the story finally broke, the Governor of Wisconsin was away, helping victims of the great Chicago Fire. Initially obscured by Chicago, Peshtigo is sometimes called “the Forgotten Fire” (Peshtigo Historical Museum n.d.).

Franklin B. Hough, head of the USDA Division of Forestry, recognized Peshtigo’s significance and turned it to his advantage. In his *Report on Forestry* (1882), he made it the centerpiece of his section “The Great Historical Fires in North America.” “Taken in connection with the great calamity at Chicago,” he declared, “the autumn of 1871 [the wildland fires in Michigan and Wisconsin] may be regarded as altogether the most extraordinary [event] in the annals of disaster from fire that has ever happened within the period of human history.”

Hough’s report was partly designed to get Congress to pass laws against free-ranging fires. In Hough’s day, fires were widely used in rural areas for purposes such as clearing land and rejuvenating forage. Fire escapes and lightning fires were largely ignored so long as they remained in the backcountry (Haines and Kuehnast 1970; Pyne 2001). When they were fought at all, it was usually only to protect mills, homesteads, and settlements.

The Peshtigo Fire seemed to show the folly of tolerating fire in the woods. For weeks, surface fires smoldered across the landscape, until changing weather conditions blew them up into a tragedy. By highlighting the horror of Peshtigo, Hough suggested that backcountry fires must be controlled before “conditions present the greatest danger.”

Hough thereby helped transform the Peshtigo Fire into a poster child for fire control. Today, despite its reputation as the Forgotten Fire, Peshtigo is “anything but” (Pyne 1999). Cited in every compendium on great fires, the Peshtigo Fire helped set the stage for the 20th-century doctrine of fire exclusion that still pervades public values.

Therein lies the true danger. As Pyne (1999) put it, “A misreading of the Peshtigo legacy—that fire exclusion was the answer to fire abuse—threatens to recreate the old burn in more modern idiom.” Today, many Americans reject prefire Peshtigo’s rural embrace of fire use, smoke, and logging. Freedom from such controls means that woody fuels today threaten to produce fires and tragedies on a scale rivaling Peshtigo.

Today, the problem is not too much fire in the woods. The problem is too little.

data from the 1870s to test the thesis that extreme drought contributed to the Peshtigo Fire (Haines and Kuehnast 1970; Haines and Sando 1969; Haines and others 1976).

"Drought was prevalent over much of the Midwest in the summer of 1871," Haines and Kuehnast (1970) confirmed, but the drought was mild compared to droughts before other historically great fires in the Upper Midwest (Haines and Sando 1969). In Wisconsin, although the winter preceding the fire was abnormally dry, the following spring was wet. Summer precipitation again fell below normal, but summer temperatures were not extreme. Haines and others (1976) also found mixed signs of drought severity. For Madison, WI, they calculated a Keetch–Byram Drought Index of 300, well below the level associated with severe drought. But they also calculated a Palmer Drought Index of –3.79, suggesting a drought that was severe but not extreme.

Ambient air conditions just before the Peshtigo Fire do not suggest extreme fire danger. The relative humidity was about 24 percent in Madison, WI (Haines and others 1976), generally low for the region but hardly record breaking (Alexander 2003). Warm air from the central Great Plains eventually raised nighttime temperatures into the 80s (27+ °C), but at least one location—Sturgeon Bay, WI—recorded a temperature of 63 °F (17 °C) at the time fire broke out (Haines and others 1976). Neither drought nor ambient air conditions alone would seem to explain the severity of the Peshtigo Fire.

Surface fires scorched tree crowns and helped dry out the overstory, making canopy fuels available for burning.

Woods on Fire

But something else was going on. Under the drought conditions, fires had broken out across the Upper Midwest in the summer and early autumn of 1871. For weeks, persistent low- to moderate-intensity surface fires had been "sweeping through the timbered country, and in some instances the prairies and openings of all that part of Wisconsin lying northward of Lake Horicon, or Winnebago Marsh, which was itself on fire" (Robinson 1872). By scorching tree crowns, the fires helped to dry out the overstory, making canopy fuels more readily available for burning.

Fire came from various sources. Loggers were piling and burning slash; farmers were burning to open new land to the plow; and workers were using fire to clear the new railroad from Chicago. According to Pernin (1999), autumn underburns were common in the region; hunters and farmers routinely left campfires burning, and the embers spread into dry autumn leaves, "so that in autumn these woods are everywhere filled with fires that have been kindled by the hand of man."

Surface fires were probably little noticed in years with more rain, but the drought was making them worse than usual. Some were going underground, particularly in dried-out bogs, where they burned down to the mineral soil. Others, to the amazement of local observers (Gess and Lutz 2002), were reburning areas that had already been blackened. Before the blowup on October 8, smoke on Green Bay was reportedly so dense that foghorns blew steadily and daylight navigation was done by compass (Hipke 2002). Trains on the expanding Chicago and Northwestern Railway ran through 50 miles (80 km) of active fire (Robinson 1872).

The "undermining burns" threatened to carry into the homesteads and settlements burgeoning in the North Woods. "The outstanding haystacks, the heavy log fences, the piles of cord-wood, hemlock-bark, fence-posts, and other products of the forests … were prompt conductors to carry the fire across these cleared plains," observed Robinson (1872). The fire hazards were perhaps somewhat like those in today's rural condition of the wildland/ urban interface,* where fuels on or near homes surrounded by fire-prone forests can pose lethal dangers.

"Presage of a Tempest"

When wells went dry, residents responded to the danger "mainly by circumvallating the property with ditches" (Robinson 1872). The rudimentary firelines generally held around homesteads and communities "so long as the fire preserved the ordinary character of previous fires" and stayed on the ground (Robinson 1872). But when the

* In the rural condition, "scattered small clusters of structures … are exposed to wildland fuels." See Brian F. Weatherford, "Study Supports Cooperative Fire Protection in the West" (*Fire Management Today* 62[1] [Winter 2002]: 11).

wind sprang up, fires sometimes spread into the canopy in terrifying events that destroyed homes and mills (Gess and Lutz 2002).

Residents generally took such events in stride, grumbling about the drought and dreading the occasional crown fires yet continuing to use fire in the woods. For people in the North Woods, fires were a way of life. The stifling smoke that blanketed the landscape was widely seen as a sign of progress. It meant that people were working, farms were growing, and the railroad was coming. For weeks, residents staved off the worst of the fires while hoping for rain.

By October 8, the worst seemed to be over in the minds of many (Wells 1968). "Everything combustible on the ground had burned out," declared Robinson (1872). Fires still smoldered, but few were actively burning. In Peshtigo, "the streets were full of people passing to and fro, having no idea but to amuse themselves with songs and laughter" (Pernin 1999). However, Pernin himself felt uneasy, noticing "a stifling and heavy atmosphere, a mysterious silence in the air—the common presage of a tempest."

A storm was indeed brewing. A reconstructed weather map for October 8 shows an intense cyclonic storm centered on Colorado and Nebraska (Pernin 1999). Based on reports by the Signal Service and the Smithsonian Institution, Haines and Kuehnast (1970) concluded that a cold front was on its way. Under the circumstances, the change in weather would prove disastrous. Haines and Sando (1969) compared the situation to loading and firing a weapon:

> A large amount of fuel was usually available before the fire; this would be analogous to a rifle shell. A unique series of climatic events prevailed during much of the fire season—*the shell is loaded into the rifle chamber.* Smaller fires were burning in the forests and bogs—*the hammer is pulled back.* A favorable synoptic weather pattern developed over the region—*the trigger is pulled and the bullet is on its way.*

The "bullet" was about to strike. At dusk, Pernin saw a red glow over the smoke pall in the darkening western sky. People soon heard "an unusual and strangely ominous sound, a gradual roaring and rumbling" (Robinson 1872). The rumble became like "a battle, with artillery, going on at a distance." Another wave of fire was clearly on its way, and people prepared to face it. But it came "not along the ground as they had been accustomed … but consuming the treetops and filling the air with a whirlwind of flame."

"Last Judgment"

A "hot southerly gale" (Robinson 1872) drove fire into towns and showered embers "upon the decks of vessels seven miles [11 km] distant on the bay." As "the flames came through the air, above the tops of the trees, and descended upon them," people thought that the Last Judgment had arrived. They fled in droves (fig. 2), perishing by the dozens. "Some were burned near the buildings," noted Robinson (1872); "some were caught in the fields and woods by the descending fires; others fled to the woods and were caught there."

The survivors told awesome tales of fire in the air. Fireballs reportedly descended from the sky and exploded (Pernin 1999). Structures and farm implements, though far from the fire front, unaccountably burst into flame (Gess and Lutz 2002; Wells 1968). Some people reported

Figure 2—*Panicked flight from the fires of 1871. Many survivors escaped to rivers and lakes (note the water in the foreground). Illustration: Courtesy of the Wisconsin Historical Society, image number 3728; drawing in* Harpers Weekly *(1871), p. 1037; created by G.J. Tisdale, 1871.*

lightning and other electrical effects. "The fire was transformed into an electric current of fervid heat, and the heavens seemed to be rolled, as it were, in a scroll," declared Robinson (1872).

Just before fleeing his home, with the flames thundering outside town, Pernin (1999) saw "a flashing that shone suddenly like grains of powder touched by fire, and that flew from room to room." He surmised that "the atmosphere was saturated with some gas; and if this gas … takes fire when nothing comes in contact with it but a breath of warm air, what will it do when the advancing flames shall strike these inflammable objects?"

Pernin would soon find out. Together with hundreds of others, he saved himself by jumping into the Peshtigo River, from where he saw everything on fire in every direction—"the houses, the trees, and the atmosphere itself" (Pernin 1999). Standing in the river, Pernin looked up and saw "nothing but flames, immense billows of flame that covered the whole sky, rolling one upon another." Filled with combustible gases, the air itself was ablaze.

Burning gases even reached the river's surface. "The flames ran upon the water as upon the ground," wrote Pernin (1999); "the air was filled with them, or rather the air was fire." Though up to their ears in water, the survivors were threatened by flames that "seized our heads, and we were obliged to throw water continually with our hands upon our hair and the parts necessarily exposed for breathing." People grabbed the clothing and bedding that floated by and covered their heads with the

One lesson is that large fires produce volatile gases that are both lethal and unpredictable.

wet material, but radiant heat from the onshore blazes dried it out so fast that it began to smoke and had to be repeatedly doused.

Phases of Combustion

From the "grains of powder touched by fire" to the flames running from shoreline over the water, Pernin's account (1999) alludes to what Byram (1957) called the first two phases of combustion: "First comes the preheating phase, in which fuels ahead of the fire are heated, dried, partially distilled, and ignited. In the second phase, the distillation of gaseous substances continues but is now accompanied by their burning or 'oxidation.'" Heat drives gases from fuels and the gases burn.

Radiation can produce similar effects through area ignition. High-intensity flame fronts on two or more sides can make areas in between erupt in flame when radiant heat drives gases from fuels and the gases are ignited by embers. Area ignition might account for the "tales of cabins suddenly bursting into flame in the middle of a large clearing, a considerable distance from the burning woods" (Wells 1968).

Many sought safety in such clearings (fig. 3), often in vain. In one case, stumps remaining in a newly cleared field caught fire and burned "like torches" (Wells 1968), driving out those seeking refuge there. Even an old clearing several miles long and half a mile (0.8 km) wide offered little protection from a fire that, according to Pernin (1999), seemed to travel through the air.

Reports of atmospheric fire effects led to now discounted theories that the

Figure 3—*Families huddled in a field to escape the Peshtigo Fire. Such openings, even when large, often failed to provide safety. Illustration: Courtesy of the Wisconsin Historical Society, image number 1881; created by Mel Kishner, 1968.*

> "The flames ran upon the water as upon the ground; the air was filled with them, or rather the air was fire."
>
> –Father Peter Pernin

fire was caused by buildups of marsh gas from the region's dried-out peat bogs (Gess and Lutz 2002; Pernin 1999). Robinson (1872) reported that weeks of underburns and hot, dry weather might have produced a "formation of gas from the long-heated pine forests of that region." Hough (1882) even speculated that the fire's severity was due to "an exceptionally strong tendency for the spread of flames in the atmosphere itself, perhaps due to electrical conditions or other causes."

Weather Change

Wells (1968) offered a more plausible explanation. For weeks, smoke had hung in the air, reducing visibility and affecting lungs (Gess and Lutz 2002; Peshtigo Historical Museum n.d.). A warm layer of air apparently separated the surface fires from the cooler air above, trapping heat and smoke relatively close to the ground. According to Wells (1968), the pattern persisted due to a precarious balance among fuel, weather, topography, and fire activity.

The balance tipped on October 8 when weather conditions changed. Wells (1968) suggested that arriving southwesterly winds whipped up the many small fires, driving them together through area ignition. The energy unleashed by the uniting smoke columns then punched through the warm, smoke-filled layer of overlying air into the colder air above. The resulting updraft of whirling air created a plume-dominated fire, with a towering smoke column and strong indrafts at the base.

Although Wells (1968) might be partly correct, rising surface winds do not seem to have triggered the blowup. In the weeks before October 8, winds had repeatedly whipped up the surface fires without generating a firestorm (Gess and Lutz 2002). Conversely, survivors made little or no mention of windy conditions on October 8 until the firestorm was visibly approaching or already at hand. Instead, most remarked on the "still" and "heavy" atmosphere in the moments before the fire.

Nor do Signal Service observations bear out the notion of a wind-driven crown fire. At 9 p.m., well after fire had already broken out, inland surface winds in Wisconsin were no more than 14 miles per hour (22 km/h) (Haines and Kuehnast 1970). "Even with major fire runs underway, evening surface winds were relatively light in most of southern Michigan and certainly did not appear to be excessive in northeast Wisconsin," concluded Haines and Kuehnast (1970). The gale-force winds later reported by survivors were undoubtedly generated by the firestorm itself.

Low-Level Jet

If surface winds did not trigger the blowup, what did? Haines and Kuehnast (1970) found that the cold front advancing through the Upper Midwest on October 8 was preceded by a low-level jet or jets. A low-level jet is a surge in windspeed at a height of about 1,600 to 2,300 feet (500–700 m) (fig. 4). Long associated with large fires, low-level jets can help small fires get big by overcoming the "wind-field barrier" (Byram 1959) formed by stable layering in the lower atmosphere.

Low-level jets are common at night over relatively flat terrain (Schroeder and Buck 1970). Formed by differences in atmospheric pressure, the jets glide along the nighttime inversion layer like a stream over its bed. They are usually broken up by the same daytime temperature changes that lift the inversion. Under overcast conditions, however, low-level jets can form without an inversion and even persist during the day. Haines and Kuehnast (1970) suggested that the

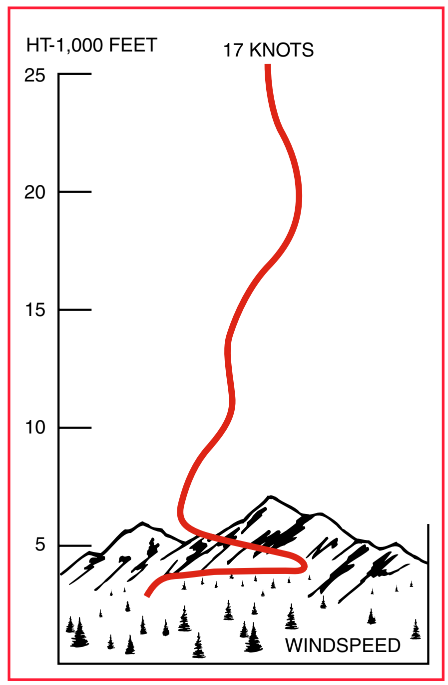

Figure 4—*Wind profile showing a low-level jet. Low-level jets usually occur over relatively flat terrain just above the nighttime inversion layer, but they can also occur under other conditions. Haines and Kuehnast (1970) attributed the blowup fires of 1871 to wind shear and turbulence caused by low-level jets associated with an approaching cold front.*

smoke pall shrouding much of the Upper Midwest functioned like cloud cover to support daytime low-level jets associated with the approaching cold front.

According to Haines and Kuehnast (1970), the low-level jets had a "strong anticyclonic shear." Resulting turbulence would have mixed the lower atmosphere, jolting the region's smoldering fires to life and driving them together. The energy released by the uniting convection columns would have pierced the weakening layer of smoke-filled overlying air and reached the cooler air above. "The flame, as it arose, drew in the surrounding atmosphere, already parched and heated in extreme degree, until it became a tornado of fire, sweeping everything before it," reported the *Detroit Tribune* (Hough 1882). A firestorm ensued—a "violent convection caused by a large, continuous area of intense fire" (Cramer 1954).

Firestorm Turbulence

Firestorm indrafts cause powerful colliding winds, producing extreme turbulence. The erratic cross-currents make burning gases roll and spin, forming fiery funnels of enormous energy. Pernin (1999) told of a "horrid whirlwind" and "vortices of wind." "The pine-tree tops were twisted off and set on fire," Robinson (1872) reported, "and the burning debris of the ground was caught up and whirled through the air in a literal column of fire."

Large firewhirls are capable of throwing firebrands far ahead of the main fire, probably accounting for the descending "fireballs" described by some. Fire tornadoes are also capable of separating from their fuel bases and traveling up to 3 miles (4.8 km) ahead of a flaming front (Byram 1959). Witnesses apparently mistook such phenomena for true tornadoes (see the sidebar below).

Firestorm turbulence also helps to explain other unusual fire behavior. Embers caught in the turbulent winds would have set volatile gases on fire, sending flames dancing across the water. The erratic cross-currents would have fed the "immense waves of flame" that Pernin (1999) saw from the river, "rolling one upon another, mounting to a prodigious height in the air, and of course far above the reach of all inflammable materials."

For many, the superheated gases proved lethal. Survivors were amazed to find so many of the dead unburned. "Men, women, and children were suffocated and found fallen on the ground with no marks of fire upon their persons," observed Robinson (1872). Pernin (1999) found it "passing strange" that "some dead bodies showed no marks of burning."

Was There a Tornado?

Contemporaries theorized that a "hurricane" (great windstorm) or even a tornado caused the Peshtigo Fire (Robinson 1872; Wells 1968). Gess and Lutz (2002) embraced the theory, maintaining that "the strongest-force tornado, an F5, struck Peshtigo at the time of the fire." As evidence, they pointed to "descriptions of cloud formations," documentation of a cyclonic storm, and "accounts of survivors who witnessed houses and loaded train cars hurled hundreds of feet through the air." The best evidence, they said, is the fact that the fire spared Peshtigo Harbor on Green Bay, 6 miles (10 km) to the southeast. They apparently reasoned that destruction on the order that befell Peshtigo followed a narrow course across the landscape, suggesting a tornado.

However, Gess and Lutz (2002) also admitted that evidence for a tornado is inconclusive. As Byram (1957) observed, "three-dimensional" fires can release an enormous amount of energy—as much as a thunderstorm. They can create "firewhirls of tornadic violence" (Graham 1952) that can encompass entire fires a thousand yards (almost a kilometer) across (Cramer 1954). Firewhirls are capable of snapping mature trees, picking up large logs, and lofting enormous firebrands for great distances (Graham 1957). Wells (1968) concluded that eyewitnesses almost certainly did observe tornadoes—but "fire tornadoes" created by the fire itself.

Moreover, large fires typically leave areas within the fire perimeter intact. The enormous 1871 fire perimeter containing Peshtigo was formed by multiple fires that spared entire areas within the perimeter, such as the town of Oconto to the south (Wells 1968). The fire that burned through Peshtigo split north of town due to changes in fuel and topography, resulting in far less damage to the towns of Marinette and Menominee (Wells 1968). The fact that Peshtigo Harbor did not burn therefore would seem to mean little.

Energy from low-level jets can contribute to rapid fire growth

The dead were "generally lying face down" (Wells 1968), as if their last moments were spent trying in vain to find breathable air. The farmer Thomas Williamson remembered successfully "rooting" with his face in the ground for air (Wells 1968). His brother John was not so lucky. Thomas found him lying in a plowed potato patch, looking "natural" but quite dead.

Lessons Reinforced

Studies of recent tragedy fires shed light on accounts of the great Peshtigo Fire. One lesson is that large fires produce volatile gases that are both lethal and unpredictable. On the South Canyon Fire in 1994, 12 firefighters died while trying to outrun the fire. Butler and others (2001), based on evidence collected during a painstaking postfire study, drafted scenarios of the firefighters' final moments. In one scenario, the firefighters were enveloped by an unexpected blast of hot air before they could reach safety.

On the Thirtymile Fire in 2001, volatile gases from a high-intensity flame front again proved fatal. Fourteen entrapped firefighters could not see the fire approaching with its flattened convection column aimed at their position (Brown 2002; USDA Forest Service 2001). The ensuing blast of hot air apparently caught them offguard. Four firefighters perished because they could not get a good seal against the ground with their fire shelters. Like many victims of the Peshtigo Fire, they died from the effects of inhaling superheated gases.

A related lesson pertains to safety zones and escape routes. On the Peshtigo Fire, radiant heat from multiple sides apparently caused area ignition across large openings. In some cases, people using such openings as safety zones might have died simply from the shock of exposure to intense radiation. Greenlee and Greenlee (2003) discussed the difficulty for firefighters of finding adequate safety zones in forests where flame fronts can be expected to reach 200 feet (60 m) in height. The difficulty would be compounded if flame fronts are possible on multiple sides. One scenario drafted by Butler and others (2001) for the failed escape route on the South Canyon Fire was area ignition due to high-intensity flame fronts on three sides.

Another lesson is that large fire behavior can be capricious and unaccountable. Gess and Lutz (2002) claimed that the fire "stripped the land of all trees," but postfire photos of forested areas near Peshtigo show many snags and possibly even stands of surviving trees. In fact, large areas within the fire perimeter were entirely spared (see the sidebar), and burned areas showed evidence of mixed fire severity. According to Robinson (1872), "Houses were burned while adjoining barns were saved. Fences, pumps, and outhouses were burned, while dwelling houses within a few yards escaped." "The fire might spare one cowering group of refugees," observed Wells (1968), "while every member of another group a short distance away was burned to death."

Similarly, the 1991 firestorm in Oakland and Berkeley, CA, destroyed some houses while leaving others intact. The 2002 Rodeo–Chediski Fire in Arizona, though uncharacteristically severe, still left a typical mosaic of burned and unburned areas (USDA Forest Service 2002). As Gess and Lutz (2002) noted, the haphazard pattern of destruction left by the fire runs of 1871 was analogous to that of a tornado.

A related lesson is that previous underburning is no guarantee of security (Butler and others 2001). On the Peshtigo Fire, low-severity fires burned for weeks before the blowup, consuming surface fuels. Crown fires are normally supported by convection from burning surface fuels (Byram 1957). Without enough surface fuels to support them, crown fires will often drop from the canopy to the ground. In one place, people escaped the Peshtigo Fire into "the adjacent timber, where the ground had been previously burned over, and were saved" (Robinson 1872).

However, their survival might have had more to do with erratic winds from firestorm turbulence than with a lack of surface fuels. Surface fires typically leave partially consumed fuels, which can later fuel another fire. Similarly, surface fires usually consume the upper fuel layers in the soil, exposing duff and other buried materials that were initially too wet to burn. Such materials can dry out and become available for later burning. Both the surface reburns that amazed local observers and the crown fires that ultimately followed evidently found enough surface fuels to support them.

Another lesson from Peshtigo is that extreme fire behavior can occur abruptly. Just before the blowup, fire behavior was deceptively benign, and people thought the worst was over. The sudden transition to extreme fire behavior was repeated on the South Canyon Fire (Butler and others 2001) and the Thirtymile Fire during the entrapment (Brown 2002; USDA Forest Service 2001).

Peshtigo reinforces yet another important lesson from South Canyon: The longer and farther a fire burns, the more likely it is to change behavior (Butler and others 2001). On the Peshtigo Fire, understory fires smoldered for weeks, drying out canopy fuels and lingering long enough for the weather to change. When a cold front approached on October 8, a blowup resulted.

Cautionary Tale

Finally, Peshtigo holds a cautionary tale. It is easy to forget that northern hardwood forests burn, because fire return intervals are normally so long. But if a hardwood forest has a coniferous understory together with large amounts of slash or other dead and down material—as was probably widely the case near Peshtigo in 1871—it can readily fuel a large, high-severity fire. Survivors noted no difference in fire effects between the Sugar Bushes, where the farm-dotted forest was probably dominated or codominated by sugar maple, and areas with more fire-prone coniferous forest types. Something similar happened in Maine in October 1947 (Wilkins 1948), when a series of firestorms covering 200,000 acres (80,000 ha) indiscriminately burned across the same forest types as in Wisconsin. Even a maple forest with large openings can fuel a firestorm under the right combination of climatic and synoptic conditions.

It is also easy to suppose that rarely burned forest types will support a crown fire only under conditions of extreme drought and high wind. Peshtigo showed the opposite. A relatively mild drought, together with persistent surface fires, set the stage for a blowup apparently brought on not by surface winds, but by low-level jets. Charney and others (2003) found something similar for the 1980 Mack Lake Fire in Michigan (Simard 1981): Atmospheric mixing from low-level jets caused a prescribed fire to escape, ultimately costing a firefighter's life. Clearly, energy from low-level jets can contribute to rapid fire growth (Byram 1959).

Unforgettable Fire

Initially obscured by the great Chicago Fire, the Peshtigo Fire has never been forgotten. Today, it is widely considered one of the greatest tragedy fires in history, overshadowing even larger or equally tragic fires (Pyne 1999), such as the Miramachi Fire in New Brunswick (1825), the Matheson Fire in Ontario (1916), or the Cloquet Fire in Minnesota (1918).

The accounts reprinted by Hough (1882) might be a good part of the reason. The powerful tales told by Pernin, Robinson, and others have inspired a series of artistic renditions of the horrors faced that night (Gess and Lutz 2002; Hipke 2002). They have lent themselves to dramatization (Gess and Lutz 2002; Wells 1968) and even to inspiration for firefighters (Leschak 2002).

To Pernin, the entire firmament had seemed ablaze, in apparent defiance of reason and faith. Today, after more than a century of experience and scientific study, the Peshtigo Fire no longer seems so baffling. Though exceptionally large and severe, Peshtigo showed typical characteristics of large fire behavior, such as concentrations of volatile gases, variable severity, and relatively sudden changes.

However, Peshtigo also serves to illustrate what Byram (1954) called "the contradictions in the facts of extreme fire behavior." Most blowup fires occur in mountainous terrain in the afternoon, whereas Peshtigo occurred in relatively flat terrain at night, when atmospheric conditions seemed stable (Wells 1968). As Haines and Kuehnast (1970) showed, the synoptic events that triggered Peshtigo under these conditions are extremely complex and difficult to fathom.

For firefighters today, the lessons from Peshtigo might not be new, but they still bear remembering. One of them is humility—to remember "the possible futility in attempting to explain each fact" (Byram 1954).

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Wildland Fire Decisionmaking

Nick Greear

Wildland firefighters have been assessing fires and addressing the need to develop and select containment strategies for decades. In the 1970s, the USDA Forest Service, as a result of the change from the 10 a.m. Policy to the Least-Cost-Plus-Loss Policy, formalized the assessment process for fires escaping initial attack. Soon other Federal agencies followed, and now many States use a similar form of analysis before selecting suppression strategies. The process, initially called an Escaped Fire Situation Analysis (EFSA), is now known as a Wildland Fire Situation Analysis (WFSA).

When wildland firefighters size up a fire, they develop and select containment strategies considering firefighter and public safety, costs, and available resources.

The Process

The Forest Service requires fire management officers to complete a WFSA when a wildland fire escapes or is expected to escape initial attack or if it escapes planned prescription parameters. A WFSA must:

- Identify criteria for evaluating suppression alternatives;
- Develop and analyze suppression alternatives;
- Receive approval and provide notification; and
- Monitor, evaluate, and document the assessment process.

Important evaluation criteria include firefighter and public safety, actions that are consistent with applicable land and resource management plans, and suppression and rehabilitation costs. Alternatives must focus on firefighter and public safety; be implemented with available suppression resources; and show how they will succeed, considering an estimate of final fire size, containment and control times, suppression costs, and anticipated resource damages.

Making an Effective WFSA

A WFSA requires the following key preparation steps:

- Begin with an appropriately scaled map to adequately display alternatives, including a worst-case alternative. Show the existing fire perimeter and its projected

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During (left) and after (right) the 2000 Bitterroot Fires near Sula, MT. Multiple fires burned hundreds of thousands of acres of State and Federal land, much of it in the wildland/urban interface. Almost a quarter of everyone in the Bitterroot Valley was either evacuated or prepared to evacuate. The situation was so complex and resources were so strained that even the best wildland fire situation analyses proved ineffective. Photos: USDA Forest Service, 2000.

growth without suppression actions during the analysis period.

- Develop alternatives, including a least-cost alternative, that are safe and feasible.
- Determine the significant criteria that will likely affect the alternatives, separating them out from the neutral criteria that have less bearing on decisionmaking.
- Conduct the analysis and select the alternative that best meets the criteria.
- Develop an initial WFSA that meets the timeframes and provides reasonable direction to incident commanders during their first operational periods. If needed—and as time and resources permit—develop and analyze subsequent WFSAs.

Plume from a blowup in the upper Lawson Creek Drainage on the Biscuit Fire, August 16, 2002. The fire was far too vast—almost 500,000 acres (200,000 ha) across four administrative units—for any single person or team to analyze. Wildland fire situation analysis on large fires like this does little to help decisionmakers develop alternatives and select effective strategies. Photo: Gary Percy, USDA Forest Service, Siskiyou National Forest, Grants Pass, OR, 2002.

Tools Used

In the late 1970s, an EFSA was a simple two-page form that guided the assessment process and documented the results for a fire escaping initial action. As analyses became more sophisticated in the 1980s, the form grew to more than six pages. In the early 1990s, demand for an automated process resulted in development of a software application. Refinements to application releases continued until the birth of the current version, WFSA Plus99.*

Using WFSA Plus99, fire managers can upload fire-planning data, including average suppression costs and resource losses, and input criteria from a land management unit or fire zone before a fire occurs. The program creates decision trees and provides a complexity analysis format to help managers determine the type of organization needed to manage a fire most effectively. The entire analysis, including a page for daily review and monitoring, can be printed for review.

Using software for a wildland fire situation analysis can lead to focusing on the numbers rather than on effective alternative development, analysis, and selection.

Limitations and Weaknesses

Fire managers and agency administrators admit that WFSA Plus99 has some problems:

- Full and correct use of the application requires a trained technician, which is often difficult for units with limited fire programs.
- Many agency administrators and fire managers are not sufficiently trained to conduct effective analysis.
- During development of a WFSA, there is often not enough time to use the application's full capabilities. "Default" values chosen in haste can lead to erroneous outcomes.
- Making the application "work" sometimes overshadows the goal of using it to make better decisions.
- WFSA Plus99 does not facilitate development of a least-cost alternative.

* Information about WFSA and WFSA Plus99 software is available on the World Wide Web at <http://www.fs.fed.us/fire/wfsa/>. A Line Officer's Guide to Wildland Fire Decision Making is available at <http://www.fs.fed.us/r3/loguide.html>.

Using WFSA for Large Fires

Developing a WFSA for large fires, especially for large fire complexes such as Bitterroot in 2000 or for megafires such as Biscuit in 2002, is difficult. The characteristics of such fires, with extreme burning conditions, multiple jurisdictions, and several incident management teams, can challenge alternative development and analysis. Consider:

- In Montana's Bitterroot Valley during the 2000 fire season, two highly skilled fire management officers developed WFSAs for the many individual and complex fires. After exhaustive analysis and use of WFSA Plus99, the results did not alter the fire strategies used. Evaluation revealed that the analysis was ineffective because too many fires existed, they were growing at unanticipated rates and were growing together, and the increasing shortage of resources prevented reasonable alternative development.

- During the Biscuit Fire in southwestern Oregon during the 2002 fire season, four administrative units burned and others were threatened. The area was too extensive—the fire perimeter reached almost 500,000 acres (200,000 ha)—for any single person or team to analyze, and separate analysis on each administrative unit would not have resulted in an overall, effective strategy.

During these fires, agency administrators directed the area command team to prepare a WFSA to meet their management criteria and provide overall strategy to the incident management teams. However, developing, analyzing, and selecting effective containment strategies using a WFSA did not occur during either incident.

Decisions concerning large fires are based on current funding, the availability of suppression resources, and other social and political factors. Therefore, allowing second- and third-level agency administrators to make decisions on very large fires might be appropriate.

- During large conflagrations, the ability of WFSA Plus99 to help decisionmakers develop alternatives and quickly analyze and select effective strategies is compromised (see sidebar).

The Future of WFSA

Wildland fire fatalities and escalating suppression costs—the Forest Service spent more than $1 billion on wildland fire suppression activities in 2002—highlight the importance of sound decisionmaking by agency administrators. Land management agencies involved in firefighting must have effective WFSA tools.

Some units are again using a hardcopy version of a WFSA. Using the form might be appropriate, especially for WFSAs prepared immediately after the first burning period when time is critical. The form simplifies the process, clearly displays the alternatives, and provides easy-to-discern evaluation criteria to make decisions. However, the form does not create a decision tree, and training and proficiency are still needed to adequately develop an effective WFSA.

> Meeting the need for effective alternative development and analysis will increase in complexity as issues surrounding wildland fire suppression mount.

Updating WFSA Plus99 to allow users to replicate the paper version for use during initial WFSA development could address some process limitations. Users could save the data entered into the new module to use in later analysis. A version update might also include development of a least-cost alternative.

The goal of a WFSA is to provide a format for developing sound alternatives and making rational decisions during wildland firefighting. While documentation is important, it is imperative is to use a process and tools that foster informed, strategic fire suppression decisions. ■

Wildland Fires in Botswana

Witness Mojeremane

Worldwide, wildland fire has long been part of the natural environment of people (DeBano and others 1998). Since the mid-Pleistocene, people have become increasingly adept at using fire to manipulate ecosystems to obtain desired benefits (Pyne and others 1996). In many places, people have altered the frequency and severity of wildland fire on a landscape level. Although fire is an important tool, uncontrolled or misused fires can adversely affect both the environment and society.

Many tropical and subtropical countries such as Botswana (see the sidebar) experience relatively large annual fires. These fires are having an increasing regional and global impact on the environment. Impacts on flora and fauna can be profound, because fire transforms the countryside. Moreover, the smoke from tropical fires carries vast amounts of atmospheric pollutants (Heikkilä and others 1993).

Fire Causes

Most wildfires in Botswana are human caused; lightning fires are few (Central Statistics Office 2000). However, the exact cause is often unknown. Known and suspected causes involve hunters, safari expeditions, smokers, campfires, wildlife poachers, motorized vehicles, fires spreading across the border (from Namibia and Zimbabwe), and farmers or villagers setting fire. In Botswana, as in many other developing countries, fire has long been an agricultural tool.

Witness Mojeremane works for the Botswana College of Agriculture, Gaborone, Botswana.

Wildfire cause and frequency depend largely on location and the size of the local population. Most fires in Botswana originate in populated areas and spread to more remote areas. Most acres burn in relatively remote areas, partly because fire control there is more difficult.

By U.S. standards, many fires in Botswana are enormous.

Fire Extent and Severity

Botswana has all types of wildland fires, from ground fires, to surface fires, to crown fires. During the long, dry winter season (see the sidebar), leaves, grasses, and other fine fuels become highly flammable. Enormous areas often burn (table 1).

By U.S. standards, many fires in Botswana are enormous. As table 1 shows, average fire size in 2001 was more than 18,000 acres (7,000 ha), compared to 42 acres (17 ha) in the United States (NIFC 2003). If the area burned in the United States in 2001 had been proportionally similar to the area burned in Botswana, more than 72 million acres (29 million ha) would have burned—about 17 times more than the 10-year average for the United States.

Wildfires in Botswana are worst following a wet summer, when grasses become highly dense. The most severe wildland fires occur in areas where annual rainfall exceeds 24 inches (600 mm). The dense vegetation here yields fuel loads in excess of 357 pounds per acre per year (400 kg ha^{-1} yr^{-1}). Where rainfall is less, fuel loads range from 134 to 178 pounds per acre per year (150–200 kg ha^{-1} yr^{-1}), resulting in fewer severe fires.

Table 1—*Wildland fires and area burned, Botswana, 1991–2001 (Agricultural Resources Board 2002).*

Year	*Number of fires*	*Acres burned*	
		Acres	*Hectares*
1991	125	2,843,155	1,151,075
1992	70	1,815,218	734,906
1993	87	3,271,925	1,324,666
1994	144	4,983,437	2,017,586
1995	56	1,211,289	490,380
1996	223	3,156,658	1,277,999
1997	199	179,826	72,804
1998	113	n.a.[a]	n.a.[a]
1999	165	35,583	14,406
2000	n.a.[a]	n.a.[a]	n.a.[a]
2001	249	4,633,424	1,875,880

a. Fires occurred but data are not available.

Botswana: Physical Conditions

Botswana is a landlocked country of 225,000 square miles (582,000 km^2). It borders the Republic of South Africa on the south, Zimbabwe on the northeast, Zambia on the north, and Namibia on the west. Elevations range from 1,200 to 4,300 feet (600–1,300 m) above sea level.

Botswana has a semiarid and arid climate marked by pronounced cycles of dry and wet years (Bhalotra 1987; Otsyina and Walker 1990). The mean annual rainfall ranges from 10 to 26 inches (250–650 mm) (Bhalotra 1987; Ntogwa 1995). More than 90 percent of the rains fall in summer (October to April), with the winter (May to September) generally dry (Mojeremane 1999). Annual temperatures in summer can exceed 95 °F (35 °C), and winter temperatures can drop below 32 °F (0 °C), with occasional nighttime frost from June to August.

About 80 percent of Botswana is covered by Kalahari sands, predominant in the western and northern parts of the country (Otsyina and Walker 1990). The sandy soils are well drained. Derived from acidic igneous rocks, they are generally infertile. The sands vary in depth from 10 feet (3 m) to occasionally more than 330 feet (100 m) (Ntogwa 1995). Highly populated eastern Botswana has moderately fertile soils ranging from sandy loams to clay loams (Otsyina and Walker 1990).

The country is moderately forested. About 25 percent of the land area is classified as forest and an additional 20 percent as woodland. Closed forests are rare and occur only in riparian zones, particularly in the Okavango swamps and along the lower reaches of the Limpopo and Shashe Rivers. The most significant forest area is in and around Chobe District in the north, where large areas of *Baikiaea* woodland occur, sustained by relatively high rainfall. More than half of the country has savanna vegetation, which occurs mainly where rainfall ranges from 8 to 14 inches (200–350 mm) (Ministry of Finance and Development Planning 1997).

Fire season in Botswana normally starts between April and June. Early-season fires are rarely severe, because the scant fuels are not yet dry and fires are easy to contain. Late-season fires from August to October are more extensive and destructive. They occur when the vegetation is dry and fire control is difficult due to high heat and wind.

Fire Effects

Wildfires have had a high impact on Botswana's environment, destroying both forest and rangeland resources. However, the damage caused by wildfires in Botswana varies from year to year (table 1). Impacts have included:

- Soil erosion,
- High water runoff,
- Loss of wild and domestic animals,
- Loss of timber resources,
- High cost of fire suppression,
- Loss of human life,
- Loss of homes and personal property, and
- Loss of tourism revenue.

Wildfires have had a high impact on Botswana's environment, destroying both forest and rangeland resources.

Fire Prevention and Control

Early (prescribed) burning is practiced in State forest reserves, national parks, and game reserves to reduce highly flammable fine fuels on the forest floor. These areas make up much of the country; State forest reserves cover 1 percent of Botswana's land area (Ntogwa 1995), and national parks and game reserves cover more than 17 percent, with an additional 22 percent in wildlife management areas (Government of Botswana 1986). Prescribed burning occurs when fuel volume is small and moisture content not too low.

Firebreaks of up to 30 feet (10 m) have been constructed in all State forest reserves, national parks, and game reserves. They are cleared of flammable vegetation by cultivation every year before the fire season starts.

Fire prevention methods include educating people about the danger of wildfires through the media and public gatherings. Fire prevention signs are also used to inform the public of regulations, restrictions, and procedures to reduce accidental and escaped fires. Signs are erected along roadsides, at campgrounds, and anywhere people congregate.

The Ministry of Environment, Wildlife and Tourism has "herbage conservation committees" in all six agricultural regions of Botswana. The committees hold public meetings on wildfires and other conservation issues. Various laws govern fire control and prevention, including the Forest Act of 1968, Agricultural Resources Conservation Act of 1974, and Prevention of Fires Act of 1977.

But fire control in Botswana faces severe constraints. In rural areas, the only way for someone to report a fire is to go to the police or nearest local authority. Many local people hesitate to do so for fear that they will be suspected of having started the fire.

Moreover, rural people often have little incentive to join in fighting a fire. Unlike government workers, they are not paid for firefighting and receive no personal protective equipment. Government vehicles are also usually in short supply to take firefighters to the fire.

Prescribed burning is practiced in State forest reserves, national parks, and game reserves to reduce highly flammable fine fuels on the forest floor.

Persistent Problem

The wildfire problem in Botswana is severe and likely to persist. Fire prevention will never eliminate all wildfires, although it can reduce them dramatically. There is a strong need for all stakeholders (government agencies, nongovernmental organizations, local people, and others) to work together to fight the problem of wildfires in Botswana.

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The Fire Below: Suppression Tactics From Above

Mike Benefield

Robert W. Mutch's essay "Why Don't We Just Leave the Fireline?" (Mutch 2002) addresses a basic approach to tactical situations involving firefighting on slopes. The concept, however, needs further exploration. In some situations, perhaps it is better to ask, "Why even approach a wildland fire on a steep slope from above?" Some important tactical aspects that build upon Mutch's observations should be noted.

Tactical Above-Fire Aspects

We need to recognize several basic tactical factors for making sound decisions regarding above-fire firefighting on steep slopes, where the area becomes a death trap as the heat rises. Many firefighting fatalities, such as on the 1994 South Canyon Fire, share two important elements:

- The initial approach was from above the fire, and
- Firefighters were traveling uphill to escape blowup conditions from below.

Although strong downslope winds can push a wildland fire downhill with amazing speed, burnovers on fires driven by downslope winds are rare. The convective heat column above a fire tends to be most efficient at driving the fire uphill,

We need to recognize several basic tactical factors for making sound decisions regarding above-fire firefighting on steep slopes.

especially through chimneys and other narrow topographic features.

Why don't we leave the fireline above the fire on a slope? Why don't we approach it from the bottom on our own terms? What factors lead to a safer tactical operation on a slope?

The Initial Approach. First, we need to safely reach our anchor point. Whenever burning conditions are extreme, approach the fire from below and avoid above-fire tactics. It might be necessary to walk a considerable distance to the fire from downcanyon or downslope. Safety also requires viable escape routes and safety zones along a well-scouted approach path—in other words, good LCES (lookouts, communications, escape routes, and safety zones).

The initial approach should reduce risk to acceptable levels for all personnel. If it is impossible to safely approach a wildland fire from below, wait to engage the fire until after it has burned to a location for successful anchoring.

Manage the fire from the bottom up: Fire the line as you advance with as direct an attack as possible

Midafternoon on the Old Fire on the San Bernardino National Forest, CA. Risk to firefighters engaged in above-fire operations increases as the burning period progresses. Photo: Mike Benefield, USDI Bureau of Land Management, Central Oregon Fire Management Service, Rivers Division, Prineville, OR, 2003.

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while defending your anchor point. Rolling material will become the greatest threat to your anchor point. Expect it and plan your tactical response before you initiate your anchor point.

Advance no farther than the amount of fireline that you can successfully defend. While this might seem a little less than "can do," it represents a time-tested and safe way to control wildland fires.

Timing. An important question to ask whenever approaching a fire in mountainous terrain is, "Will the timing of above-fire tactics place firefighters above the fire between the hours of 10 a.m. and 10 p.m.—the driest, hottest part of the day—at the peak of the local fire season?" The window of increased risk is between the beginning of the fire season and a season-ending event. The timing of this window might vary with drought conditions.

Location. A planned fireline should have a well-established anchor point and not place firefighters in a confined space (such as narrow canyons or chimneys) above the fire. Avoid midslope tactics in chutes and narrow canyons with the fire below.

Additionally, a planned fireline should not place firefighters within thermal belts with the fire below. In such situations, avoid midslope tactics. Instead, locate the thermal belt and observe the fire's behavior between 10 p.m. and midnight. The thermal belt is usually the most active area higher on the slope.

Fuels. Avoid above-fire tactics with continuous and partially burned fuel below. Fuel that appears burned might merely be primed for repeat ignition. Some fuels produce rolling material. Preparation is crucial.

Weather. Avoid above-fire tactics whenever cold fronts are forecasted. Slope and wind-driven fire make for an explosive mix. Cold fronts and nighttime diurnal winds also pose problems for firefighters below the fire.

Let's Not Race

Should we abandon the practice of downhill line construction? No. We can, however, reduce risk to acceptable levels with proper preparation.

Lookout posted in brush 12 feet (4 m) high on the Old Fire, San Bernardino National Forest, CA. Experienced lookouts with reliable communications gear are critical for any above-fire tactical operation. Photo: Mike Benefield, USDI Bureau of Land Management, Central Oregon Fire Management Service, Rivers Division, Prineville, OR, 2003.

> Whenever burning conditions are extreme, approach the fire from below and avoid above-fire tactics.

Guidelines in *The Fireline Handbook* (NWCG 1998) provide the foundation for assessing and mitigating the risks involved in constructing downhill fireline.

However, it is important to mitigate the hazards of above-fire tactics by practicing avoidance when conditions are extreme and by adjusting the amount of time that firefighters are exposed to the increased risk. Even with good LCES in place, firefighters should never challenge a wildland fire to a foot race on a slope. The fire almost always wins.

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Improving a Wildland Fire Situation Analysis Through GIS

Matthew Galyardt, LLoyd Queen, and Laura Ward

The wildland fire situation analysis (WFSA) is a great way to assess wildland fires that escape initial attack (see the sidebar). It documents the situation, sets forth objectives, and facilitates communication on the ground. Yet it has a basic drawback: The WFSA relies entirely on text to describe a changing situation on the ground. Without a spatial or mapping component, it's hard to visualize what the fire is actually doing (MacGregor n.d.).

Now there's a way of visualizing the changing situation on the ground by integrating a geographic information system (GIS) into the WFSA. A GIS can graphically show how fire location, direction of spread, and topography relate to sensitive resources and the wildland/urban interface (WUI). Fire managers can then better anticipate concerns, make decisions, and communicate with incident management teams (IMTs).

What Is a Wildland Fire Situation Analysis?

When a fire escapes initial attack, local fire managers must complete a wildland fire situation analysis (WFSA). The WFSA is a decisionmaking and communication tool that allows fire managers to make effective and timely decisions while at the same time directing and clarifying discussion. A WFSA:

- Details the current wildland fire situation,
- Outlines objectives of, and constraints to, suppression efforts,
- Describes and compares alternative suppression strategies, and
- Chooses a strategy.

The WFSA process documents actions and decisions, helping other fire managers and the general public see the logic behind suppression strategies and tactics. Level of detail and depth of analysis depend on the complexity of the wildland fire situation. A large fire staffed by a type 1 or type 2 incident management team generally requires a full-length WFSA, whereas an incident that will be contained and controlled in 3 to 7 days usually requires a short WFSA with at most two suppression alternatives.

The Project

In spring 2002, the Ninemile Ranger District on the Lolo National Forest in Huson, MT, and The National Center for Landscape Fire Analysis at the University of Montana in Missoula, MT, began discussing the idea of using a GIS to support a WFSA. The Ninemile Ranger District can count on an extended-attack fire every fire season. It consistently receives resources from other units and has to manage large fires and numerous resources for extended timeframes. The district wondered whether GIS technology could be used to update incident-related maps, review and validate WFSA objectives, and pass better direction and information to incoming resources and IMTs.

> A GIS can graphically show how fire location, direction of spread, and topography relate to sensitive resources and the WUI.

Through ArcGIS,* we developed an application for using maps and spatial analysis to more accurately depict the process described by a WFSA. We picked ArcGIS due to its functionality and built-in Incident Command System symbology. We also anticipated that the wildland fire community will eventually

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switch to ArcGIS. ArcGIS is a scalable framework of products that form a complete GIS, from data storage, to editing, to display, to mapping. Within the ArcGIS framework, our application uses ArcInfo 8.x for continued development and administrative tasks and ArcView 8.x for everyday user tasks.

Transitioning to the newer versions of ArcInfo and ArcView will take time. Many ranger districts and wildland fire personnel are concerned about the cost and time associated with learning the new software. The Ninemile Ranger District viewed this project as an excellent opportunity to begin the transition, and learning the new software did not prove overly difficult for district personnel. Especially with a working knowledge of ArcView 3.x, the user can quickly master the basics.

Data Collection

Based on the types of maps the district wanted to produce for the WFSA, we collected the following types of data:

- Low-level flight hazards, such as powerlines and communication towers;
- Sensitive resources, such as endangered species habitat or recreational and archeological sites;
- Wildland/urban interface data, such as roads, homes, and the defensibility of private property;
- Environmental features, such as cover type, hydrology, and digital elevation models;
- Administrative boundaries, such as national forest boundaries, private inholdings, and fire protection jurisdictions; and
- Data that can be created on-the-fly, such as different types of firefighting resources, their locations, and fire perimeters.

The GIS application easily incorporates data collected through global positioning systems into the WFSA.

Although the data took time to organize and compile, they were readily available. Most data came from the Lolo National Forest supervisor's office and the rest from the Federal Aviation Administration, the Frenchtown Rural Fire Department, and the Natural Resource Information System of the Montana State Library (on the World Wide Web at <http://nris.state.mt.us>).

We stitched together 1:100,000 and 1:24,000 digital raster graphics from the USDI U.S. Geological Survey to create a seamless base map for the Ninemile Ranger District. For a seamless overhead photo of the entire district, we plan to supplement the base map by adding digital orthophoto quarter quadrangles when they become available.

Figure 1 shows where the GIS is integrated into the WFSA process. There is no physical link—each

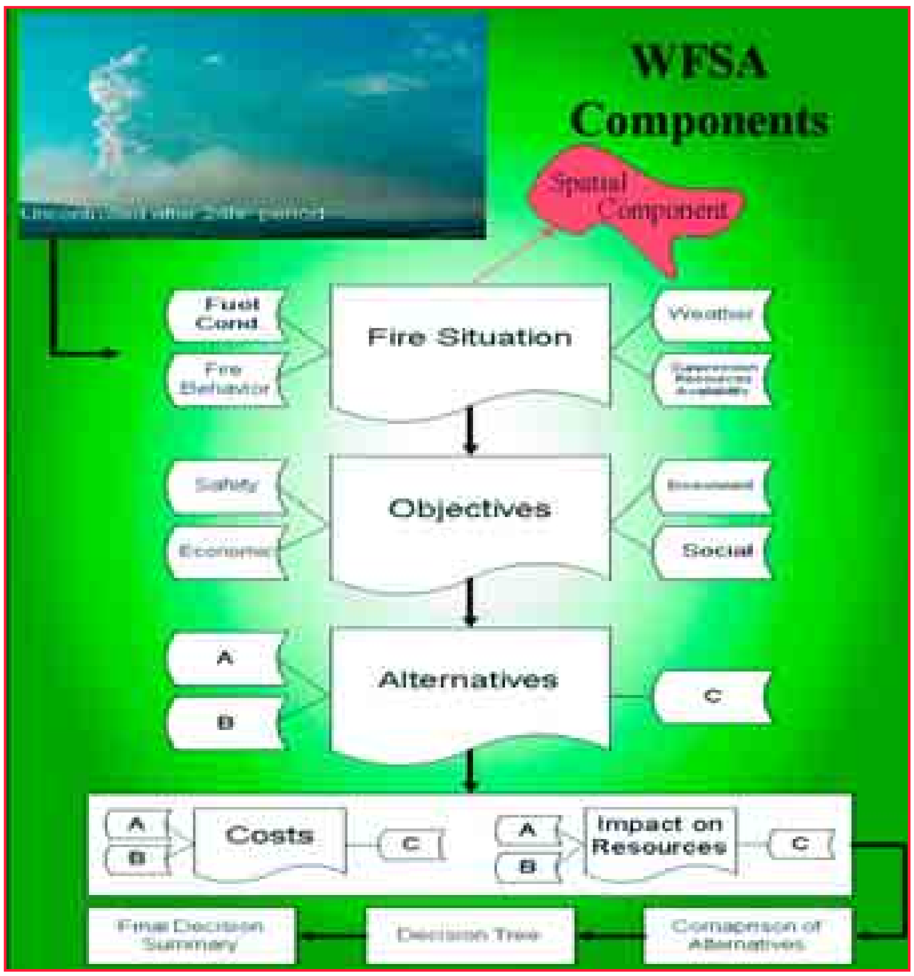

Figure 1—*The geographic information system (GIS) is integrated into the fire situation stage of a wildland fire situation analysis.*

desktop application remains separate. The link is through process and information. While fire personnel complete the fire situation component of the WFSA, they utilize the GIS for map production and spatial analysis. In addition, some of the information required to complete a WFSA is now stored and organized within the GIS.

General Advantages

Map production is a key advantage of integrating GIS into a WFSA. Maps are vital for achieving situational awareness, especially on complex incidents, and certain types of maps have become standard on all large fires (Albright and others 2002). By linking a GIS to a WFSA document, such maps can be predefined and produced before a wildland fire occurs. Fire perimeter data and desired symbology can quickly be added, and the maps are ready for distribution to firefighters upon arrival.

The GIS mapping feature is particularly helpful for short WFSAs, where only one or two alternatives are required. During extended attack, there is no need for data acquisition and map design. Incoming resources get accurate maps, and harried local fire managers can quickly bring a developing incident into focus.

The GIS application easily incorporates data collected through global positioning systems into the WFSA. Fire perimeter updates can be added to maps as soon as data are collected by air and ground resources. Situational awareness improves, and managers can better plan their strategies and tactics. Moreover, the spatial analysis capabilities of the GIS greatly aid managers in modifying WFSA objectives as the fire perimeter changes.

The GIS application also taps useful nonspatial data. For example, it gives information associated with private homes (fig. 2), such as contact names, phone numbers, street addresses, digital photos, and defensibility information. Such information can be vital for contacting residents in the event of an emergency, such as an approaching wildland fire.

Mapping Flexibility

For the Ninemile Ranger District, we created a map template to give all WFSA maps a common appearance. The district asked us to predefine and design five maps:

- A vicinity map (fig. 3),
- A low-level flight hazard map,
- A map of sensitive natural resources (fig. 4),
- A WUI map (fig. 2), and
- An incident action map (figure 5).

With the exception of the vicinity map, the maps are limited to the district's jurisdictional boundaries, including non-Federal inholdings. By clipping data to these boundaries, we created a data catalog specific to the district, eliminating the large data files that commonly cover an entire national forest.

Two of the five maps—the vicinity and flight hazard maps—are static. They do not require regular updating or tailoring. The most common addition to these maps is fire perimeter data.

The other three maps are dynamic. They can be tailored to different purposes. For example, they might support a generalized briefing, a detailed incident action plan, or postfire rehabilitation; or they

Line officers can use the GIS application for spatial analysis to support decisionmaking.

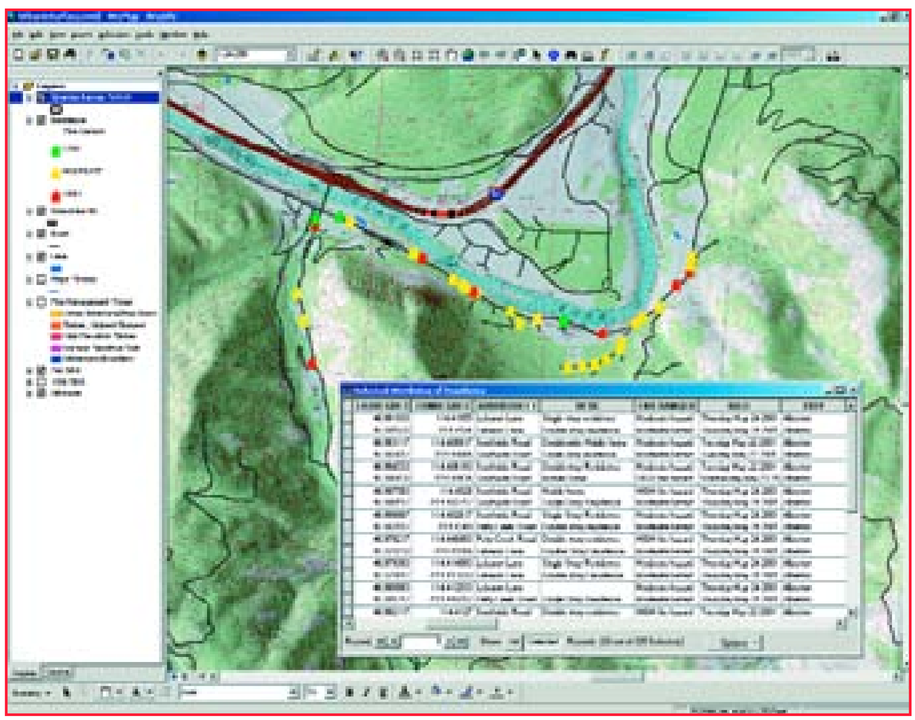

Figure 2—*Firewise data collected by the Frenchtown Rural Fire Department are spatially represented within the GIS application.*

The user can generate virtually any kind of map needed by simply turning on and off data layers.

might show fire progression, endangered wildlife habitat, or threatened residences and their defensibility. The district can generate virtually any kind of map needed by simply turning on and off data layers.

The Ninemile Ranger District also wanted to increase its data-sharing capabilities. We prepared the data and map templates so that they can be burned to just two CD's totaling about 800 megabytes. Fire management personnel from the district can simply pass the CDs along with the rest of a WFSA to incoming IMTs. Having the data readily at hand saves time for the IMT, letting it quickly get maps into the hands of firefighters.

Spatial Analysis

The GIS application also helps with spatial analysis. For example, it can show which houses are closest to the fire and where the access routes are located (fig. 6). In a matter of minutes, fire managers can find nearby water sources, see any water quality or other restrictions on their use, and decide how best to reach them. Line officers can use the GIS application for spatial analysis to support the decision-making process associated with the WFSA.

Figure 3—*Vicinity map for the Ninemile Ranger District (dark green) on the Lolo National Forest in Montana.*

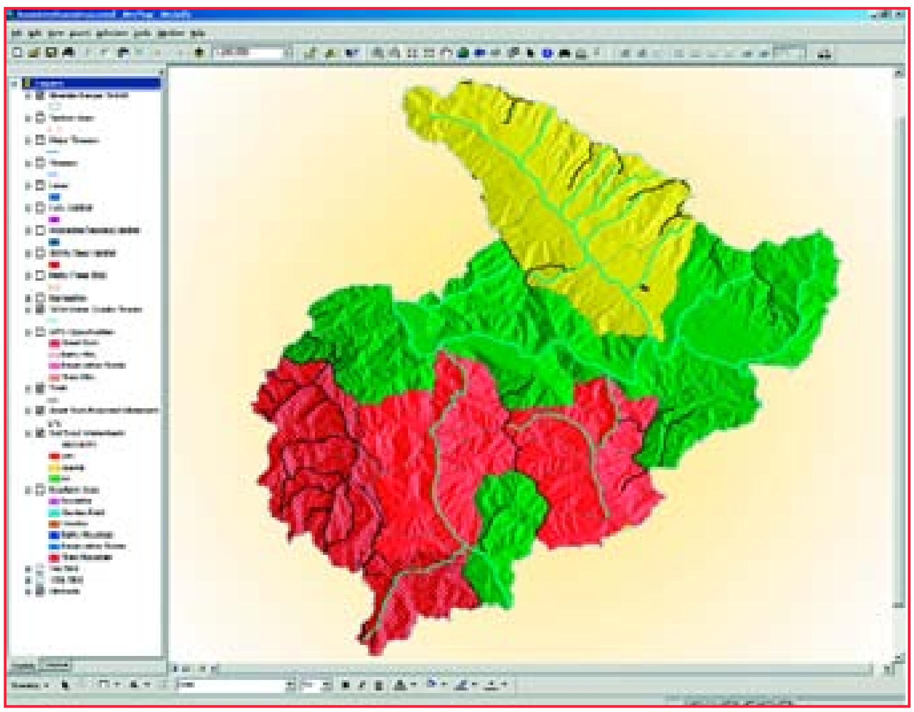

Figure 4—*Managers can view how sensitive resources such as bull trout watersheds, 303d water quality streams, proposed wilderness areas, and hiking trails spatially relate to future wildland fires.*

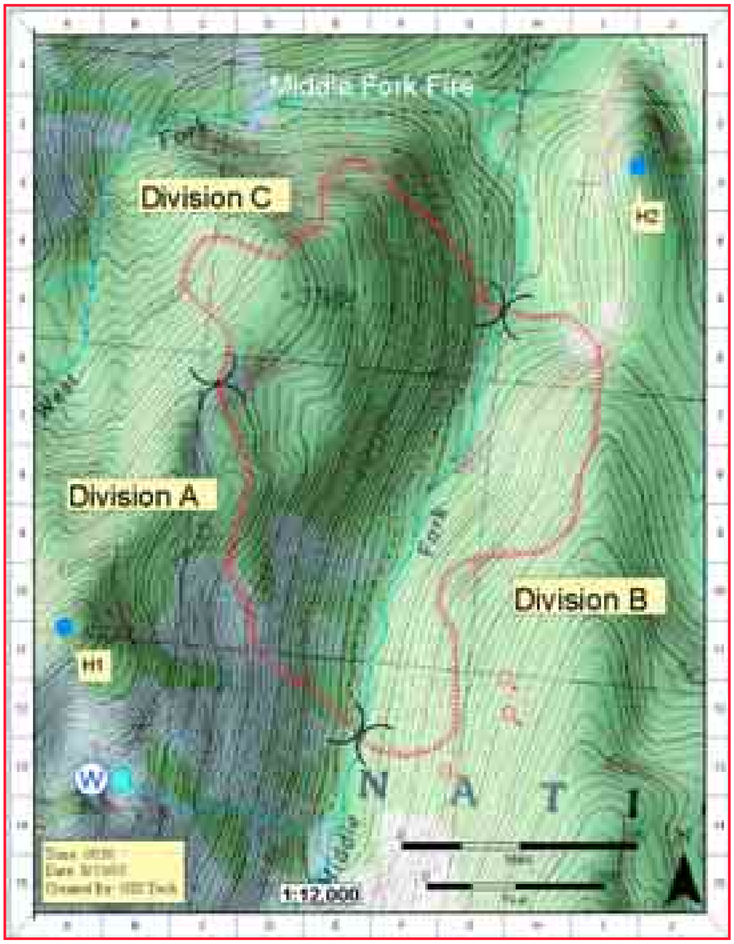

Figure 5—*Map of a hypothetical fire perimeter on the Ninemile Ranger District of the sort that the district or an incident management team might use for an incident action plan.*

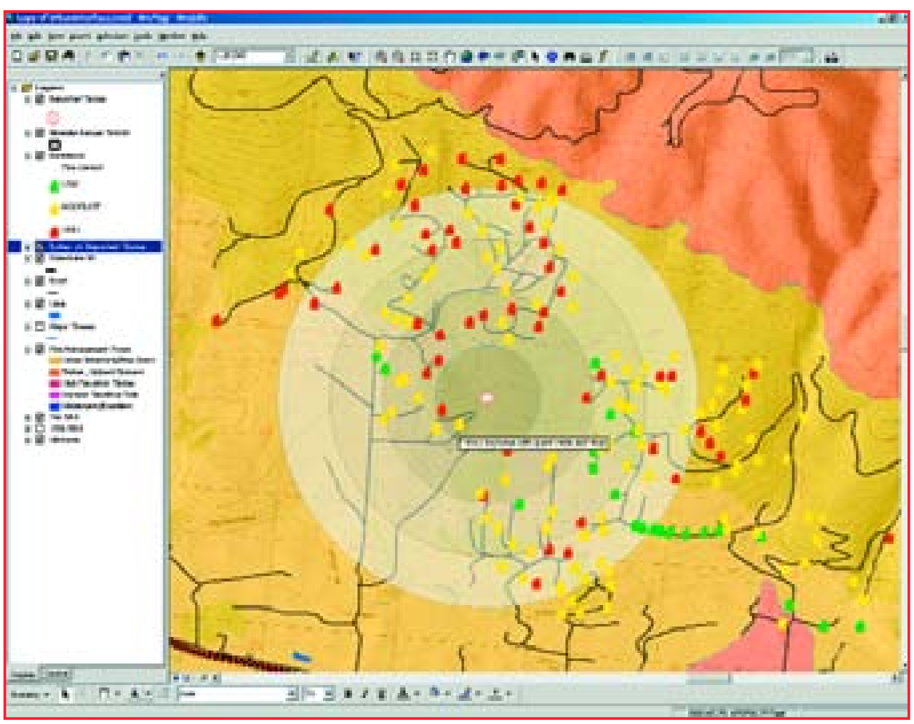

Figure 6—*Quarter-mile (400-m) buffer rings surrounding a hypothetical ignition in the wildland/urban interface. The GIS application's spatial analysis capabilities can help fire managers and law enforcement officers anticipate evacuation plans and egress routes.*

However, the usefulness of the GIS application goes beyond situations associated with a WFSA. The Ninemile Ranger District uses the application for any situation during fire season and even for offseason planning work. The GIS application can help managers improve planning and situational awareness during a mid-August lightning bust and an overwinter prescribed burn alike.

For more information, contact Matthew Galyardt, National Center for Landscape Fire Analysis, University of Montana, Missoula, MT 59801, 406-243-2000 (tel.), 406-243-2011 (fax), galyardt@ntsg.umt.edu (e-mail).

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The Pocket PC Can Increase Your Productivity

Ed Martin

A relatively new technology exists that can help local, State, and Federal wildland fire and aviation management programs reduce paperwork and improve productivity. It's called the Pocket PC. Several makes and models are commercially available.

> The Pocket PC comes with the same standard built-in applications that we use on our desktop computers and interfaces nicely with them.

Growing Workload

The Air Operations Section in the Montana Department of Natural Resources and Conservation operates a fleet of five helicopters and three single-engine aircraft obtained mainly through the Federal Excess Personal Property program. We have a small staff, a growing workload, and little hope of hiring additional personnel.

To find ways to reduce our workload, we reviewed our entire aviation management program, from the simplest tasks all the way up to our management style. We found that aircraft maintenance involved an enormous volume of repetitive paperwork. Whether moving around the hangar or traveling across the State, we are rarely at our computers, so we usually make paper notations and later type them into a computer.

One of our most time-consuming tasks is managing our inventory of aircraft parts. The duplicated effort of typing data into the computer from paper notations was cumbersome and error prone, as was our existing computer application. We wasted a great deal of time correcting errors. By updating or replacing our forms and procedures as well as our antiquated computer system, we could improve productivity.

Ed Martin is the aircraft maintenance supervisor for the Montana Department of Natural Resources and Conservation, Fire and Aviation Management, Aviation Section, Helena, MT.

Low-Cost Solution

We looked for a low-cost solution that we could develop and implement inhouse. We chose a Personal Data Assistant, or Pocket PC, for its portability and versatility. The Pocket PC comes with the same standard built-in applications that we use on our desktop computers, and the interface works nicely. Other applications are also available (see the sidebar).

We chose a model with built-in wireless capabilities, allowing us to print to a printer without cables, to access a network, and to utilize specialty applications. The system has fewer printing features than does a desktop application, but it still works quite well.

Key to making the system work is data synchronization between the Pocket PC and the desktop computer. When you connect your Pocket PC to your desktop computer, a program automatically checks for

The Pocket PC Has Many Applications

In addition to interfacing with the standard programs on a desktop computer, the Pocket PC supports hundreds of more specialized programs, ranging from flight-planning calculators to wildland fire behavior calculations and hydraulics. For example, the Pocket PC lets us:

- Create aircraft weight and balance forms for our helicopters.
- Access the Internet by cell phone—slow in our area, but still useful.
- Order parts or check bulletins from the Federal Aviation Administration.
- Create a purchase order and possibly fax it by cell phone (we're still working on that).
- Connect to a global positioning system unit and use it as a moving map.
- Use coordinates from an air crew to navigate directly to an aircraft in the field.

changes made to either system and then updates both. Multiple Pocket PCs can thereby be synchronized to the same database.

We selected a database program that lets us implement a barcode tracking system for our parts inventory, from requisition to consumption. Upon receipt of a part, we can print the barcode tag directly from the Pocket PC to a printer; no desktop or network connection is required. In short, the whole process of requisitioning, ordering, tracking, and using the parts is handled right on the Pocket PC. The system works so well that we use the desktop computer only for data synchronization and backup.

Future Improvements

Our next project is to implement a work order system integrated with the new parts system. The system will allow us to perform all recordkeeping tasks directly on the Pocket PC. As we scan the part, the barcode system will automatically log parts onto the work order,

> The Pocket PC has already reduced our workload and improved productivity, but we believe that we have only scratched the surface of what is possible.

adjust the inventory, prompt to reorder, and update the timelife-tracking application. Right there in our hand we will have everything we need to initiate, complete, and print a work order in the field.

We also expect other improvements. Already, the Pocket PC can download PDF versions of manuals, such as the Army Maintenance Test Flight Manual. Although the charts are unreadable, the instructions are fully legible. The PDF manufacturer predicts that the manuals will soon be printable from the Pocket PC. When that happens, we will no longer need to carry large sets of manuals with us.

The Pocket PC has already reduced our workload and improved productivity, but we believe that we have only scratched the surface of what is possible with this kind of technology. For more information, please contact the author at Montana Department of Natural Resources and Conservation, Fire and Aviation Management, Aviation Section, 2800 Airport Road, Helena, MT 59620-1601, 406-444-0789 (tel.), 406-444-0790 (fax), emartin@state.mt.us (e-mail). ■

Websites on Fire*

Fire Risk Research

On average every year, wildfires burn 17,300 acres (7,000 ha) in New Zealand. Reducing the number and consequences of wildfires and promoting the effective use of wildland fire as a management tool are the goals of New Zealand's Forest and Rural Fire Research program. Visitors to the Website can enjoy current and archived project news and fire-related information from around the world. Links are provided to the latest research publications, relevant news, and general information. Current projects include fire behavior modeling, tussock fire ecology, and technology transfer. Online shopping with free delivery provides users with the opportunity to purchase publications, images, videos, and other products. Also included are many links to various fire research publications worldwide.

Found at **<http://www.forestresearch.co.nz/topic.asp?topic=Fire+Risk+Research&title=Fire+Risk+Research>**

* Occasionally, *Fire Management Today* briefly describes Websites brought to our attention by the wildland fire community. Readers should not construe the description of these sites as in any way exhaustive or as an official endorsement by the USDA Forest Service. To have a Website described, contact the managing editor, Hutch Brown, at USDA Forest Service, Office of the Chief, Yates Building, 4th Floor Northwest, 201 14th Street, SW, Washington, DC 20024, 202-205-0878 (tel.), 202-205-1765 (fax), hutchbrown@fs.fed.us (e-mail).

A New Tool for Mopup and Other Fire Management Tasks

Bill Gray

Ever dream of a mopup tool that could blast both above- and below-ground fires, without the need for high pressure? Well, dream no more. The mopup nozzle* (fig. 1) can spray either water or wet air-aspirated class A fire foam on above-ground fires and inject either substance into the ground to extinguish fires burning up to 3 feet (1 m) deep—all without requiring the use of high pressure.

Ever dream of a single mopup tool that could blast both above- and below-ground fires? Well, dream no more.

Injection Device

This is the first firefighting tool that injects water into underground areas of burning material. The old method of extinguishing ground fires requires two firefighters: a hose operator to spray the ground and a second firefighter to remove the top 2 to 3 inches (5–8 cm) of smoldering material with a shovel. The two-step process is repeated until a depth of about 2 feet (60 cm) is reached.

With a mopup nozzle, one firefighter can do the job alone. Connected to a hose, the mopup nozzle can inject water deep into hard clay soil around tree roots (fig. 1), flooding and extinguishing any burning material. If the tree roots must be exposed, the nozzle's underground washing action liquifies the clay, turning it into mud that can easily be removed with a shovel. The same washing action can inject class A foam solution and flood underground areas of burning and smoldering leaves and other duff.

Mopup Flexibility

The mopup nozzle comes in seven different sizes, allowing firefighters to tailor flow rate, nozzle pressure, and throw distance to a given situation. Table 1 shows flow rates at four different nozzle pressures. Table 2 shows that horizontal throw distances are good, considering the relatively low pressures used. Vertical throw distances, by eyeball estimate, are about two-thirds of horizontal throw distances.

Figure 1—*The new mopup nozzle. The nozzle connected to the hose has washed its way 15 inches (38 cm) deep into the hard clay soil around the tree roots. The clay has turned to mud, which can easily be removed with a shovel. The nozzle can also inject class A foam solution into underground areas. Photographer: Bill Gray, San Antonio, TX, 2004.*

The key advantage of using low-pressure nozzles for mopup is their ability to connect to the end of very long hoselines that are, in turn, connected to low-pressure pumps that draft water from small water tanks containing from 50 to 200 gallons (189–757 L). Long hoselines have advantages for mopup work. They can be followed from truck to mopup crew, allowing the crew to follow the hoseline back to the truck. This is particularly helpful at night or when smoke has reduced ground-level visibility. Long hoses also offer weight and cost advantages. The 5/8-inch (16-mm) and 3/4-inch (19-mm) firehoses are particularly lightweight and inexpensive.

Long hoselines do allow pressure loss, which varies with each manufacturer. The pressure losses shown in table 3 are average values that can be used with reasonable accuracy to estimate pressure losses in long hoselines. The values in table 1 and 3 suggest the usefulness of the mopup nozzle for operations with long hoselines.

Bill Gray is a retired civil engineer and the owner of Bill Gray, San Antonio, TX.

* 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*.

For example, suppose you have a pickup truck with a 100-gallon (379-L) water tank, a pumping capacity of 100 pounds per square inch (psi) (7 kg/cm^2), 1,000 feet (305 m) of 3/4-inch (19-mm) hose, and another 1,000 feet (305 m) of 5/8-inch (16-mm) hose. Also suppose that you want to limit the flow rate to 2 gallons (7.6 L) per minute. At that rate, the friction loss in the 3/4-inch (19-mm) hose is 7 psi (0.5 kg/cm^2) and the loss in the 5/8-inch (16-mm) hose is 14 psi (1 kg/cm^2), for a combined friction loss of 21 psi (1.5 kg/cm^2). With a 100-psi (7-kg/cm2) pump, you still have a nozzle pressure of 79 psi (5.6 kg/cm^2). The size 9 nozzle would probably meet your requirements.

More Than Mopup

In addition to mopup work, the nozzles are useful for controlling pasture burning and other small prescribed fires. Foresters, ranchers, farmers, and park rangers who drive pickup trucks with a small water tank capacity will find the nozzles particularly useful. When foam concentrate is added to the tank water, the air-aspirated foam produced is 10 times more effective than water alone.

All mopup nozzles include a brass nozzle tip that produces a solid stream of wet air-aspirated fire foam, a 3-foot (0.9-m) nozzle rod, a nozzle handle, a 90-degree ball valve, a high-pressure stainless steel swivel, and an upstream connection with a 3/4-inch (19-mm) female firehose thread. The materials are brass, stainless steel, galvanized steel, and galvanized malleable iron.

These nonplastic materials provide years of useful service and make the nozzles indestructible. The overall length is 46 inches (117 cm). The nozzles weigh only 3.2 pounds (1.5 kg), making them easy to use for long periods of time. The nozzles are designed for a maximum working pressure of 300 psi (21 kg/cm^2). For more information, contact Bill Gray, Oakdell Way Apartments, 6020 Danny Kaye #2302, San Antonio, TX 78240, 210-614-4020 (tel.), 210-610-4080 (fax), billgray1@SBCglobal.net (e-mail). ■

Table 1—*Flow rates (gallons per minute) for seven nozzles at four nozzle pressures.*

Nozzle size	*Nozzle pressure (pounds per square inch)*			
	40	*100*	*200*	*300*
6	0.6	1.0	1.3	1.6
7	0.8	1.3	1.8	2.2
8	1.0	1.6	2.2	2.7
9	1.5	2.4	3.4	4.1
10	2.0	3.2	4.5	5.5
11	2.5	4.0	5.6	6.9
12	3.0	4.7	6.7	8.2

Table 2—*Horizontal throw distances (feet) for seven nozzles at four nozzle pressures.**

Nozzle size	*Nozzle pressure (pounds per square inch)*			
	40	*100*	*200*	*300*
6	27	34	39	41
7	30	38	43	45
8	31	40	46	48
9	33	42	48	51
10	34	44	50	53
11	36	46	53	56
12	38	49	56	59

* Horizontal throw distances are obtained when the solid-stream nozzle is pointed upward at an angle of 30 degrees above horizontal.

Table 3—*Pressure loss (pounds per square inch) per hundred feet of hose at varying flow rates for three hose sizes.*

Flow rate (gal/min)	*Hose diameter*		
	5/8 in	*3/4 in*	*1 in*
1	0.4	0.2	0.1
2	1.4	0.7	0.1
3	3.2	1.5	0.3
4	5.8	2.5	0.6
5	9.0	3.8	0.9
6	13.0	5.3	1.3
7	17.6	7.1	1.7
8	23.0	9.2	2.2

Developing the Fire Service Workforce Through Mentoring

Joette Borzik

The fire management workforce appears to be shrinking. Many experienced employees will soon retire, and the pool of qualified replacements is small. Job-related demands on employees, family responsibilities, and low overtime pay have decreased the willingness of many employees to take part in incident response (Hyde 1999). Additionally, the length of time required to recruit and train an employee for an upper management position in incident response—17 to 22 years (GAO 1999)—makes it difficult to ensure that the next generation of fire leaders will be ready when needed.

In 1999, the USDI Fish and Wildlife Service developed a Fire Management Mentoring Program to help train and develop potential fire incident responders and future fire leaders. The program taps knowledge and experience within the agency in a personal, interactive manner.

Fire Management Mentoring Program

Enrollment in the Fire Management Mentoring Program is a 2-year voluntary commitment. The relationship can end whenever one of the partners believes it is no longer productive.

The program uses a partnership agreement that, while not binding, creates some formal accountability. Additionally, an individual development plan is prepared to document the steps needed to accomplish identified goals and to track accomplishments. The mentoring partners set the scope and content of their relationship.

> A mentor can foster insight, identify experience needed, and expand career horizons.

The program identifies potential mentors and mentees through an application process. The program's steering committee, six representatives from different levels in the fire workforce and a mentoring expert, compares applications to selection criteria and makes prospective matches.

After a draft list of selections is made, regional fire managers comment on the prospective pairing. A final list is approved, and individuals are notified of the selections.

Selected participants are asked to take a personality-type indicator test. The personality-type testing is a communication tool—there is no right or wrong type, and there are no better or worse combinations of types in work or relationships (Myers 1998). The results of the test are shared with the participants at the orientation and training session and are available for participants to share with their assigned mentor or mentee.

An orientation-and-training session is mandatory for all program participants. The 3-day session is often the first meeting for a mentor and mentee. Team-building exercises and icebreakers help foster an environment of learning and comfort.

Evaluating Results

The U.S. Fish and Wildlife Service set up a process for evaluating the Fire Management Mentoring Program. The evaluation is based on an online form that program participants fill out biannually, a cost-effective method of data collection. Steering committee members also make informal telephone calls to participants to assess program effectiveness, but this method can be tedious, costly, and not as effective.

Many factors must be considered when drawing conclusions about the success or failure of a mentoring program. The success of any mentoring program is a combination of desired outcomes. The values measured, the assessment instruments, and the approach all influence the findings (Murray and Owen 1991).

The first online program evaluation for the Fire Management Mentoring Program was in 2001, with a followup in 2002. Results

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indicate that nearly 90 percent of the individuals who responded had an excellent or good mentoring relationship.

New Workforce Generation

The value of the Fire Management Mentoring Program is the extent to which it contributes to the overall success of the U.S. Fish and Wildlife Service's wildland fire organization. The mentoring program is helping to address some of the issues that the agency faces as new generations move into the fire management workforce and more experienced employees retire. Although the mentoring program is not a career placement program, it is likely to enhance an employee's professional development.

The desire for mentoring comes from all levels of the fire workforce. Strategic planning is based on the recognition that we must make the commitment and invest in our employees if a wildland fire organization is to succeed.

The desire for mentoring comes from all levels of the fire management workforce, and employees at all levels can participate.

For additional information about the value and challenges of a mentoring relationship, contact Joette Borzik, National Conservation Training Center, 698 Conservation Way, Shepherdstown, WV 25443, 304-876-7749 (tel.), 304-876-7751 (fax), joette_borzik@fws.gov (e-mail).

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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:

USDA Forest Service
Attn: April J. Baily, F&AM Staff
Mail Stop 1107
1400 Independence Avenue, SW
Washington, DC 20250-1107
tel. 202-205-0891, fax 202-205-1272
e-mail: abaily@fs.fed.us

USDA Forest Service
Attn: Hutch Brown, Office of Communication
Mail Stop 1111
1400 Independence Avenue, SW
Washington, DC 20250-1111
tel. 202-205-0878, fax 202-205-0885
e-mail: hutchbrown@fs.fed.us

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Attn: Hutch Brown, 2CEN Yates
201 14th Street, SW
Washington, DC 20024

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*, as required by the U.S. Department of Agriculture. 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.

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Electronic Files. See special mailing instructions above. 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, 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
- Cooperation
- Ecosystem management
- Equipment/Technology
- Fire behavior
- Fire ecology
- Fire effects
- Fire history
- Fire science
- Fire use (including prescribed fire)
- Fuels management
- Firefighting experiences
- Incident management
- Information management (including systems)
- Personnel
- Planning (including budgeting)
- Preparedness
- Prevention/Education
- Safety
- Suppression
- Training
- Weather
- Wildland–urban interface

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

Photo Contest Announcement

Fire Management Today (FMT) invites you to submit your best fire-related photos to be judged in our annual competition. Judging begins after the first Friday in March of each year.

Awards

All contestants will receive a CD with the images remaining after technical review. The CD will identify the winners by category. Winning photos will appear in a future issue of *FMT.* In addition, winners in each category will receive:

- 1st place—Camera equipment worth $300 and a 16- by 20-inch framed copy of your photo.
- 2nd place—An 11- by 14-inch framed copy of your photo.
- 3rd place—An 8- by 10-inch framed copy of your photo.

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 taken at any time. No photos judged in previous *FMT* contests may be entered.
- You must have the right to grant the Forest Service unlimited use of the image, and you must agree that the image will become public domain. Moreover, the image must not have been previously published.
- We prefer original slides or negatives; however, we will accept duplicate slides or high-quality prints (for example, those with good focus, contrast level, and depth of field). *Note:* We will not return your slides, negatives, or prints.
- We will also accept digital images if the image was shot at the highest resolution using a camera with at least 2.5 megapixels or if the image was scanned at 300 lines per inch or equivalent with a minimum output size of 5 x 7. Digital image files should be TIFFs or highest quality JPGs.
- You must indicate only one competition category per image. To ensure fair evaluation, we reserve the right to change the competition category for your image.
- You must provide a detailed caption for each image. For example: *A Sikorsky S–64 Skycrane delivers retardant on the 1996 Clark Peak Fire, Coronado National Forest, AZ. Photo: name, professional affiliation, town, state, year image captured.*
- A panel of experienced judges determines the winners. Its decision is final.
- We will eliminate photos from competition if they are obtained by illegal or unauthorized access to restricted areas; 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).
- You must complete and sign the release statement granting the USDA Forest Service rights to use your image(s). Mail your completed release with your entry or fax it (970-295-5815) at the same time you e-mail digital images.

Mail entries to:

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Fire Management Today Photo Contest
Madelyn Dillon
2150 Centre Avenue
Building A, Suite 361
Fort Collins, CO 80526
or
e-mail images and captions to:
mdillon@fs.fed.us and
fax signed release form to
970-295-5815 (attn: Madelyn Dillon)

Postmark Deadline

First Friday in March

Sample Photo Release Statement

Enclosed is/are __________ (number) image(s) for publication by the USDA Forest Service. For each image 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 image(s) and am aware that, if used, it/they will be in the public domain and appear on the World Wide Web.

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