

Fire Management *today*

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FIRE IMPACTS ON WATER QUALITY
SMOKE SCIENCE PLAN
ORDERING ON A FIRE
AND MORE ...



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On the Cover:



Firefighters on the 2017 Thomas Fire on the Los Padres National Forest near Ventura, CA. The Thomas Fire was the largest wildfire in California history. Photo: Los Padres National Forest, Forest Service.

The USDA Forest Service's Fire and Aviation Management Staff has adopted a logo reflecting three central principles of wildland fire management:

- **Innovation:** We will respect and value thinking minds, voices, and thoughts of those that challenge the status quo while focusing on the greater good.
- **Execution:** We will do what we say we will do. Achieving program objectives, improving diversity, and accomplishing targets are essential to our credibility.
- **Discipline:** What we do, we will do well. Fiscal, managerial, and operational discipline are at the core of our ability to fulfill our mission.



**Firefighter and public safety
is our first priority.**

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By Shawna A. Legarza, Psy.D.
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COPING WITH CHANGE *

Over the past decade, we have wanted and seen both organizational and systematic changes in the wildland fire community. Change is constant and transformation takes time, yet even the most experienced fire managers may feel overwhelmed, confused, and uncertain—both within themselves and with regard to the decisions of fire management agencies. Although we continue to work diligently to keep up with changes and obtain good results, we often feel our lives spinning out of control; and, thus, the cycle continues. It seems we have less and less free time to communicate effectively with our families and take care of our inner selves. Where have our fundamental priorities gone?

As we balance our fate and ideology as wildland firefighters, we need to allow time for personal reflection and remember our fundamental priorities. I believe we need to be the leaders of organizational and systematic change; we need to continue to develop the wildland firefighting culture within our doctrine in order to take better care of ourselves, our families, and our employees.

The Ultimate Challenge

While enduring political, global, and ecological challenges and the structured flows of technology, we often find not only ourselves but

also our employees overwhelmed by the stress and implications of change. Employees who become overwhelmed have difficulty managing stress and, thus, lessen the connections with their coworkers and families.

Is it plausible to relax and communicate in moments of uncertainty and confusion?

So we must ask: How do we become receptive to the effects that change has upon ourselves as well as our coworkers, subordinates, and families? Is it plausible to relax and communicate in moments of uncertainty and confusion?

Historically, it is clear that change can raise doubts about personal beliefs and the existing order. Statistical comparisons show that the inability to deal with change closely correlates to a negative subliminal behavior exhibited briefly during times of undue stress. With that said, understanding the process and the effects of change is a challenge for any leader. During your career, the connection between challenges in your personal life and organizational changes in your professional career can evolve into a complex web of confusion

that can become highly stressful and profoundly unhealthy. You can become addicted to the risk of change and the speed of the emergency without truly knowing the long-term physiological and psychological effects.

In the competitive subculture of firefighting, we often forget to take care of ourselves and others because we, too, have become obsessed with trying to understand and keep up with all the changes that make us uneasy—and sometimes outright unmanageable. During this negative reinforcing loop, communication and personal reflection become even more important. Personal reflection will allow you to evaluate yourself.

In time, you might find a relationship between your inner self and the observed chaos in the outside world. By understanding this inner reflection, it can become easier to embrace change and differentiate between the fundamental variables defining your personal and professional life styles. Take time to slow down.

Individual Leadership Traits

I believe we all have unique leadership traits in our internal toolbox. The traits in your toolbox will allow you to manage the transformation of change on an

* The article is adapted from the summer 2009 issue of *Fire Management Today* (volume 69(3), pp. 13–14).

You may become addicted to the risk of change and the speed of the emergency, while not truly knowing the long-term physiological and psychological effects.

individual basis. Some people may add various skills to their toolbox and use them to their utmost, others just a little or not at all. It is your choice to accept and understand change, just as it is your choice to be a leader, a follower, or a leader of leaders.

Individuals have different leadership traits, supported by different types of incremental change; and with all levels of leadership come individual challenges and complexities. We must continue to lead within during times of uncertainty, to communicate honestly with ourselves and with others, and to find peace within and on the outside. Knowing how to effectively lead yourself during times of change is difficult for even the most gifted individuals.

The principal difficulty in evaluating your own success

is contemplating your own experiences with trials and tribulations. During some leadership opportunities in the past, you might have used trial and error to learn lessons for next time. If you make substantial changes within yourself following your mistakes, you can learn to communicate more effectively about your feelings. You can express your feelings about change to yourself, your coworkers, and your family, thereby reducing the stress-related effects of sensemaking—the ability to see things how they are and to be open to other frameworks during times of change, and the ability to find your passion and connect your passion with leadership. To understand and communicate effectively within yourself is self-leadership; to understand yourself is to understand life. All the while, understanding the success of your life is to understand the variables of incremental change over time.

Embracing Change

As leaders in the wildland fire community, we need to continue to embrace change while educating our employees about taking effective care of themselves (self-leadership) and their employees (leadership). I believe the essence of leadership is leading your passion within through the challenges in life. To honestly believe what is true to you is the most reflective self-leadership discipline.

Dig deep to find your answers. Remember, the most consistent event in your life will be the challenge of coping with change. With the global challenges we are now facing, we need to continuously embrace the transformation of change by being adaptive and creative in both our personal and our professional lives. We will all learn from those who remember the fundamental priorities and embrace the transformation of change within themselves and their organizations. ■

LEARNING TO LIVE WITH FIRE

Thomas L. Tidwell



Each year, the wildfire season in the Western United States brings headlines and news reports, mostly factual but sometimes misleading. This year is no different, a case in point being “Let Forest Fires Burn? What the Black-Backed Woodpecker Knows” (Gillis 2017).

Stories like this feed widespread misperceptions in the United States: that most wildfires burn on the national forests and grasslands; that the Forest Service does most of the firefighting, suppressing every fire it can; and that the Forest Service is responsible for most of the effects, including homes lost and wildlife habitat destroyed.

Tom Tidwell was Chief of the Forest Service from 2009 to 2017, Washington Office, Washington, DC.

None of this is true. The issue is national in scope. As Americans, we are all in this together. We need to learn to live with fire.

On average each year, only 1 in 10 wildfires breaks out on the National Forest System (NICC 2017), even though the national forests and grasslands protect almost 20 percent of the Nation’s forest lands. Most wildfires, about 7 in 10, happen on State and private lands.

Most wildfires, about 7 in 10, happen on State and private lands.

The area burned on Federal and Tribal lands is larger—about 59 percent of the total area burned—but that only stands to reason. Many wildfires on Federal lands are remote and hard to reach. Moreover, the Federal and Tribal agencies manage many wildfires in remote areas for resource benefits, including habitat for fire-dependent species such as the black-backed woodpecker. Recognizing the natural role of wildland fire, land managers want certain areas to burn.

Still, the area burned on the national forests and grasslands averages only about 53 percent of the area burned on State and

private lands each year—and in some years far less. It was only about 18 percent in 2010, for example, and only about 14 percent in 2004.

So why does the myth persist that most fires happen on the national forests and grasslands? Perhaps because Smokey Bear is a Forest Service symbol—and perhaps because the media often feature Forest Service firefighters and aircraft during fire season. Such imagery might create the mistaken impression that wildfires typically happen on Federal lands.

In reality, the vast majority of wildfires break out on State and private land, and the first responders are therefore typically local firefighters. Rural volunteer fire departments deserve tremendous recognition—much more than they get. So do the State and Federal partnership programs that supply them with the equipment they need to be as effective as they are in defending homes and communities from wildfire.

In fact, the entire wildland fire community works together to manage wildland fire through the National Cohesive Wildland Fire Management Strategy, completed in 2014. Under the strategy, a major goal is to return the natural role of fire to fire-adapted landscapes in order to restore healthy, resilient forest and grassland ecosystems. Where

Federal land managers can safely use fire, they do—for example, in many national parks and wilderness areas.

Unfortunately, letting natural fires burn, even under carefully controlled conditions, is often too dangerous. For the past 50 years or more, Americans in search of natural amenities (clean air, scenic beauty, and the like) have been

Where Federal land managers can safely use fire, they do—for example, in many national parks and wilderness areas.

expanding homes and communities into the wildland–urban interface (WUI). The WUI now has about 44 million homes (Martinuzzi and others 2015), about one-third of

all housing units in the United States, and many WUI areas are seasonally prone to wildland fire. Not surprisingly, the expansion of the WUI in the last 50 years closely correlates with the expanding number of homes destroyed by wildfire (ICC 2008; NICC 2017).

The wildland fire community has an obligation to protect lives, homes, and communities from the ravages of wildfire. Accordingly, local, State, Tribal, and Federal land managers work together to suppress wildfires before they can threaten the WUI.

However, scientists have found that the best protection from wildfires is for homeowners to take steps to protect their own properties (Calkin and others 2014; Cohen 2000, 2008, 2010; Schoennagel and others 2016), such as using fireproof building materials and removing fire hazards near their homes. Accordingly, another major goal of the National Cohesive Strategy is to help build fire-adapted human communities. The Forest Service is working with partners through programs like Firewise to help homeowners take responsibility for protecting their own homes and communities from wildfire.

The bottom line is this: Americans are all in this together. Most American landscapes are adapted to fire, having evolved over millions of years with wildland fire; sooner or later, they will burn—and they should. Therefore,



Black-backed woodpecker on a conifer. Black-backed woodpeckers require burned forests with standing dead trees for feeding habitat. Photo: U.S. Fish and Wildlife Service.

Scientists have found that the best protection from wildfires is for homeowners to take steps to protect their own properties.

we need to learn to live with fire. The safer America's homes and communities in the WUI can become from wildfire, the more fire we can return to the land and the healthier our fire-adapted landscapes will become. ■

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WATER QUALITY IMPACTS OF WILDLAND FIRES *

Aregai Teclé and Daniel Neary

In the arid and semiarid Southwestern United States, the forest understory vegetation (mostly grasses, forbs, and shrubs) is dry and susceptible to wildland fires. Fire in the form of prescribed burning is often used to protect these areas from wildfire. However, wildland fire suppression has resulted in dense forest fuels in many watersheds. Such fuel buildups, along with frequently recurring drought and widespread insect infestations, have made forest systems susceptible to catastrophic fires that scorch many of the Nation's forests, rangelands, parklands, and private properties (Safford and others 2008; Lutz and others 2009; Stein and others 2013).

In 2013, lightning started a total of 9,230 wildfires in the United States, burning 3,057,566 acres. In the same year, 38,349 human-caused wildfires burned 1,261,980 acres. The total area burned by both types of fires in 2013 was 4,319,546 acres (NIFC 2014). From 2000 to 2011, such fires accounted for a total of \$13.7 billion in total economic losses in the United States, including \$7.9 billion in insured losses (Haldane 2013; IAWF 2013).

Aregai Teclé is a professor of hydrology in the School of Forestry at Northern Arizona University, Flagstaff, AZ; and Daniel Neary is a supervisory research soil scientist for the Forest Service, Rocky Mountain Research Station, Flagstaff, AZ.

Large fires have tremendous effects on the characteristics of water-producing watersheds and the quality of the water coming out of them.

In addition to causing economic losses, these burns have tremendous effects on the characteristics of water-producing watersheds and the quality of the water coming out of them, especially the quality of surface water. Surface water is the main source of water for most domestic, industrial, and commercial water supplies in the United States. Most surface water results from runoff from precipitation that falls as snow or rain on forested and rangeland watersheds.

This article discusses the effects of wildland fires on water quality and suggests ways of managing fire-prone forested water source areas to prevent their degradation from wildfires. The article uses information from three major fires in Arizona to demonstrate the effects of wildfires on water quality.

General Wildfire Effects

In recent years, the Western United States has seen dramatic increases in the number and intensity of wildfires, causing enormous damage to forests, rangelands, and other rural parts of Arizona and the Southwest. In 2013 alone, for example, five Federal agencies (the Bureau of Land Management, Bureau of Indian Affairs, U.S. Fish and Wildlife Service, National Park Service, and Forest Service) together spent \$1,740,934,000 to suppress wildfires nationwide (NIFC 2014). Such costs, though very large, do not include the monetary and material expenditures by other Federal, State, and local agencies and by private entities. State land departments as well as rural and urban community firefighters and land managers also spend substantial amounts to suppress wildfires at the State and local level.

In the last 15 years, three very large fires in Arizona cost the State greatly in terms of financial, environmental, and other valuable resources. From smallest to largest, they are the Cave Creek Complex Fire, the Rodeo–Chediski Fire, and the Wallow Fire. The Cave Creek Complex in 2005 burned 248,310 acres of public and private property in central Arizona, costing \$16,471,000 to suppress. The 2002 Rodeo–Chediski burned 468,638 acres and destroyed 491 structures

* The article appears in a 2015 issue of the *Journal of Pollution Effects and Control* 3: 140. DOI: 10.4172/2375-4397.1000140.

in the White Mountains, part of 7.2 million acres that burned nationwide that year. The Wallow Fire in 2011, the largest fire in Arizona history, burned 535,039 acres, destroyed 72 buildings, and injured 16 people, mainly on the Apache–Sitgreaves National Forest.

Such big fires have many damaging effects, some immediate and others delayed. The effects can be short and/or long term. The fires damage or destroy valuable resources such as timber, wildlife and wildlife habitat, understory vegetation, soil and soil chemicals, historical artifacts, and residential homes and other structures. The delayed effects include postfire environmental degradation such as loss of vegetation cover, which leaves the land exposed to impacts from rainfall, runoff, wind, and solar radiation. The result is soil hydrophobicity (DeBano and others 1998); flooding and soil erosion; and offsite downstream degradation of streams, lakes, and reservoirs (Morgan and Rickson 1995; Veenhuis 2002). A good understanding of these possibilities is important for developing appropriate forest and other landscape management to minimize the effects of wildland fires on water quality.

Fire Effects on Water Quality and Flooding

With respect to wildfires, the main concerns for hydrologists and water resource managers are fire effects on water quality and peak flow. The hydrologic influence of vegetation cover ranges from intercepting precipitation and reducing the amount of it reaching the ground to enhancing the rate of infiltration and thereby decreasing the amount and rate of surface flow.

Peak flows in burned areas in the Southwest commonly increase in magnitude from 500 to 9,600 percent during the summer months.

Factors Affecting Soils

Wildfire not only burns the vegetation cover but also destroys material on the forest floor, leaving the ground bare and sometimes with hydrophobic soils that slow infiltration and allow for more and faster surface water movement (DeBano 1981; Morgan and Erickson 1995; Zwolinski 2000; Neary and others 2008; Verma and Jayakumar 2012). Soil hydrophobicity disappears when soil temperatures in areas burned reach 572 °F (300 °C), but temperatures usually remain below this level, leading to hydrophobicity and subsequent increases in flowing water (Dlapa and others 2006). Apart from decreased infiltration and faster surface flow, the other major effect of wildland fires is on water quality.

Factors Affecting Waterflows

The factors that affect postfire water quality are complex and vary significantly from place to place, depending on effective precipitation; soil and vegetation cover characteristics; and the geologic, topographic, and fire severity conditions in the area (Robichaud and others 2000). The water quality concerns may be grouped into physical- and chemical-related problems. The physical water quality and associated problems that follow wildland fires include erosion and sediment yield, turbidity, flooding, and increased water temperature. The chemical water quality problems may include decreased oxygen levels as well as increased production of macronutrients, micronutrients, and basic and acidic ions. Some of the

additional chemicals come from the disturbed and bare ground; others are produced from burned plant material. Increases in streamflow also change with time following fire disturbance. In general, Hibbert (1971) and Hibbert and others (1982) found that first-year water yield from various burned watersheds in Arizona increased from as little as 12 percent to more than 1,400 percent of normal flow.

The effects of fires on storm peak flows are highly variable; the magnitude and variability of peak flows depend on factors such as topography, soil and vegetation cover characteristics, fire severity, and precipitation intensity. Peak flows in burned areas in the Southwest commonly increase in magnitude from 500 to 9,600 percent during the summer months (table 1), when intense monsoonal thunderstorms are the norm in the area. For example, the Salt River peak flow rose by 4,000 percent in the year following the Rodeo–Chediski and Wallow Fires. The increases can even be higher, as table 1 shows for a burned chaparral watershed, with peak flow increasing by as much as 45,000 percent. Such results indicate the need for careful management of southwestern watersheds to minimize the occurrence of severe wildfires that disrupt the normal quality and quantity of water flowing from forested areas.

Fire Impacts on Water Quality

The influence of wildfires on water quality can be substantial,

Table 1—Percent increase in peak flow following wildland fires, by location and vegetation type.

| Location | Vegetation type | Percent increase | References |
|----------------------------|-----------------|------------------|---|
| Eastern Oregon | Ponderosa pine | 45 | Anderson and others (1976) |
| Central Arizona | Mixed conifer | 500–1,500 | Rich (1962) |
| Central Arizona | Ponderosa pine | 9,600 | Anderson and others (1976) |
| Northern Arizona | Ponderosa pine | 200–5,000 | Leao (2005) |
| Cape Region, South Africa | Monterey pine | 290 | Scott (1993) |
| Southwestern United States | Chaparral | 200–45,000 | Sinclair and Hamilton (1955); Glendening and others (1961) |

depending on the severity of the wildfire, the nature of vegetation cover, and the physical and chemical characteristics of the burned area (DeBano and others 1998). Large and fast streamflows from burned areas can transport large amounts of debris, sediment, and chemicals that significantly affect the quality and use of water downstream. Also, wildfires interrupt or terminate nutrient uptake while increasing mineralization and mineral weathering.

Large and fast
streamflows from
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The Cave Creek Complex Fire of 2005 generated huge amounts of sediment load in streams. The most obvious environmental effects of the Wallow Fire of 2011 were in the form of bedload and suspended sediments in lakes, reservoirs, and streamflows, affecting fish and other wildlife. Area reservoirs such as Nelson, River, and Luna received large ash flows from severely burned areas,

resulting in significant fish kill. Lakes such as Helsey Lake and Ackre Lake were filled with sediment and suffered the most, with their entire fish populations killed. Also, a number of Apache trout and Gila trout streams suffered significant fish kill, including the South Fork of the Little Colorado River, Bear Wallow Creek, Hannagan Creek, KP Creek, Raspberry Creek, and upper Coleman Creek. However, the effects of ash flows and flooding were highly variable, with greater impacts on fish populations in some areas than in others (Meyer 2011).

The most destructive of the three big fires was the Rodeo–Chediski Fire of 2002, with major environmental effects in the form of physical and chemical problems that affected downstream water quality. Various water quality parameters measured at the Salt River entrance to Roosevelt Lake showed significant increases in the concentration of the major macronutrients calcium, magnesium, and potassium (fig. 1), as well as sulfate, phosphorus, and total nitrogen (fig. 2).

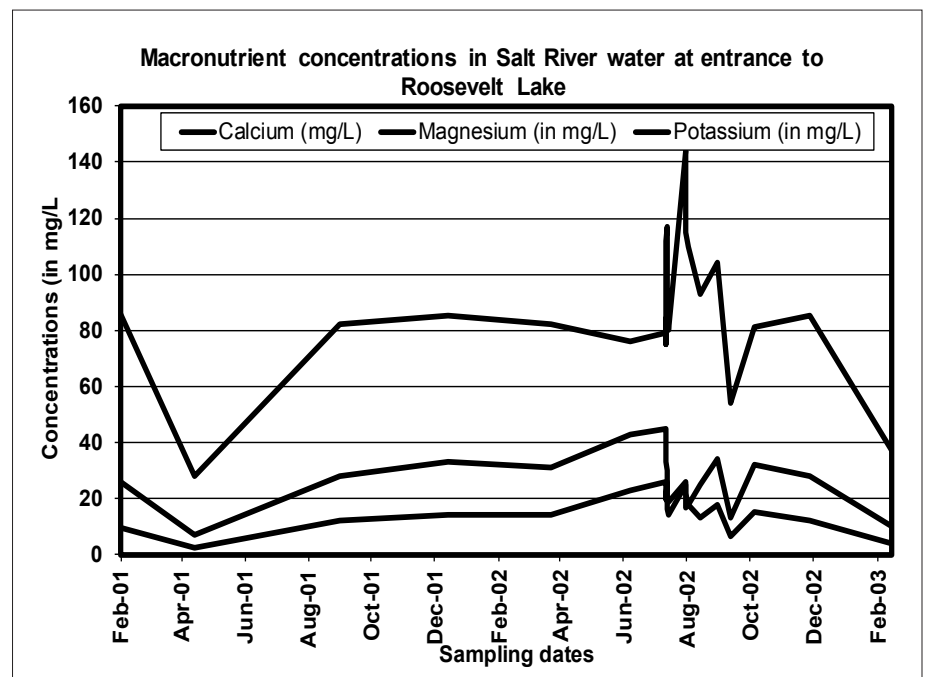


Figure 1—Macronutrient concentrations of calcium, magnesium, and potassium following the 2002 Rodeo–Chediski Fire in the Salt River at the entrance to Roosevelt Lake.

Despite increases in calcium and sulfur concentrations following the fire, the values remained less than half of the standard concentrations set by the U.S. Environmental Protection Agency (EPA). For magnesium, potassium, phosphorus, and total

nitrogen, however, the respective concentrations rose to twice, 5 times, 390 times, and 22 times their standard levels.

Figure 3 shows the concentrations of the hazardous chemicals arsenic, copper, iron, and lead

following Rodeo–Chediski in the Salt River where it enters Lake Roosevelt. The values were high and dangerous, rising to about 6,850 percent, 300 percent, 3,000 percent, and 460 percent of the respective EPA standards.

Figure 4 shows the physical factors

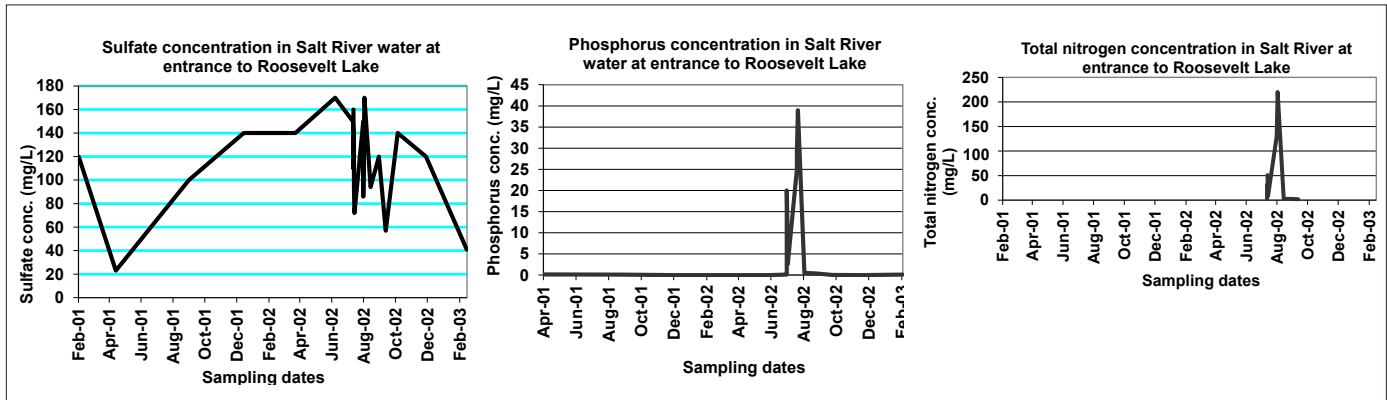


Figure 2—Macronutrient concentrations of sulfur, phosphorus, and nitrogen following the 2002 Rodeo–Chediski Fire in the Salt River at the entrance to Roosevelt Lake.

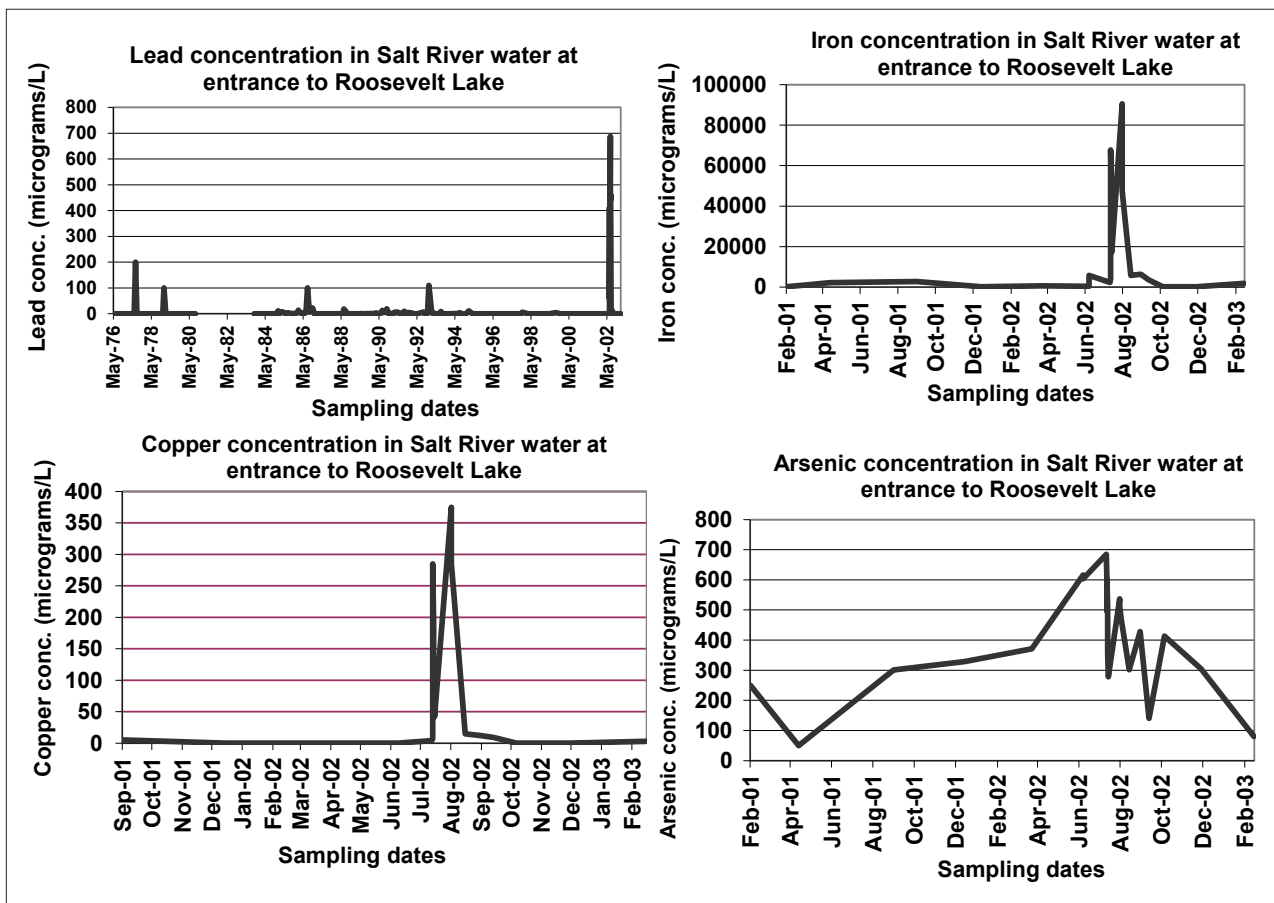


Figure 3—Hazardous mineral concentrations following the 2002 Rodeo–Chediski Fire in the Salt River at the entrance to Roosevelt Lake.

of flooding, turbidity, temperature, and specific conductivity in the Salt River following Rodeo–Chediski. The flood magnitude increased by 6,000 percent. Turbidity and specific conductivity measurements showed, respectively, about 1,500,000 percent and 422 percent of EPA standards, and the temperature rose to an uncomfortably high level of 84 °F (29 °C). Table 2 shows values associated with water quality parameters following the Rodeo–Chediski Fire, and it compares the values with standard values for drinking water established by the World Health Organization and the EPA.

Wildfire can have devastating effects on water quality and on water-dependent living things and the physical environment.

To summarize, wildfire can have devastating effects on water quality and on water-dependent living things and the physical environment, as shown by the chemical concentrations and physical water quality levels in table 2. Most of these values are very high and dangerous to aquatic life and other living things. For example, the turbidity value of 51,000 nephelometric turbidity units, if it persisted, would make the

reservoir water nontransparent and practically too dark for any limnetic and deeper dwelling aquatic organisms to function properly.

Likewise, the high temperature value as well as the highly elevated presence of salts and other chemicals would make the water unsuitable for many organisms, as shown following the Wallow Fire, when all the fish died in Lake Helsey and Lake Ackre. The very

Table 2—Rodeo–Chediski fire effects on water quality in the Salt River at the entrance to Roosevelt Lake, by parameters.

| Parameter | Postfire water quality level | Guidelines for drinking water quality | |
|-----------------------|------------------------------|---------------------------------------|--|
| | | World Health Organization | Environmental Protection Agency |
| Arsenic | 0.685 mg/L | 0.01 mg/L | 0.01 mg/L |
| Bicarbonate | 312 mg/L | n.i. | 380 mg/L |
| Calcium | 144 mg/L | n.i. | 380 mg/L |
| Chloride | 2,110 mg/L | (>250 mg/L) | 250 mg/L ^a |
| Copper | 0.375 mg/L | 2 mg/L | 1.3 mg/L |
| Iron | 90 mg/L | 2 mg/L | 0.3 mg/L ^a |
| Lead | 0.690 mg/L | 0.010 mg/L | 0.015 mg/L |
| Magnesium | 45 mg/L | n.i. | 20 mg/L ^a |
| Mercury | 0.7 mg/L | 0.006 mg/L | 0.002 mg/L |
| Phosphorus | 39 mg/ | n.i. | 0.1 mg/L ^a |
| Potassium | 26 mg/L | n.i. | 5 mg/L |
| Sulfate | 170 mg/L | (>250 mg/L) | 250 mg/L |
| Total nitrogen | 220 mg/L | n.i. | 10 mg/L ^a |
| Dissolved oxygen | 7.4 mg/L | n.i. | >5 mg/L ^a |
| Suspended sediment | 25,800 mg/L | >600 mg/L (TDS) | 500 mg/L (TDS) ^a |
| Specific conductivity | 6,970 µS/cm | n.i. | 1650 µS/cm |
| Temperature | 29 °C | n.i. | 18–20 °C (for adult trout and salmon) ^b |
| Turbidity | 51,000 NTU | n.i. | 1 NTU ^a |

^a Secondary drinking water standard.

^b U.S. Environmental Protection Agency (2003).

Note: n.i. = no information; µS/cm = microsiemens per centimeter; TDS = total dissolved solids; NTU = nephelometric turbidity units.

high macro- and micronutrient values would also lead to increased algal growth and eutrophication of the water, making it unfit for drinking and for aquatic habitat.

Luckily, the serious effect of the Wallow Fire on the various water quality parameters did not persist for long (Paterson and others 2002; Wondzell and others 2003). As figures 1–4 show, the highly elevated levels of the various Salt River water quality parameters decreased rapidly within a short time after the burn period.

Postfire Watershed Degradation

The impacts of wildfires on peak flow and water quality can greatly vary. Because insufficient

vegetation cover is left in watersheds after wildfires and because soils become hydrophobic, most precipitation is readily converted to surface flow, which moves downstream with little or no difficulty. Such flows may be large, with velocities forceful enough to severely disturb and damage watersheds and stream channels. This may produce large quantities of sediment and other chemical contaminants that can be detrimental to downstream ecosystems. Wildfires can also interrupt or terminate nutrient uptake, increase soil mineralization, and lead to mineral weathering. Increased water temperatures decrease dissolved oxygen; along with the introduction of nutrients and toxic materials into water bodies,

lack of dissolved oxygen can cause eutrophication, destroying aquatic life. As a result, downstream ecosystems and socioeconomic conditions deteriorate.

To remedy the problem, it is important that land managers and other interested parties make every effort to minimize the occurrence of damaging fires. This can be done through forest thinning at the right level made with the appropriate harvesting methods or through a carefully designed prescribed fire. To use such methods successfully, forest managers should pay careful attention to the causes of wildfires and other harmful forest disturbances. Land managers need help from well-educated and insightful decision makers;

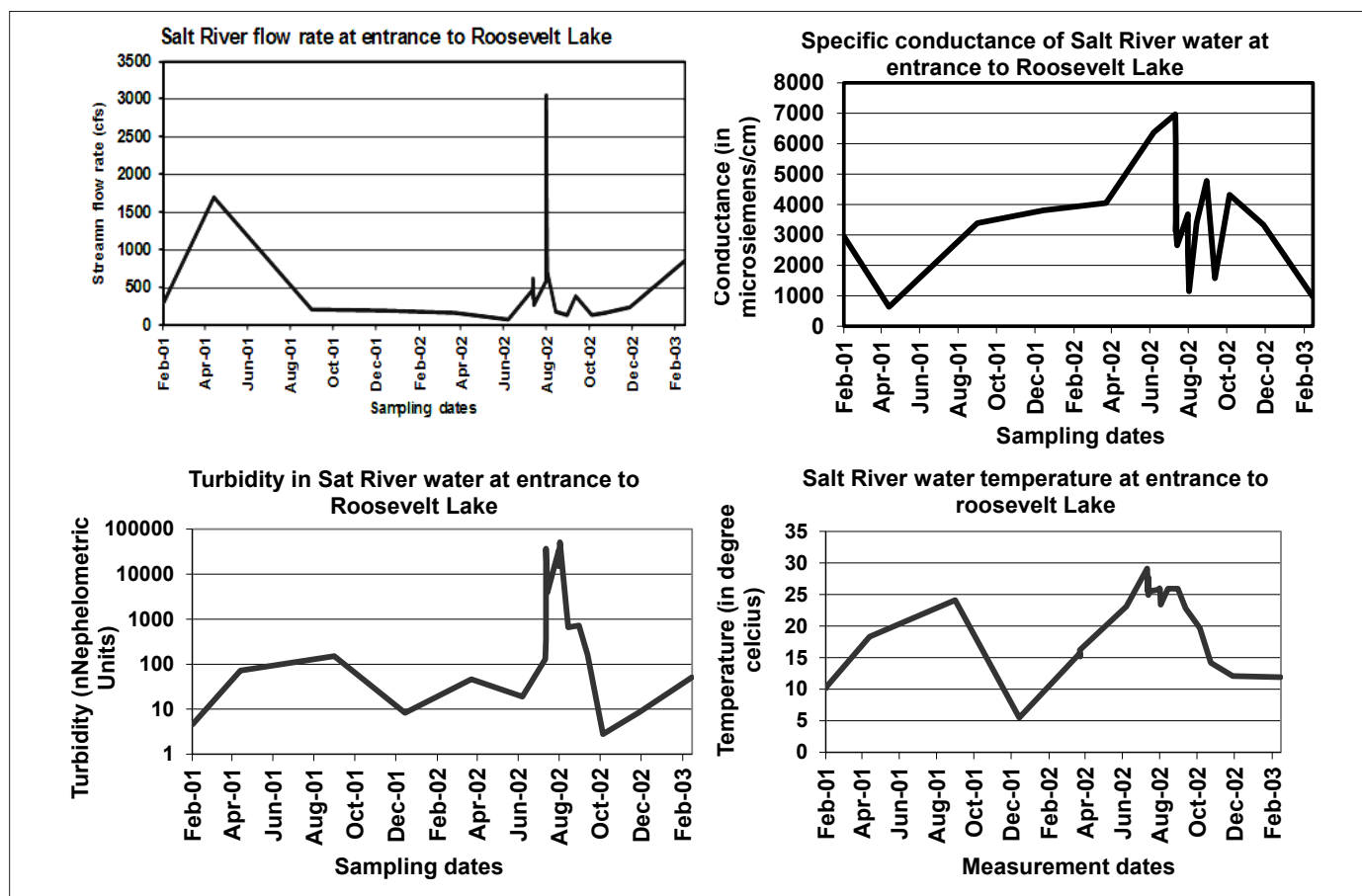


Figure 4—Flooding and physical water quality effects of the 2002 Rodeo–Chediski Fire in the Salt River at the entrance to Roosevelt Lake.

appropriate rules and regulations to serve as guidelines; and adequate budgets, along with skilled workers to prevent and control wildfires. Preventing wildfires is preferable to postfire remediation because restoring burned and/or degraded forested watersheds to predisturbance conditions is extremely expensive and takes a very long time. ■

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JOINT FIRE SCIENCE PROGRAM SMOKE SCIENCE PLAN, 2010–2016: RESULTS AND IMPACTS

Allen Riebau, Douglas Fox, and Cindy Huber

The Smoke Science Plan (SSP) was built upon personal interviews and an extensive web-based needs identification with scientists, fire managers, and air quality managers using online questionnaires (Riebau and Fox 2010a, 2010b). It is structured around four themes, which are conceptualized as complementary investigative areas to further smoke science as well as smoke and air quality management. The themes are:

1. Smoke emissions inventory research,
2. Fire and smoke model validation,
3. Smoke and populations, and
4. Smoke and climate change.

Since 2010, the Joint Fire Science Program (JFSP) has carried out the SSP using a series of competitive grant awards and smaller targeted supplemental contracts. In this paper, we review the desired outcome of each of the four themes in the SSP and the progress made in each thematic area. Finally, we suggest some “knowledge gaps” and application needs that may remain after completion of the SSP in 2016.

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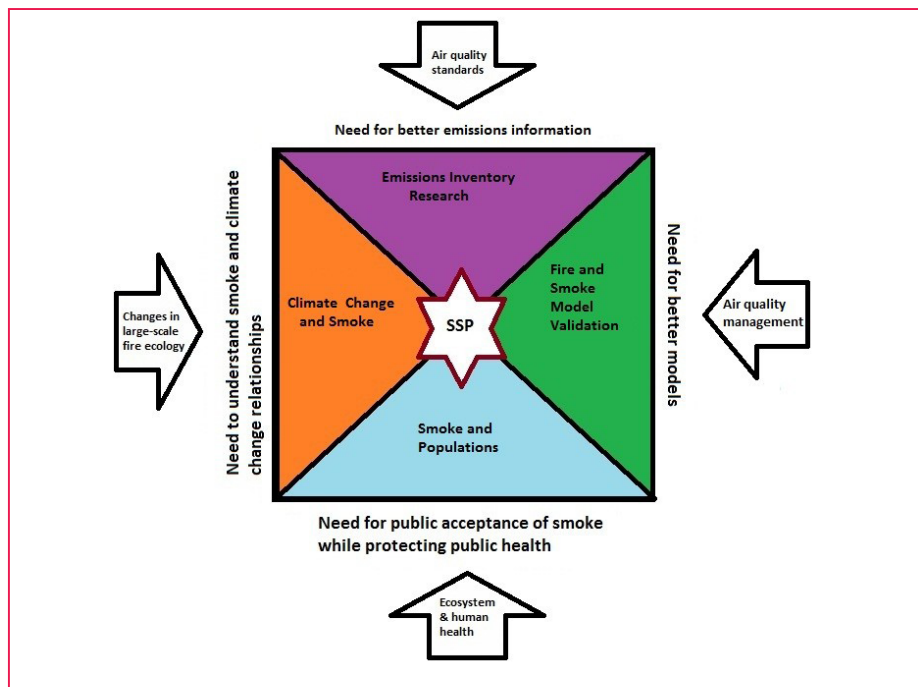


Figure 1—The Smoke Science Plan (SSP) unites four themes, each addressing a need. Each need results from a large “driver” that has historically affected and will continue to affect wildland fire management in the United States. Source: LeQuire and Hunter (2012).

The Four Themes and Associated Research Projects

The SSP’s four themes target specific needs of fire, smoke, and air quality managers. The themes were designed to address large societal forces (or “drivers”) influencing fire and air quality managers (fig. 1). The themes suggest incremental research projects for JFSP funding, which in turn lead to achieving specific objectives. Thus, research under the SSP is not an open-ended search for new knowledge about smoke but rather a targeted activity to address high-priority needs.

The objective of the *smoke emissions inventory research theme* is to develop science and knowledge needed to improve national wildland fire emissions inventories, paving the way for the design of a national consensus inventory system.

The objective of the *fire and smoke model validation theme* is to identify the scientific scope, techniques, and partnerships needed to objectively validate smoke and fire models using field data.

The objectives of the *smoke and populations theme* are to quantify the impact of wildland fire smoke

on population centers and on firefighters and to elucidate the mechanisms of public smoke acceptance, in light of the needed balance between human exposure to risks from smoke and the risks to ecosystems associated with fire (and smoke) exclusion. Ultimately, the research under this theme is designed to help in the development of a national smoke-hazard warning system/methodology based on best science.

The objectives of the *smoke and climate change theme* are to understand the implications of climate change for smoke from wildland fires; and, conversely, to delineate the implications of smoke from wildland fires on climate change using, for guidance, the future climate

scenarios outlined by the United Nations Intergovernmental Panel on Climate Change (IPCC).

Fire and smoke model validation has been a focus of fire science for some time.

Smoke Emissions Inventory Research

Emissions inventories are fundamental to air quality management. For smoke, at least two distinct types of emissions inventories are needed. One type is for real-time (or as close as possible to real-time)

emissions used to model smoke concentrations to aid operational decision making during fire events or during a series of geographically related smoke events.

The second type is retrospective for regulatory purposes: using fire emissions data corrected and quality assured after the fire to help quantify fire impacts on the measured air quality during and following fire events. This quantification is needed both for planning future emissions limitations (State implementation plans) and for segregating human from natural contributions (exceptional events policy). Of course, this is a broad simplification; but clearly these two inventory categories address different scientific questions

Table 1—Projects funded under the SSP emissions inventory research theme.

| JFSP Project Number/ Principal Investigator | Title | Completed/ Expected Completion Date | Primary User Communities Benefited by Project |
|--|--|--|--|
| 09-1-3-01 Jeffrey Collett | Experimental Determination of Secondary Organic Aerosol Production from Biomass Combustion | Yes | Atmospheric research scientists and air quality modelers |
| 11-1-5-16 Brian Benscoter | Influence of Fuel Moisture and Density on Black Carbon Formation During Combustion of Boreal Peat Fuels | Yes | Fire, smoke, and air quality managers |
| 11-1-6-06 Tom Moore | Deterministic and Empirical Assessment of Smoke Contribution to Ozone | Yes | Fire, smoke, and air quality managers |
| 12-1-7-01 Wei Min Hao | Critical Assessment of Wildland Fire Emissions Inventories: Methodology, Uncertainty, Effectiveness | 2017 | Air quality modelers and managers |
| 12-1-7-02 Sim Larkin | Assessment of Prescribed Fire Emissions and Inventories | 2017 | Air quality modelers and managers |
| 12-1-8-31 Tom Moore | Particulate Matter Deterministic and Empirical Tagging and Assessment of Impacts on Levels | 2017 | Fire, smoke, and air quality managers |
| 14-1-03-44 Sonia Kreidenweis | Phase Dynamics of Wildland Fire Smoke Emissions and Their Secondary Organic Aerosols | Yes | Atmospheric research scientists and air quality modelers |
| 14-1-04-16 Kelley Barsanti | Synthesis of Comprehensive Emissions Measurements and Multi-scale Modeling for Understanding Secondary Organic Aerosol Chemistry in Wildland Fire Smoke Plumes | 2017 | Atmospheric research scientists and air quality modelers |
| 15-1-01-1 Nancy French | Mapping Fuels for Regional Smoke Management and Emissions Inventories | 2018 | Fire, smoke, and air quality managers |
| 16-1-08-1 Talat Odman | Southern Integrated Prescribed Fire Information System for Air Quality and Health Impacts | 2018 | Fire, smoke, and air quality managers |

Note: SSP = Smoke Science Plan; JFSP = Joint Fire Science Program.

and relevant time and space scales (Battye and Battye 2002; Fox and Riebau 2000). Under the emissions inventory theme, JFSP research has sought to provide the science needed to clarify and improve both types of inventories.

Before the SSP, fire emission inventories existed, but many generated different results. Methods used to create inventories were not necessarily transparent or well documented. SSP research has focused on critically evaluating emission factors in general (Hao, table 1) and for boreal fuels (Benscoter, table 1) and prescribed fire (Larkin, table 1). It has also been directed toward understanding how smoke emissions contribute to ambient air quality ozone and fine particulate matter (PM^{2.5}). Perhaps the greatest opportunity arose in working with States to develop two automated systems to calculate emissions from validated postfire data (Moore, table 1). These systems (DEASCO3 and PMDETAIL) form, in essence, a prototype retrospective fire emissions inventory system based on validated data.

The JFSP determined that more information was needed on the formation of secondary organic aerosols in fire emissions, and the program started to fund the corresponding research. Collett's project (table 1) measured emissions from fires at the Missoula Fire Laboratory chamber and experimentally quantified secondary organic aerosols resulting from the corresponding biomass burning. In addition, research has continued to address secondary organic aerosols and related questions about fire emissions (Kreidenweis, table

Smoke from wildland fires can affect not only the wildland-urban interface but also large urban areas some distance away from the fires.

1), and work by Barsanti (table 1) is testing the implementation of new photochemical modeling mechanisms to better simulate fire's contributions to the secondary organic aerosols making up regional fine particulate matter. The final projects funded under this theme include improving the national mapping of fuels for building emission inventories (French, table 1) and developing a southern prescribed fire information system with the Southern Fire Exchange (Odman, table 1).

Fire and Smoke Model Validation

Fire and smoke model validation has been a focus of the JFSP and of fire science for some time (Sandburg and others 1999). This is especially true for fire behavior.

As the SSP came into being, a significant portfolio of smoke model validation research was in progress. Projects included work on fuels consumption model validation for emissions calculation (Ottmar, table 2) and "superfog" formation in the Eastern States (Princevac, table 2). Additional outstanding work was being accomplished on plume rise conceptualization (Liu, table 2) and model validation (Odman, table 2). Two projects focused on smoke transport from lower intensity subcanopy fires (Heilman, table 2; Strand, table 2), and another project used new techniques to track smoke dispersion more accurately (Urbanski, table 2). The Smoke and Emissions Model Intercomparison Project (Larkin, table 2) gathered datasets and evaluated a suite of models against the data to not only

evaluate model performance but also guide future model development. Incorporated into the SSP, these projects represent incremental research that both validates component models and clarifies the scope of the effort needed for a large-scale model validation activity.

A wide variety of models are used to project and analyze smoke and its impacts on people and resources. Some models and supporting data are incorporated into such application systems as BlueSky (<http://www.airfire.org/>) and Western Regional Air Partnership tools (<https://www.wraptools.org/>), which facilitate the application of models for both fire and air quality managers' use. However, demonstrating and quantifying just how well the models work for general fire applications remain elusive. Uncertainties with respect to fire emissions and fire behavior modeling cascade into uncertainties regarding plume rise, plume chemistry, and smoke dispersion, thereby compounding errors.

The single scientific need most identified in developing the SSP was the validation of smoke models and their modeling systems. Validation of smoke modeling has been and continues to be limited by insufficient quantity and quality of field data. Indeed, the lack of data limits even the development of new conceptual models. However, because of the complexity and diversity of the data needed, the data deficiency cannot be rectified by any one scientific group (Bytnerowicz and others

2009). In simple terms, the effort needed is large and extremely expensive, and it requires ground-based and airborne measurements. Clearly, no single group has the resources or scientific capabilities needed. Thus, the objectives of this theme are to develop the vision and to identify potential partnerships needed to accomplish such a large undertaking.

In 2011, the SSP participated in evaluating and planning the RxCADRE project, a successful comprehensive field study focused on fire behavior and emissions (Ottmar, table 2). In 2013, a special project was developed to identify the scope and magnitude of a comprehensive interdisciplinary

plan to address the data needed to validate models (Brown, table 2). As a capstone to this theme, the JFSP is working with the U.S. Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and Federal land managers to plan and execute highly instrumented field measurements of a few intense prescribed burns through the Fire and Smoke Model Evaluation Experiment.

Smoke and Populations

A sage once opined, “Smoke is the most widespread of fire impacts on the wildland–urban interface, impacting more people and more

places than anything else, even if its impacts are not always catastrophic.” In recent years, it has become clear that smoke from wildland fires can affect not only the wildland–urban interface but also large urban areas some distance away from the fires.

In 2010, the JFSP funded research on public acceptance of smoke (Hall, table 3; Toman, table 3), and their projects have been incorporated into the SSP. The funded projects addressed the public’s perception of smoke and examined the influence of communications and partnerships on the perception of smoke management, but they did not answer fundamental questions

Table 2—Research projects under the SSP fire and smoke model validation research theme.

| JFSP Project Number/Principal Investigator | Title | Completed/Expected Completion Date | Primary User Communities Benefited by Project |
|---|--|---|--|
| 08–1–6–01 Roger Ottmar | Validation of Fuel Consumption Models for Smoke Management Planning in the Eastern Regions of the US | Yes | Fire, smoke, and air quality managers |
| 08–1–6–04 Talat Odman | Evaluation of Smoke Models and Sensitivity Analysis for Determining Their Emission Related Uncertainties | Yes | Air quality modelers and air quality managers |
| 08–1–6–06 Yong Liu | Evaluation and Improvement of Smoke Plume Rise Modeling | Yes | Air quality modelers |
| 08–1–6–09 Shawn Urbanski | Airborne and Lidar Experiments for the Validation of Smoke Transport Models | Yes | Atmospheric research scientists |
| 08–1–6–10 Sim Larkin | Creation of a Smoke and Emissions Model Intercomparison Project (SEMIP) and Evaluation of Current Models | Yes | Atmospheric research scientists and air quality modelers |
| 09–1–4–01 Warren Heilman | Development of Modeling Tools for Predicting Smoke Dispersion from Low-Intensity Fires | Yes | Fire, smoke, and air quality managers |
| 09–1–4–02 Tara Strand | Sub-Canopy Transport and Dispersion of Smoke: A Unique Observation Dataset and Model Evaluation | Yes | Atmospheric research scientists and smoke managers |
| 09–1–4–05 Marko Princevac | Superfog Formation: Laboratory Experiments and Model Development | Yes | Atmospheric research scientists and smoke managers |
| 11–2–1–11 Roger Ottmar | Data Set for Fuels, Fire Behaviour, Smoke and Fire Effects Model Development and Evaluation (Rx Cadre) | Yes | Atmospheric research scientists |
| 13–S–01–01 Tim Brown | Fire and Smoke Model Validation Workshop | Yes | Atmospheric research scientists |
| 15–S–01–01 Roger Ottmar | Fire and Smoke Model Evaluation Experiment, Phase I | 2017 | Atmospheric research scientists |

Note: SSP = Smoke Science Plan; JFSP = Joint Fire Science Program.

Table 3—Projects funded under the SSP smoke and populations research theme.

| JFSP Project Number/ Principal Investigator | Title | Completed/Expected Completion Date | Primary User Communities Benefited by Project |
|--|---|---------------------------------------|--|
| 10-1-3-02 Troy Hall | Examining the Influence of Communication Programs and Partnerships on Perceptions of Smoke Management | Yes | Social scientists and health officials |
| 10-1-3-07 Eric Toman | Public Perceptions of Smoke: Contrasting Tolerance Amongst WUI and Urban Communities in the Interior West and the SE US | Yes | Fire managers |
| 13-1-02-14 Joe Domitrovich | Wildland Fire Smoke Health Effects on Wildland Fire Fighters and the Public | 2017 | Fire, smoke, and air quality managers and health officials |
| 13-C-01-01 William Malm | Visual Range and Particulate Matter Data Analysis and Literature Review | Yes | Smoke and air quality managers |
| 14-1-04-16 Ian Gilmour | The Role of Composition and Particle Size on the Toxicity of Wildfire Emissions | 2017 | Fire, smoke, and air quality managers and health officials |
| 14-1-04-5 Michael Jerrett | Health Effects From Wildfire Air Pollution: A Spatiotemporal Modeling Approach | 2017 | Fire, smoke, and air quality managers and health officials |
| 14-1-04-9 Brian Reich | Estimating Fire Smoke Related Health Burden and Novel Tools to Manage Impacts on Urban Populations | 2017 | Fire, smoke, and air quality managers and health officials |
| 15-1-02-2 Joseph Vaughn | AIRPACT—Fire Enhanced Communication of Human Health Risk with Improved Wildfire Smoke Modelling | 2018 | Air quality modelers |
| 15-1-02-4 Sim Larkin | US Smoke Hazard Warning System: Prototype and Enhancements to Operational Systems | 2018 | Fire, smoke, and air quality managers and health officials |

Note: SSP = Smoke Science Plan; JFSP = Joint Fire Science Program.

about actual health impacts from smoke.

The SSP chose to focus on providing additional insight into the actual concentrations of fine particulate matter and other pollutants that adversely affect public health. Ongoing projects are studying health effects of smoke from wildfires on firefighters (Domitrovich, table 3) and the general public (Reich, table 3; Jerrett, table 3). One project, in cooperation with EPA, is examining the actual toxicology of smoke from forest fuels (Gilmour, table 3). A special project, formulated in response to a concern expressed by the

National Wildfire Coordinating Group’s Smoke Committee, clarified relationships between impaired visibility and fine particulate matter health standards (Malm, table 3); the study has been used in a recent publication for fire managers (Hyde and others 2016). As a capstone to this theme, two projects were funded to develop a prototype operational National Fire Smoke Hazard Warning System (Larkin, table 3) and improve a smoke-modeling system to enhance its ability to communicate health risks (Vaughn, table 3).

Smoke and Climate Change

One of the most important issues facing forest management is

climate change. It is apparent that climate and smoke emissions are interrelated (Westerling and others 2006; Williams and others 2005), but generating science useful to fire managers in this area has proven problematic. The JFSP has chosen to focus on how fire emissions and resultant air quality impacts are likely to be altered under a changed climate. Other important issues include how smoke emissions and the associated atmospheric chemical processing will feed back into the climate system; black carbon emissions from fire and their impacts; and identifying large population centers in the United States that might be at greatest risk from smoke

exposure from megafires in the climate-changed future.

Before the SSP, there was significant concern about smoke and climate change. Speculation and dramatic projections were appearing in the literature, occasionally based on dubious modeling results, not so much of future climate but of future ecosystems, fuel loadings, and fire regimes. The SSP sought to move the research toward more mainstream climate and ecosystem (fuel and fire regimes) research by linking work to the research results of the United Nations' IPCC. Responding in part to concerns raised by the

National Wildfire Coordinating Group's Smoke Committee, three projects addressing black carbon were funded. One project (Kreidenweis, table 4) made aircraft measurements of black carbon and associated carbon forms in smoke plumes from experimental burns on military lands in the Southeast (in cooperation with the U.S. Department of Defense Strategic Environmental Research and Development Program). Another project identified conditions needed for smoke from wildfires in the United States to transport black carbon to the Arctic (Larkin, table 4). The third black carbon project modeled fire's contribution to regional atmospheric

concentrations of black carbon and its rates of deposition in the Western United States (Chung, table 4). Two megacity and megafire projects approached the problem differently, one building a simulation model of future ecosystems and fire regimes based on IPCC climate models (Liu, table 4) and the second constructing a statistical model of potential fire and smoke impacts (Larkin, table 4).

The SSP also developed two special projects under the smoke and climate change theme to develop critical review papers. The first assessed the state of the science of simulating effects of climate change on forest ecosystems,

Table 4—Funded projects under the SSP smoke and climate change research theme.

| JFSP Project Number/ Principal Investigator | Title | Completed/Expected Completion Date | Primary User Communities Benefited by Project |
|--|---|---------------------------------------|---|
| 10-S-2-01 Sim Larkin | Identification of Necessary Conditions for Arctic Transport of Smoke from US Fires | Yes | Fire managers |
| 11-1-5-12 Sonia Kreidenweis | Measuring the Optical Properties and Climate Impacts of Aerosol from Wild and Prescribed Fires in the US | Yes | Air quality modelers and atmospheric research scientists |
| 11-1-5-13 Serena Chung | Modeling Study of the Contribution of Fire Emissions on Black Carbon Concentrations and Deposition Rates | Yes | Air quality modelers and atmospheric research scientists |
| 11-1-7-02 Yong Liu | Impacts of Mega-Fires on Large US Urban Area Air Quality Under Changing Climate and Fuels | Yes | Fire, smoke, and air quality managers |
| 11-1-7-04 Sim Larkin | Future Mega-Fires and Smoke Impacts | Yes | Fire, smoke, and air quality managers |
| 12-S-1-02 Don McKenzie | Smoke Consequences of IPCC's Scenarios Projected Climate and Ecosystems Changes in the US—Review Paper | Yes | Fire and climate change research scientists |
| 13-1-01-16 Uma Shankar | Assessing the Impacts on Smoke, Fire and Air Quality Due to Changes in Climate, Fuel Loads, and Wildfire Activity over the SE United States | 2017 | Fire and climate change research scientists and fire planners |
| 13-1-01-4 Jeffrey Pierce | Estimating the Effects of Changing Climate on Fires and Consequences for US Air Quality Using a Set of Global and Regional Climate Models | 2017 | Fire and climate change research scientists and fire planners |
| 16-S-01-2 Richard Birdsey | Potential Climate Feedbacks of Changing Fire Regimes in the US: A Review | Yes | Fire and climate change research scientists |

Note: SSP = Smoke Science Plan; JFSP = Joint Fire Science Program.

The JFSP has begun implementing a formal Smoke Communications Plan to ensure that Smoke Science Plan products are effectively delivered.

fuels, fire regimes, and smoke from wildland fires (McKenzie and others 2014). The second project assessed the state of science on simulating feedbacks from landscape change, fire, and smoke on the climate (Birdsey, table 4). Finally, two ongoing projects are using IPCC climate scenarios and their global-scale modeling results for the mid- to late 21st century to drive dynamic downscaling from the global-scale climate, to regional-scale climates, to local-scale climates. The projects will simulate changed ecosystems, vegetation, and fire regimes to estimate resulting smoke and air quality at the national scale (Pierce, table 4) and at a regional scale for the Southeastern United States (Shankar, table 4).

Future Prospects

The SSP will accomplish most of its thematic goals by 2018, but outstanding questions will remain to be addressed in the future. This section explores some of those questions and issues.

Smoke Emissions Inventory

Research already completed, plus new results anticipated over the next few years, will give solid answers regarding the distribution of black-carbon fire emissions, the quantification of fire impacts on concentrations of both ozone and particulate matter, and the identification of strengths and weaknesses in existing inventory methods. The research portfolio for the smoke-emissions theme will deliver improved systems for inventorying smoke emissions;

some are already supported by the EPA and the State air agencies. However, a remaining limitation in developing useful emissions inventories is the *lack of accurate and complete fire-activity data*. The JFSP has funded projects to evaluate the effectiveness of remote sensing techniques to obtain this information for use in emissions inventories, but time and again, air quality practitioners tell us that the available fire-activity data are insufficient to attribute emissions to particular sources. This issue is being tackled regionally through the Odman project for the Southeast but will need to be expanded to include all States to fully address the limitation.

In part as a result of the research that the JFSP has funded, it is becoming clearer that *organic aerosols from biomass burning, both primary emissions and secondary formations*, are important and are not fully understood. Organic aerosol issues are closely tied to newly promulgated and tightened ambient air quality standards for both ozone (in 2015) and fine particulate matter (in 2013); to planned revisions of the EPA's regional haze regulations; and to recently codified new policies on exceptional events. EPA has specifically addressed wildfire in both the proposed regional haze regulations (<https://www.epa.gov/visibility/visibility-regulatory-actions>) and in the new exceptional-events policy (<http://www2.epa.gov/air-quality-analysis/treatment-data-influenced-exceptional-events>). The new rules do not

necessarily imply that prescribed fire will be more restricted in the future, but they do imply that fire managers will need to become even more engaged in regulatory analysis, debate, and decision making with air quality managers and State and local regulatory agencies.

Fire and Smoke Model Validation

The objectives of this theme were based on a cooperative program of work that could only be achieved as a multiyear, multiagency legacy activity, with the JFSP acting as a partner and mentor and cooperating with other agencies, especially with the U.S. Department of Defense, EPA, NASA, and NOAA. The objectives will be largely achieved through the planning and execution of the currently developing Fire and Smoke Model Evaluation Experiment.

A new consideration in smoke model validation is the emerging understanding that wildfire emissions have been consistently underestimated. The assumption has been that wildfire emissions were much the same as prescribed fire emissions in their constituents but on a larger scale. Wildfire emissions could therefore be calculated by simply scaling up and apportioning emissions between the flaming and smoldering fire phases. This assumption has led toward misrepresenting emissions (for example, emissions chemistry, particle size distributions, and plume entrainment), with a bias toward underestimation.

Future field studies will need to focus on larger fires that replicate wildfire conditions. The effects on public health from long-range transport of wildfire smoke may be larger than we have anticipated.

The implications for regional haze and air standards may also be larger than anticipated. A new understanding of wildfire intensity, emissions profiles, and smoke transport is needed, along with development of new and perhaps more challenging research techniques.

Smoke and Populations

The JFSP-funded projects should result in vastly improved knowledge about the impacts of ambient smoke concentrations on the public. They should also help researchers better understand and quantify the biochemical pathways affected by smoke constituents. Progress is also being made in understanding the short-term health impacts of smoke on firefighters, and several completed projects have clarified our understanding of public perceptions of smoke. The knowledge base for developing a smoke-risk warning system will soon be more complete than ever before and will help in establishing a research prototype risk warning system.

However, this theme is so broad that important issues will remain. An unexpected and increasing public concern is the impacts of long-term smoke exposure on the health of firefighters and the public. Recent studies have suggested that long-term exposure to smoke will likely have different health consequences than short-term exposure in terms of the type and severity of the impacts as well as the affected population cohorts (USDA Forest Service 1997; Rappold and others 2011). Using our existing work on short-term smoke exposure as a foundation, *thematic research on smoke and populations should begin to shift in focus toward longer term*

exposure studies. The complexities and confounding factors associated with such studies will require new research approaches. Understanding and defining long-term health consequences to smoke exposure, combined with what we are learning about the health effects of short-term exposures, will be pivotal in improving public awareness of smoke hazards and the importance of protecting the health of firefighters.

Smoke and Climate Change

We believe that ongoing funded research projects will make progress toward achieving stated theme objectives. Every year, however, new climate change research is improving our understanding of the nature of future climates and creating better projections of potential future impacts (IPCC 2013). SSP-funded research will conclude in 2018, having developed new foundational science and information; but because the magnitude of the issue is larger and more difficult than ever, research will need to continue.

Perhaps the most significant thing we have learned is that vegetation models must be linked to climate models to provide a two-way information exchange. Most previous modeling approaches have changed climate without considering vegetation changes or changed vegetation without considering how the changes altered the climate at regional or subregional scales. Moreover, statistical approaches are likely to be of only limited value in both downscaling future climates to the scales needed to study fire and smoke impacts and in projecting ecosystem and fire regime changes. This issue is becoming one of increasing concern, because

observations are starting to show feedbacks exacerbating greenhouse gas concentrations on a planetary scale (such as boreal feedbacks for both carbon dioxide and methane). The complexity of vegetation and climate feedbacks is fundamental, and it is far from being completely explained by current science, especially as the rate of change in the climate system accelerates. With respect to wildland fire management, the potential feedback between vegetation and climate at subregional scales is a critical issue for fire ecology.

Communicating Results

As a necessary complement to the SSP, the JFSP has begun implementing a formal Smoke Communications Plan, a newly designed activity to ensure that SSP products are effectively delivered to users nationwide though the JFSP Fire Exchange Network of technology transfer consortia. The communication of SSP research results has been a hallmark of the JFSP as it works not only to foster better science but also to ensure that new science is communicated appropriately. Each SSP project team is required to write a formal report of results and science impacts (such as publications, seminars, and workshops). A project summary based on the final reports is widely distributed through the consortia. Finally, a webinar is conducted and placed in a video archive that can be accessed at any time by anyone interested in project results.

After the SSP Concludes

The true measure of success for the SSP is the scientific progress made and how much it benefits those involved in managing smoke. The SSP has resulted in significant

progress in its thematic research areas. Smoke research has been a major investment topic and line of work for the JFSP. As important as smoke is and has been historically, the JFSP must now rebalance the focus of its entire program of research with current realities. Major issues that the JFSP faces are organized as “lines of work.” Smoke has been a line of work since 2008. In the future, smoke research will no longer be a formal line of work for the JFSP and will not be organized under a formal follow-on smoke science plan.

Since the JFSP will not have a formal smoke line of work, its smoke research investments may decrease as the program rebalances its investment strategy to better meet the needs of its various constituencies. Smoke needs will not be abandoned but rather addressed by focused shorter term investments rather than a formal version II SSP. Perhaps the testament to the SSP’s success is that its objectives will have been so well met by the portfolio of research it engendered that a follow-on plan is not seen as needed.

Acknowledgments

The authors would like to thank the JFSP and especially its program manager, John Cissel (now retired), for support of the SSP and the smoke line of work. We would also like to thank everyone who advised us in our work through completing online surveys and communicating with us in many other ways, formal and informal. Of special note has been our partnership with the National Wildfire Coordinating Group’s Smoke Committee.

Finally, it is impossible to complete science without

investigators. We have been fortunate to have seen a wide array of distinguished scientists, both in the United States and internationally, vie for research funding under the SSP. The accomplishments of these investigators have surely resulted in a body of publications and other products that will truly transform the practice of smoke and air quality management during the next two decades. ■

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ORDERING ON A FIRE: GETTING WHAT YOU NEED

Ed Delaney

Wildland fire management involves specialization and a division of labor.

When you order supplies on a wildland fire, you should keep that in mind. In your own specialty area, you need support from others who don't necessarily have your level of knowledge. To get what you need, you have to communicate clearly. Remember, you will be communicating requirements to nonspecialists.

Ordering What You Need

If you're working on a fire, you need certain things in place to succeed. If you're a medical unit leader, you might need splints, eyewash, pain relievers, and so forth. If you're a helibase manager, you might need a case of antifreeze to activate ping-pong balls for a burnout. If you are a hotshot superintendent, you might need chainsaw bar nuts, chains, spark plugs, and wedges.

The process for placing an order through Dispatch is twofold:

1. You complete a General Message form (ICS 213); and
2. You submit the form through your chain of command to the ordering manager on the incident.

When he wrote and submitted the article, Ed Delaney was the lead fire contracting officer for the Bureau of Land Management in Oregon and Washington.

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Remember, you will be communicating requirements to nonspecialists.

On a new and growing incident, local staff with purchasing capabilities might be called on to get you what you need. On an established or rapidly growing fire, a buying team might be called in. Either way, someone has to obtain whatever it is you need—and understand what it is you want.

Why is it sometimes so difficult to explain to the person doing the buying that you just wanted X, not Y or Z? My purpose here is to help make sure that what you really need is what you get.

A few suggestions:

- Describe items generically. Avoid brand names unless no substitutions are allowed.
- Briefly explain how an item will be used and give its dimensions, for example, so a buyer can look for suitable alternatives.
- Check your spelling and handwriting.
- Submit multiple General Message forms when appropriate and/or group items by type.

General Message Form

The General Message form is admittedly an imperfect tool for

communicating a request for goods or services, but it's what we have to work with. So how do we pursue the best possible outcomes under imperfect conditions? There are a few basic things you can do to get your message across.

First, make sure that the form is legible. If people joke about your handwriting, print (or get someone else to print) your message. Remember, your form will generally be faxed, which will add distortion to the image arriving on the other end.

Second, when ordering several items, put them into related groups. Don't mix chainsaw parts with medical supplies, for example. Ideally, send a separate General Message form for each class or category of things (or services) you need.

Third, get someone else, like the ordering manager, to read your General Message form. Pretend that your proofreader is not operationally trained. Could someone new to the job understand the acronyms, abbreviations, and technical terms you have used?

Be Specific

When you place an order for a type 2 dozer, you are going to get a crawler tractor with 100 to 199 horsepower. There's a standard definition that has been agreed upon, and you can count on a terse order for a type 2 dozer to convey enough information.

But when you place orders for items not in the National Fire Equipment System, especially those with trade names or unusual names, it's in your best interest to be clear about what you need. If you need a 2½-gallon (9.5-L) plastic gas can for mixing saw gas, placing an order for a "Dolmar" might not get you what you need when you need it.

If you are ordering something like antifreeze, stating the purpose (to ignite ping-pong balls) only takes a few more penstrokes but can be critical in getting what you need. When ordering incendiary ping-pong balls, stating the adjective "incendiary" could be very important. The story is true about a buying team scouring sporting goods stores for 1,000 table tennis balls for a helibase.

If you are ordering 300 feet (90 m) of 3-inch (7.5-cm) camlock hose, is that enough information? The person charged with obtaining the hose might not know that intake hose is different from discharge hose. Is accordion hose acceptable? Can the 300 feet (91 m) be in three 100-foot (30-m) lengths? Bottom line: The more specific you are, the better for you and your operation.

Be Clear

Keep in mind, miscommunication and especially ambiguity create delay. When Dispatch receives an unclear order, it might spend considerable time trying to figure out exactly what you mean. Or Dispatch might not understand the potential for specific characteristics and just pass your ambiguous order on for purchase.

Small-town suppliers might not be able to offer unusual items (such as long lengths of large camlock hose). If it has to be ordered from hundreds of miles away, it might take a long time to receive and then additional time to be delivered where needed. If you get the wrong thing, it might be more days before what you requested arrives. You might no longer need it by the time it arrives, and it might be nonreturnable.

Get someone else, like the ordering manager, to read your General Message form.

If your spelling is atrocious or your usage imprecise, beware!

In 2015, a buying team spent time with Dispatch trying to figure out what a "30 coker with looper bail" was. The mystery was solved when someone suggested it might be a "30-foot [9-m] choker with loop bail." It turned out that a logging supplier could make it onsite, but what size cable was needed— $\frac{5}{8}$ -inch (1.6-cm), $\frac{3}{4}$ -inch (1.9-cm),

or 1-inch (2.5-cm)? The person placing the order couldn't be contacted, so an arbitrary decision was made and a pair of $\frac{5}{8}$ -inch (1.6-cm) chokers were sent out to the line. It turned out to be just what was needed, but it was a lucky guess.

Using brand names is one way to reduce confusion but can limit your ability to buy what you need in the quantity you need. If generic diphenhydramine will work, specifying the trade name for the original product might limit you to 3 or 4 units, whereas the generic product would be available in the 25 units you ordered. Especially for medical supplies, you might face delays in getting what you need unless you follow the brand name with "or equivalent."

Foolproof Ordering

As President William Howard Taft put it, "Don't write so that you can be understood. Write so that you can't be misunderstood."

Even if your request is urgent, make it foolproof. Taking a few extra moments to check the clarity (including the legibility and spelling) of your request—or having it proofread—can save hours or days (and acres burned) in getting you what you need. ■

SAVING LIVES, PROPERTY, AND TAX DOLLARS IN NEBRASKA

Deloris Pittman



In 2012, the Mead Volunteer Fire and Rescue Department in Nebraska found itself in a tight spot. Equipment needed to be updated, and purchasing a brand new truck was not feasible. The department's executive board met with the Nebraska Rural Fire District Board to discuss how best to use taxpayer money while giving the community the best possible fire protection.



Mead Volunteer Fire and Rescue Department HEMMTs in action. Standard size for these heavy-duty vehicles is over 30 feet (9.1 m) long, 8 feet (2.4 m) wide, and 9 feet (2.7 m) high. Photo: Nick Raver, Mead Volunteer Fire and Rescue Department.

By making the trucks into multiple-use emergency vehicles, the department has saved the district about \$600,000.

Heavy-Duty Fire Trucks

Fire Chief Nick Raver met with Lew Sieber, manager of the Nebraska Forest Service Fire Shop, to see whether the Fire Shop could help in finding a truck that would work for the department. The department needed a tanker that could hold at least 2,000 gallons (7,571 L) and could go offroad. The Fire Shop

offered a 2,500-gallon (9,464-L) heavy expanded-mobility tactical truck (HEMTT).

HEMTTs are used by the U.S. Army. The 8-by-8 offroad trucks are capable of fording water crossings up to 48 inches (122 cm) deep. Standard size for these heavy-duty vehicles is over 30 feet (9.1 m) long, 8 feet (2.4 m) wide, and 9 feet (2.7 m) high. With this type of build, the HEMTT seemed to be a good fit for the Mead Volunteer Fire and Rescue Department.

The department took delivery of the tanker in 2013 and spent about \$55,000 to get it up and running.

"We made the truck so it only took one firefighter to run the truck," said Raver. "After using the truck for a couple years, we went back to the rural board and requested another HEMTT."

More Capacity With Cost Savings

In 2015, the department acquired a second HEMTT, making it capable of transporting 5,000 gallons (18,927 L) of water. Both trucks are equipped with spray bars and monitoring guns for field fires. The second truck was also outfitted with a PyroLance, a specialized, ultra-high-pressure spraying tool for firefighting.

"Since getting the two trucks," Raver noted, "we have been mutual-aided to five different counties. We have used the trucks for all fires, car accidents, snowstorms, and most recently, a water rescue."

By making the trucks into multiple-use emergency vehicles, the department has saved the district about \$600,000. The trucks also serve as a great recruiting tool: It's not every day you see a fire truck like this! ■

Deloris Pittman is the marketing and promotions manager for the University of Nebraska Agricultural Research and Development Center near Mead, NE.

MINNESOTA PROGRAMS BENEFIT RURAL FIRE DEPARTMENTS

Christi Powers

The Brimson Fire Department is now better prepared to fight fires, thanks to the Minnesota Department of Natural Resources's (DNR's) partnership with the U.S. Department of Defense (DoD). The DNR's Rural Fire Department program, in cooperation with the DoD's Firefighter Property Program, delivers equipment to rural fire departments.

An Affordable Acquisition

In July 2016, the 14-member Brimson Fire Department northeast of Duluth, MN, added a 2009 water tender to its aging fleet of firefighting vehicles. The department saved thousands of dollars by acquiring the vehicle through military surplus.

"We paid about \$4,300 to acquire the vehicle and another \$10,000 for paint and accessories for a truck that costs nearly \$100,000 new," said Fire Chief Paul Tiné, a founding member of the Brimson Fire Department.

The volunteer fire department, established in 1981, offers fire suppression and emergency services to a 360-square-mile (930-km²) area that includes portions of the Superior National Forest and the Cloquet Valley State Forest.

Christi Powers is a public information officer for the Minnesota Interagency Fire Center, Grand Rapids, MN.

The new addition to the Brimson fleet will aid in area fire suppression efforts.



Brimson Fire Department water tender. Photo: Paul Tiné, Brimson Fire Department.

The department works closely with the Forest Service and the Minnesota DNR to fight wildfires.

The six-cylinder diesel-fueled water tender can haul 1,200 gallons (4,542 L) of water to service a pumper and is easier to drive offroad than the vehicle it replaced. Over the years, the Brimson Fire Department received many calls to assist on wildfires in the area.

"We have more wildland fires than structural fires," said Tiné.

"This new water tender has a higher wheel base and will give us better clearance over grass and on rough terrain."

Through municipal and interagency agreements, other organizations will benefit from the acquisition. The Brimson Fire Department has helped the DNR office in Two Harbors, MN, on wildfires. The new addition to the Brimson fleet will aid in fire suppression efforts throughout the area.

Rural Fire Programs

Aside from its Federal partnerships, the DNR has several programs for assisting fire departments in rural Minnesota through low-cost equipment, cost-share grants, technical assistance, and wildland fire training.

The Wildland Fire Equipment Sales program, also known as “fire cache sales,” offers wildland fire suppression equipment to Minnesota fire departments at a low cost. Equipment sold through this program meets wildland fire specifications.

“Our rural fire program delivers surplus equipment at low cost to communities that might not otherwise afford it,” said Tim Oland, rural fire department coordinator.

Minnesota’s rural fire program delivers surplus equipment at low cost to communities that might not otherwise afford it.

“Communities give us their wish lists and we scout surplus programs to suit their needs.”

The Volunteer Fire Assistance Grant program is a cost-share program that gives financial and technical assistance to Minnesota fire departments in cities or communities with populations under 10,000. The main goals of the program are saving lives and protecting property in rural areas.

Fire departments with the greatest need take priority, as

do counties and communities with a community wildfire protection plan or a county all-hazard mitigation plan. Additional considerations include the type of project, fire runs, and previous funding received.

Oland estimated that nearly \$3 million worth of surplus equipment was delivered to Minnesota rural fire departments in 2015. ■

ASSESSING FIRE MANAGEMENT NEEDS IN THE PACIFIC ISLANDS: A COLLABORATIVE APPROACH

Clay Trauernicht, Elizabeth Pickett, Pablo Beimler, Christian P. Giardina, Susan Cordell, J.B. Friday, Eric Moller, and Creighton M. Litton

Wildland fire is a significant and growing threat to communities and natural resources on Hawai'i and the U.S.-affiliated Pacific Islands, including Guam, American Samoa, the Commonwealth of the Northern Mariana Islands, the Republic of Palau, the Federated States of Micronesia, and the Republic of the Marshall Islands (see, for example, Trauernicht and others 2015). Collaborative approaches to fire management are critical because multiple interacting factors—including climate, ecosystem composition, land use history, social-ecological impacts, and cultural perceptions—create highly complex problems (Dellasala and others 2004). However, identifying effective strategies to promote dialogue and knowledge

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To meet our objectives, we developed a stakeholder assessment process specifically designed to guide the activities of the Pacific Fire Exchange.

exchange among practitioners and researchers and to bridge the “science–management divide” remains a challenge (Roux and others 2006).

Here, we outline our process of facilitating bidirectional knowledge exchange to meet fire management needs for the Pacific Island region through an initial assessment of on-the-ground needs of stakeholders. Our objectives were to provide an opportunity for active engagement among stakeholders, to create a foundation for identifying the availability and relevance of existing information based on management needs, and to inform the development of new fire science.

Facilitating Knowledge Exchange Through Boundary Organizations

Recent work has stressed the importance of “boundary organizations” that can facilitate knowledge exchange by “understanding the decision context and stakeholder perspective, developing strong stakeholder relationships, and

providing information that is accurate [and] credible” (Kocher and others 2012). The Joint Fire Science Program’s (JFSP’s) Fire Science Exchange Network was created as a direct response to the need for improved two-way communication between practitioners and researchers (Wright 2010; LeQuire 2011). The Fire Science Exchange Network consists of 15 consortia working towards improving fire-focused knowledge exchange across all the major ecoregions of the United States (http://www.firescience.gov/JFSP_exchanges.cfm). The guiding principles for the network stress inclusivity, impartiality, facilitation, and (most importantly) the development and delivery of information based on the needs of and continuous feedback from the end users.

Effective knowledge exchange requires identifying not only whom to engage but also how to engage them. Stakeholders are typically identified based on the problem at hand; but differentiating them based on, for example, their relative degrees of interest in a problem and their relative abilities

to influence its outcome can be useful for targeting key sources of information and identifying underrepresented groups (Reed and others 2009). Successful stakeholder engagement, on the other hand, is best approached as a structured, continuous process that identifies explicit, agreed-upon objectives and emphasizes empowerment, equity, trust, and learning (Reed 2008). The success of the JFSP's Fire Science Exchange Network and other "boundary organizations" therefore depends upon their ability to facilitate communication and relationships and thereby provide a service that may be outside the scope of work or skillset of the stakeholders involved.

To meet our objectives, we developed a stakeholder assessment process specifically designed to guide the activities of the Pacific Fire Exchange (PFX; <http://www.pacificfireexchange.org/>). The PFX is a JFSP knowledge exchange consortium established to serve Hawai'i and the U.S.-affiliated Pacific Islands. Although specific to the Pacific Island region, the process we developed might be a useful model for stakeholder engagement elsewhere, and our results offer insight into the needs and challenges inherent in bridging fire science and management.

Wildland Fire on Pacific Islands

The context in which fire occurs on and affects Pacific Island landscapes can be markedly different from continental systems. Prior to human arrival, wildland fire was relatively infrequent and limited locally to volcanic events and rare

The context in which fire occurs on and affects Pacific Island landscapes can be markedly different from continental systems.

lightning strikes. The region was one of the last places on Earth to be colonized by people (1,000 to 3,000 years ago), and they brought with them the use of fire for agriculture and clearing land. For instance, burning by early Polynesian settlers in New Zealand has been linked to widespread habitat conversion (Perry and others 2012). Similarly, in Micronesia, the establishment and persistence of native savanna vegetation has been attributed to frequent burning by people (Athens and Ward 2004), a practice that continues today.

More recently, the flammability of many Pacific Island landscapes has increased dramatically due to the introduction and rapid spread of nonnative fire-prone grasses and shrubs. These species have altered fuel composition and loads in Fijian and Micronesian savannas, and they form the dominant vegetation cover across nearly one-quarter of the inhabited Hawaiian archipelago (Trauernicht and others 2015). The consequent increase in the availability and continuity of fine fuels, combined with drought, topographically defined dry ecosystems, and abundant human-caused ignitions, has created conditions for frequent, often year-round occurrence of wildland fire throughout the region. For instance, it is estimated that 20 percent of Yap burned under severe drought conditions during the 1998 El Niño (FSM-DRD 2010), while wildland fire records from Hawai'i, Guam, and Palau

indicate that the proportion of total land area burned annually on these islands in some years exceeds that of the Western United States (see, for example, Trauernicht and others 2015).

The impacts of wildland fire are particularly acute on Pacific Islands, given the region's limited land area, the relative sensitivity of its native ecosystems to fire, and the proximity of upland and coastal resources. However, development of fire research and management knowledge on Pacific Islands is limited relative to continental ecosystems. Established tools for fire prediction and operational response, such as standard fuel and fire-spread models and the National Fire Danger Rating System, have uncertain applicability due to extremely steep environmental gradients, sparse weather data, and novel fuel types (Fujioka and others 2000; Weise and others 2010; but see Pierce and others 2014). Given the knowledge gaps, it is imperative that efforts to develop fire science in the Pacific Island region explicitly meet the needs of land managers, fire managers, and fire responders.

The Need for Fire Science Knowledge Exchange

In 2011, the Forest Service's Institute of Pacific Island Forestry, the Hawai'i Wildfire Management Organization, and the College of Tropical Agriculture and Human Resources of the University of

Hawai'i at Mānoa partnered to develop the PFX. The exchange's overarching goal is to improve communication between the science and practitioner communities in Hawai'i and the U.S.-affiliated Pacific Islands by increasing collaboration and by developing and disseminating science-based best practices for fire management based on stakeholder needs.

In 2011, the PFX conducted an initial needs assessment among 46 individual scientists, educators, land managers, and fire responders in Hawai'i and the Pacific Island region as part of a national survey developed by the JFSP (Kocher and others 2012). The top fire-related concerns identified by respondents were watershed protection, land management, and native and invasive/nonnative species, concerns that reflect the drivers and impacts of wildfire. Stakeholders are attuned to such issues, even though a statewide fire assessment did not exist until 2015.

Although the percentage of practitioners who ranked fire as a high-priority issue was large (75 to 86 percent), most respondents consulted fire science information only "sometimes," "rarely," or "never." When split across professions, the percentage who responded in these three ways was 60 percent for fire suppression, 57 percent for habitat restoration, and 75 percent for both mitigation/fuels management and education/outreach. The top two challenges to accessing scientific information on fire management identified by respondents—"the lack of regionally relevant information" and "no centralized source of information"—likely explain

these patterns; they pointed to a pressing need for something like the PFX. In addition, most respondents (72 percent) identified "improved partner communication and collaboration" as the greatest communication need for enhancing fire management in the region.

The impacts of wildland fire are particularly acute on Pacific Islands.

Identifying PFX Knowledge Themes

Given the challenge of bridging these information needs, the PFX Steering Committee undertook a collaborative effort to identify and prioritize fire management knowledge gaps for the Pacific Island region. In September 2013, we organized a workshop at the University of Hawai'i at Mānoa to elicit the expert opinion of members of both the PFX Steering Committee and the Advisory Panel. These two governing bodies meet monthly and biannually, respectively, bringing together

a diverse range of perspectives and expertise to ensure that PFX deliverables address stakeholder needs. The experts convened at the workshop included 14 fire managers, fire responders, land managers, cooperative extension specialists, and researchers representing the following agencies and organizations: the Center for Environmental Management of Military Lands; the Hawai'i Division of Forestry and Wildlife; the Hawai'i Wildfire Management Organization; Kamehameha Schools; the Oahu Army Natural Resources Program; the Pacific Disaster Center; University of Hawai'i Cooperative Extension; the University of Hawai'i at Manoa; the U.S. Fish and Wildlife Service; and the USDA Forest Service and Natural Resources Conservation Service. The participants were divided into two groups to brainstorm and discuss any and all wildfire-related knowledge gaps and information needs for the region, categorized broadly into research and management needs. After about 40 minutes, the participants regrouped, outlined the topics brought up, and included any additional ideas raised.

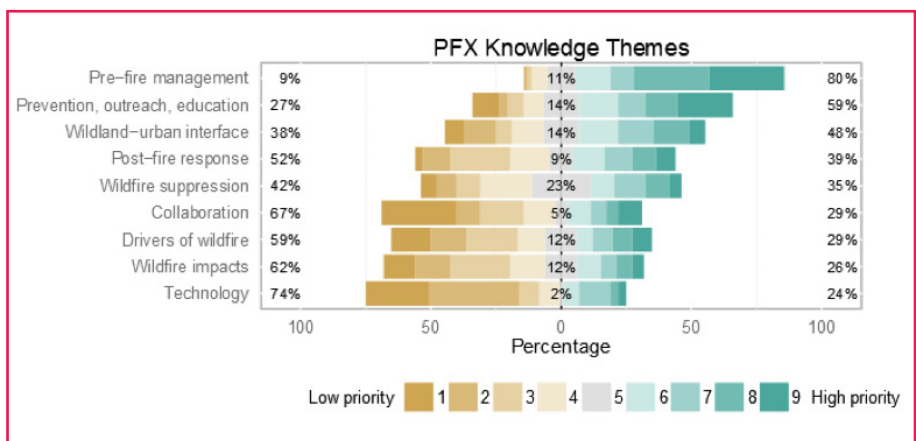


Figure 1—Stakeholder rankings (1 = low priority, 9 = high priority) of the nine Pacific Fire Exchange (PFX) Knowledge Themes that emerged from a PFX Advisory Panel workshop of key stakeholders in fire and land management and research for the Pacific Island region

After the workshop, we organized the resulting topics into a master list of 9 “PFX Knowledge Themes,” each with 5 to 10 subtopics (fig. 1). Given the diversity of needs identified, the PFX Knowledge Themes allowed us to structure stakeholder concerns in a manner reflecting the JFSP’s “lines of work” (http://www.firescience.gov/JFSP_line_of_work.cfm). This approach acknowledges that fire management problems are complex, require the integration of multiple information components, and demand a central role for stakeholders in defining information needs. The PFX Knowledge Themes also allowed us to identify how Pacific Island fire management needs align with the overarching goals of fire-resilient landscapes, fire-adapted communities, and improved fire suppression outlined in the National Cohesive Strategy for Wildland Fire Management (Jewell and Vilsack 2014).

Prioritizing Knowledge Themes

After the PFX Knowledge Themes and corresponding subtopics were outlined, we asked stakeholders to prioritize the development of knowledge exchange products and activities from the list. We sent out a survey (using [kwiksurvey.com](http://www.kwiksurvey.com)) in February 2014 and received responses from 66 participants, who gave their relevant work field(s) as land management (70 percent); fire response (17 percent); research (23 percent); agriculture/ranching (12 percent); outreach/education (23 percent); planning (17 percent); and other (11 percent). The respondents also designated their work area as a single

Among the main Knowledge Themes, Pre-Fire Management was ranked the highest priority by far among information needs.

Hawaiian island (50 percent); all Hawaiian Islands (22 percent); Hawai’i and the U.S.-affiliated Pacific Islands (22 percent); and the U.S.-affiliated Pacific Islands only (6 percent).

Respondents were given a brief explanation of the nine PFX Knowledge Themes and then asked to rank them in order of importance to their work areas. For the Pre-Fire Management Knowledge Theme, for instance, we gave examples of the subtopics within the theme, such as fuels reduction, fuelbreaks, and prefire planning. We then asked participants to separately rank all subtopics identified within each Knowledge Theme in order of importance.

Survey Highlights

Among the main PFX Knowledge Themes, Pre-Fire Management was ranked the highest priority by far among information needs (fig. 1), reflecting the interest

in proactive land management strategies to reduce wildfire risk. The top-ranked subtopics for this particular theme included Firebreaks and Fuelbreaks, Community Wildfire Protection Plans, Greenstrips or Living/ Shaded Fuelbreaks, and Pre-Fire Planning for Land Managers (fig. 2). Prioritizing these subtopics not only helps focus future PFX product development but also allows for the identification of research needs based on the availability of existing information. For example, resources are available for prefire planning and fuelbreak placement and specifications even in tropical nonnative grasslands. By contrast, the design of greenstrips might differ greatly on the Pacific Islands from temperate continental systems, where most existing information comes from. The differences might be in terms of management objectives (such as shading out tropical grasses) and the species that are best suited for this use.

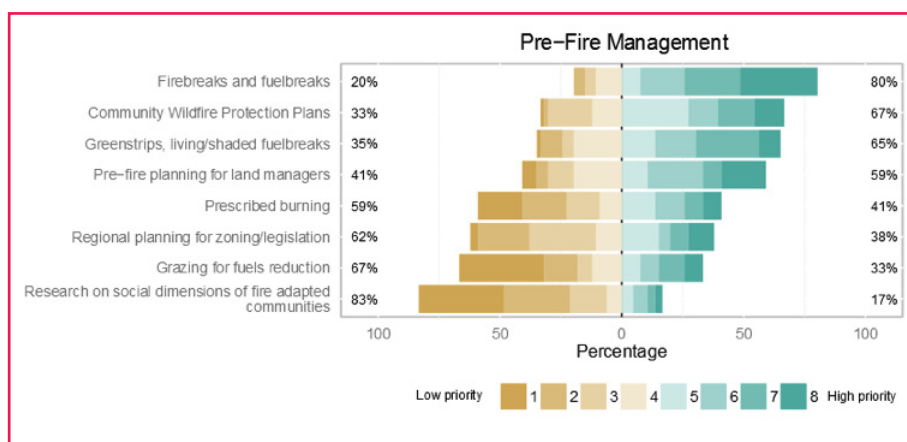


Figure 2—Stakeholder rankings (1 = low priority, 8 = high priority) of the eight subtopics organized within the Pre-Fire Management Knowledge Theme.

The next two highest ranked Knowledge Themes were Prevention/Outreach/Education and the Wildland–Urban Interface (WUI). These priorities highlight the recognition that human dimensions and social issues are critical to improving fire management on Pacific Islands. The vast majority of wildfires in the Pacific Island region are human caused (see, for example, Trauernicht and others 2015), yet no research available for the region examines social questions such as risk perception or the effectiveness of fire prevention messaging.

Wildfire Preparedness Materials and Workshops were ranked highest among the subtopics within the Prevention/Outreach/Education Knowledge Theme. These priorities highlight the importance of efforts to engage communities in fire issues through organizations such as the Hawai'i Wildfire Management Organization. There is also a need to integrate local contexts and cultural perspectives into wildfire outreach information. For example, the Hawai'i Wildfire Management Organization collaborated with the University of Hawai'i Cooperative Extension program to put together images and data from a PFX synthesis of Hawai'i's fire history for the production of a Ready, Set, Go! guide for wildfire preparedness specific to Hawai'i.

The high priority given to prefire management and WUI issues in Hawai'i and the Pacific Island region also attests to the need to develop regionally relevant information. On the U.S. mainland, for instance, wildfire risk increases as development pushes into native fire-prone

habitats; by contrast, wildfire risk in Hawai'i's WUI is primarily linked to the expansion of nonnative fire-prone vegetation and the abandonment of agricultural lands around existing communities. Identifying these issues also indicates how the dissemination of existing resources can be prioritized. For example, statewide community hazard maps are now available through the Hawai'i Wildfire Management Organization (<http://www.hawaiiwildfire.org/wildfire-hazard-assessments>), providing a perfect opportunity to develop strategies for effectively delivering this resource to interested stakeholders.

Wildfire preparedness materials and workshops were ranked highest among the subtopics within the Prevention/Outreach/Education Knowledge Theme.

The need to address local issues is also related to the Wildfire Suppression Knowledge Theme. Hawai'i's novel fuel types and sharp gradients in rainfall and elevation present unique challenges that confound many of the predictive tools applied in the continental United States. In particular, nonnative grasslands in Hawai'i attain incredibly high fine fuel loads (that is, 7 to 15 tons per acre (15,685–27,885 kg/ha)) and cover vast expanses due to widespread abandonment of

agricultural lands (Trauernicht and others 2015). These concerns were also reflected in the top-ranked subtopics within the Drivers of Wildfire Knowledge Theme: Vegetation and Fuels, Effects of Different Land/Resource Uses, Fire Behavior, and Introduced Species.

For the Post-Fire Response Knowledge Theme, Preparedness for Post-Fire Conditions ranked highest among subtopics, reflecting the challenges in Hawai'i and other Pacific Islands of obtaining sufficient quantities of native plant material for site rehabilitation and of using wildfires as restoration opportunities (Loh and others 2009). The low ranking of Wildfire Impacts among the PFX Knowledge Themes may reflect a general understanding that wildfires largely have negative impacts on Pacific Island landscapes and that there is greater need for information on how to proactively mitigate those impacts. Among Wildfire Impact subtopics, Addressing Watershed and Landscape Spatial Scales ranked highest, followed by Native Habitat and Species and by Soils.

Lessons Learned

The PFX Knowledge Themes emerged intuitively from the topics identified by the PFX Advisory Panel. However, asking respondents to sort more than five items can limit any meaningful distinctions among the “middle ground” categories. Therefore, the survey for ranking subtopics within each PFX Knowledge Theme might have been more effective had we asked participants to score the importance of each subtopic individually (such as on a Likert scale of 1 to 5).

Yet a conservative interpretation focused on the top and bottom rankings still affords a clear understanding of stakeholder priorities. In addition, initially dividing the PFX Advisory Panel into separate discussions on research and management might not have served our objectives and was likely unnecessary, given the considerable overlap in participant contributions between these two categories. Finally, we highly recommend the use of “diverging stacked bar charts,” as shown in figures 1 and 2, to effectively visualize, interpret, and communicate the types of data produced by stakeholder assessments (Robbins and others 2011).

The dual-stage approach employed here to identify stakeholder needs was a productive way to engage partners and effectively identify fire management needs in the Pacific Island region. Drawing on decades of collective experience in wildland fire research, management, and response among key stakeholders on the PFX Steering Committee and Advisory Panel helped rapidly identify the major areas of concern. Structuring these needs across the PFX Knowledge Themes streamlined the prioritization process involving a wider group of stakeholders who are concerned about fire but may lack the expertise to identify the full range of fire-related needs.

The initial outcome for the PFX is a “roadmap” for guiding the development and dissemination of best practices for fire management over the coming decade. This information will also allow PFX project leaders and others to assess whether and

how stakeholder needs change as communication and information availability improve. Finally, this process established the importance of stakeholder input for PFX products and activities at the outset and set a precedent for maintaining feedback and building relationships that will increase the impact and application of fire science moving forward.

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FIRE CONTROL AND THE 2015 CANYON CREEK COMPLEX FIRE

Hutch Brown

Fire control—the notion that all wildland fires can and should be quickly controlled, with fire largely excluded from the landscape—is ingrained in public expectations of government in the United States. A review of the issue for the International Code Council summarized the thinking of many homeowners in the wildland–urban interface (WUI):

In the event that a wildland fire should break out near your peaceful sanctuary, government firefighting agencies will respond with “quasi military” might. You won’t see a bill for their services. And if your home burns down, insurance money will build you another ... coupled with the “it won’t happen to me” syndrome, [is] one of the explanations why so many are making the decision to live in these areas (Bailey 2007).

A False Sense of Security

In fact, the chance of any given home in the WUI burning down in a wildfire in any given year is negligible. From 2010 to 2016, for example, 3,754 structures burned on average in wildfires each year (NICC 2017), whereas the WUI nationwide had 43.8 million homes (Martinuzzi and others 2015).

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Arguments on both sides focused on wildland firefighting, with few questions asked about how well prepared homes were.

Accordingly, the average annual risk of a wildfire destroying a home in the WUI was less than 1 one-hundredth of 1 percent.

Of course, the risk is much higher in fire-prone parts of the South and West, but so are expectations that government firefighters will come to the rescue (NWCG 2001; Pyne 2015; Stein and others 2013). Confident that they can shape wildlandscapes to their liking, people have bought homes in the WUI believing that wildfires could be controlled (Bramwell 2014; Gorte 1995). They did so in part because the Forest Service had told them so. For most of its history, the agency waged a relentless war on wildfire (Pyne 1982, 2001, 2015), “creating a false sense of security and outsized expectations from homeowners” (Bramwell 2014).

The expectations persist. During fire season, the prevailing mindset in the public, the media, and the Forest Service alike revolves around wildland fire suppression, despite the limitations of fire control—and despite the responsibility of homeowners for treating fuels in and around their homes. So when

disaster strikes and homes burn down, the natural reaction is to blame the Forest Service for fire control failure and for the Forest Service to blame fuels, weather, insufficient resources—anything but the susceptibility of the homes themselves to ignition and destruction.

Investigative Report

A classic case was an instance of investigative reporting on the Forest Service’s response to a disastrous wildfire in Oregon in 2015 (Gunderson and Sickinger 2016). On August 12, under severe drought conditions, lightning ignited fires on the Malheur National Forest, which lies in the spectacular Blue Mountains about 5 miles (8 km) south of the town of John Day in eastern Oregon (fig. 1). Driven by high winds, the fires burned together to form the Canyon Creek Complex Fire. Vigorously fought from the start, the fire was finally declared controlled on November 5, but not before it had spread across 110,261 acres (44,621 ha) and destroyed 43 homes and at least 100 outbuildings. It was the most homes destroyed by a wildfire in Oregon since the Bandon Fire in 1936.

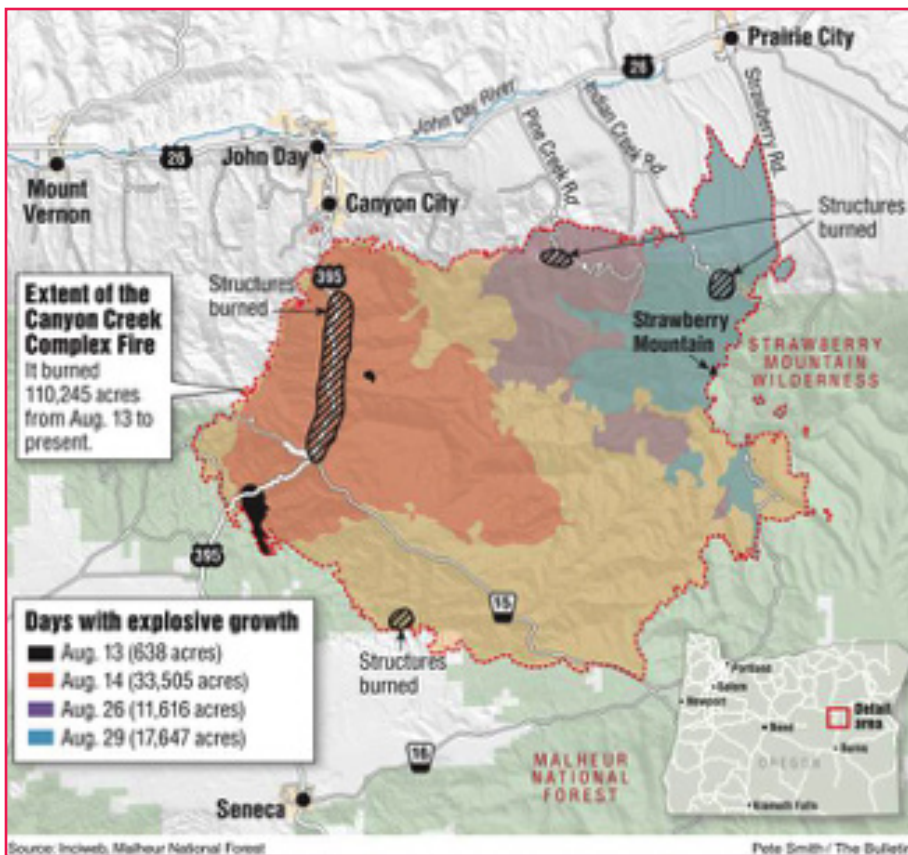


Figure 1—Fire perimeter (dotted red line) of the Canyon Creek Complex Fire, August 12 to November 4, 2015. Structures burned included 39 homes along U.S. Route 395 during the first major fire run (August 14) and 4 homes along Indian Creek Road during the third major fire run (August 29). Although the fire burned structures along Pine Creek Road during the second major fire run (August 26), no homes were lost in the Pine Creek community, which had an active Firewise program. Source: Blue Mountain Eagle (2016).

Most of the damage was in a scenic canyon along U.S. Route 395 (fig. 1), which follows Canyon Creek north to John Day. Canyon Creek reaches deep into the interior of the Blue Mountains, and its canyon floor was historically an open woodland made up of conifers (ponderosa pine, western larch, and Douglas-fir), with frequent fire return intervals (0 to 30 years) and low-severity fires. A century of fire control had left the area overgrown by dense mixed-conifer forest, with many missed fire return intervals and the threat of an uncharacteristically severe fire.

Much of the Malheur National Forest is part of a large-scale, long-term restoration project

(the Southern Blues Restoration Coalition Project) under the Forest Service’s Collaborative Forest Landscape Restoration Program. As part of the restoration project, the Canyon Creek area had been scheduled for thinning treatments, followed by the reintroduction of low-severity fire (MNF 2016).

Fire Control Failure?

The Canyon Creek Complex Fire preempted many of the planned restoration treatments, highlighting delays associated with collaborative projects, environmental analysis under the National Environmental Policy Act, and a lack of sufficient Forest Service funding for ecological

restoration (Brown 2016). But the investigative reporters focused almost entirely on wildland fire suppression, blaming “poor planning and tactical errors” for a “monster wildfire that could have been tamed” (Gunderson and Sickinger 2016). Setting the theme for the article, the reporters quoted a distraught homeowner: “They should have put this fire out.”

That judgment was followed in the article by a litany of complaints about the Forest Service, such as failing to hoard firefighting resources for local use, using excessive caution to protect firefighter safety, and conducting morning briefings instead of fighting the fire (Gunderson and Sickinger 2016). In response, the Forest Service noted that the Pacific Northwest Region was dealing with 88 new fires at the time, including 17 uncontained large fires and 12 new fire starts on the Malheur National Forest alone. Accordingly, all incident management teams in the region were overtaxed and understaffed.



Forest Service Chief Tom Tidwell and Oregon Governor Kate Brown at a briefing on the Canyon Creek Complex Fire on August 19, 2015. Source: NWCG (2016); photo: Lori Iverson, U.S. Fish and Wildlife Service.

Forest Service Chief Tom Tidwell, who came to the Canyon Creek Complex Fire for briefings, later emphasized the difficulty of making wildland firefighting decisions during “a record year for large, hot, destructive, and costly wildfires” (Tidwell 2016). A Forest Service report called the 2015 fire season in the Pacific Northwest “the most severe in modern history from a number of standpoints,” including the number of wildfires (3,800) and the extent of the area burned (1.6 million acres (0.6 million ha)) (Blue Mountain Eagle 2016).

Homes Unprepared

Whatever their merits, the arguments on both sides focused on wildland firefighting, with few questions asked about how well prepared homes in the Canyon Creek WUI were for surviving a megafire like the Canyon Creek Complex. For an investigative report that was months in the making, that is surprising because

Grant County—where the fire took place—had signed a community wildfire protection plan in 2013 (Jerome 2013).

The countywide plan was designed to encourage individual communities to adopt plans of their own or to become Firewise communities. Whether the community along Canyon Creek had taken corresponding steps is unclear; none were reported (Gunderson and Sickinger 2016), and apparently some homes were unprepared (fig. 2). For example, one homeowner tried to defend his home with a hose until “the pine tree next to the house suddenly burst into flames, sending a ball of super-heated gases under the eaves” (Gunderson and Sickinger 2016). That home, bordered by a combustible pine, went up in flames.

By contrast, the John Day community of Pine Creek, registered in the Firewise Community Program since 2014, survived the Canyon Creek

Complex Fire unscathed, with no homes lost (NWCG 2015; Zaitz 2015). The community members had pruned, mowed, thinned trees, and improved local access routes. They had located water sources and set up sprinklers. Before the fire made a run toward their community on August 26, they had evacuated their homes. Upon returning, they found that the fire had bypassed their homes, which engine crews from fire departments in the John Day area could protect by extinguishing spot fires. Every home had survived.

The Firewise success story was reported at the time by *The Oregonian* (Zaitz 2015), the same paper that carried the subsequent investigative report (Gunderson and Sickinger 2016). Yet the investigative reporters made no mention of the Pine Creek story, focusing instead on the Forest Service’s supposed failure to prevent the destruction of homes along Canyon Creek.

Safety First

Sensational reporting about “monster fires” notwithstanding, the Canyon Creek Complex Fire was neither unusual nor unexpected, given regional drought and decades of fuel buildups. Canyon Creek was only the latest in a series of 13 megafires in Oregon since 2000 (see the sidebar), several of them much larger than Canyon Creek. The only thing distinctive about Canyon Creek was the number of homes burned.

Extinguishing the fire in the first day or two would have done nothing to alter the explosive burning conditions; it would have only postponed the



Area of dense vegetation and uncles ladder fuels allows for crown fire.

Figure 2—Area of dense vegetation and uncles ladder fuels allows a crown fire around a home. Source: NWCG (2016); photo: Forest Service.



Homes with trees widely spaced and pruned up high provide defensible space.

Home that is firesafe, with enough defensible space. Source: NWCG (2016); photo: Forest Service.

Megafires in Oregon, 2000–2015

2015

| | |
|---------------------------|---------------------------|
| Canyon Creek Complex..... | 110,261 acres (44,621 ha) |
| Comet–Windy Ridge | 102,089 acres (41,314 ha) |

2014

| | |
|----------------------|----------------------------|
| Buzzard Complex..... | 395,747 acres (160,153 ha) |
|----------------------|----------------------------|

2012

| | |
|-----------------------|----------------------------|
| Long Draw | 557,628 acres (225,664 ha) |
| Miller Homestead..... | 160,853 acres (65,095 ha) |

2011

| | |
|--------------------|----------------------------|
| High Cascades..... | (108,154 acres (43,768 ha) |
|--------------------|----------------------------|

2007

| | |
|---------------------|---------------------------|
| Egley Complex | 140,359 acres (56,809 ha) |
|---------------------|---------------------------|

2006

| | |
|------------------------|---------------------------|
| South End Complex..... | 117,553 acres (47,572 ha) |
| Columbia Complex | 109,259 acres (44,216 ha) |

2002

| | |
|------------------------|----------------------------|
| Biscuit..... | 500,068 acres (202,370 ha) |
| Tool Box Complex | 120,085 acres (48,597 ha) |

2001

| | |
|------------------------|---------------------------|
| Lakeview Complex | 179,400 acres (72,601 ha) |
|------------------------|---------------------------|

2000

| | |
|--------------|---------------------------|
| Jackson..... | 108,000 acres (43,706 ha) |
|--------------|---------------------------|

Source: NIFC (2016).

inevitable. After winds drove the fire out of control 2 days after it started, firefighters did what they normally do on large wind-driven fires: they stopped trying to control the fire and started protecting points of value, such as infrastructure and individual communities, by evacuating large areas and using backfires and burnouts to “herd” the fire around sensitive points. Despite the steep and difficult terrain and the extreme fire behavior—such as multiple fire runs across more than 10,000 acres (4,000 ha) in a single burning period (on August 14, 26, and 29)—nobody was seriously hurt on the fire, a remarkable success; safety is the first priority on any fire.

After burning through the Canyon Creek area on August 14, the fire threatened other WUI communities, yet no more than a handful of homes were lost (fig. 1), partly due to successful point protection by firefighters. And as the fire spread into the backcountry, it burned areas long overdue for a wildland fire, restoring fire to vast areas of fire-adapted forest that desperately needed it—a beneficial effect of any large fire like Canyon Creek.

Lessons Learned

In short, the Canyon Creek fire disaster was not a lesson in suppression gone awry but in WUI fuels done wrong—and done right by the Pine Creek community. Sooner or later, fire-adapted landscapes in places like the Blue Mountains will burn. The best way of protecting the WUI on their outskirts, in Oregon and elsewhere across the country, is for homeowners to take responsibility for altering the fuels in and around

their own homes (Calkin and others 2014; Cohen 2000, 2008, 2010; Reinhardt and others 2008).

Clearly, wildland fire suppression is often needed to protect homes, communities, infrastructure, and other values. But the fire control mindset of so many in the public—and in the wildland fire community—is a holdover from a bygone era. Based on wishful thinking about conditions that no longer exist (if ever they did), it distracts from what actually needs to be done: managing fuels within a 100-foot (30-m) home ignition zone so that a home in the WUI can survive even a severe wildland fire (fig. 3).

The community of Pine Creek, registered in the Firewise Community Program since 2014, survived the Canyon Creek Complex Fire unscathed, with no homes lost.

Wildland fire organizations can help by featuring Firewise success stories, acknowledging the corresponding accomplishments, and giving awards. Organizing an event featuring the Firewise community of Pine Creek, for example, might have shifted the focus and changed the story of the Canyon Creek Complex Fire, saving firefighters from undeserved blame. ■

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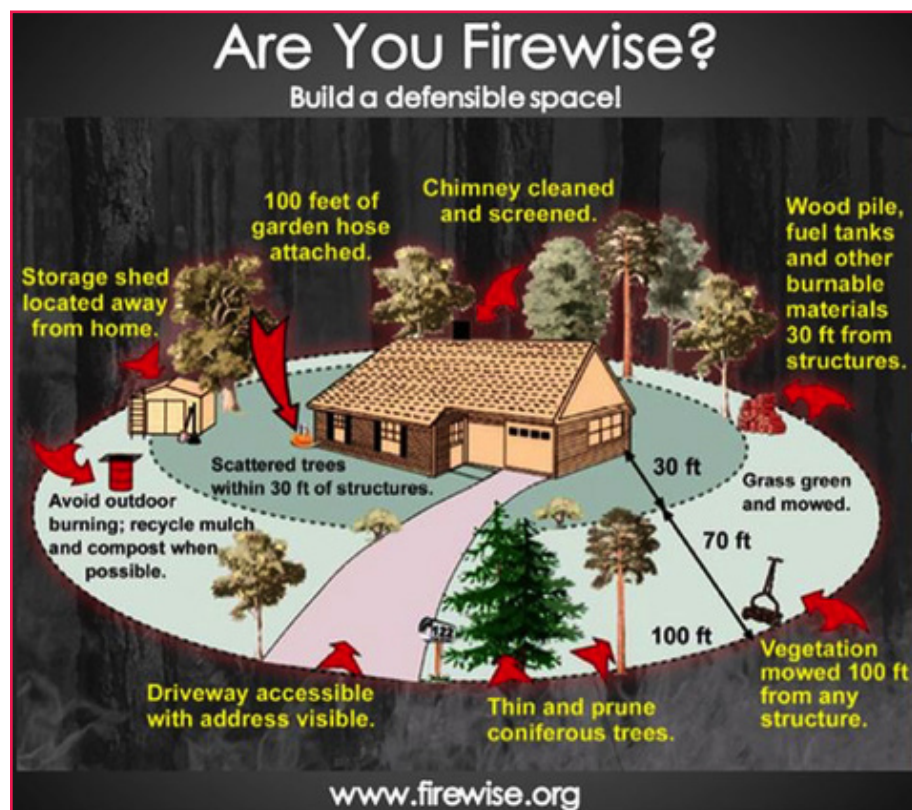


Figure 3—Measures for managing fuels within a 100-foot (30-m) home ignition zone, as prescribed by the Firewise program. Source: Gabbert (2015).

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THE ROLE OF TRUST IN HOMEOWNER FIREWISE ACTIONS*

Josh McDaniel



Consider this situation: A homeowner living in the fire-prone wildland–urban interface is told by a Forest Service community outreach representative that she should replace the windows in her house with double-paned tempered-glass windows to increase fire resistance. This renovation will likely cost thousands of dollars. However, the representative has presented a great deal of convincing data on the effectiveness of this step in reducing the risk that the home will be destroyed by fire.

How much does the homeowner trust the information presented? How much does she trust the competency of the agency involved? How does trust influence her decision to take the step or not?

These are the questions that James Absher and Jerry Vaske asked in a recent study published in the *International Journal of Wildland Fire* exploring linkages in measures of trust and specific Firewise actions taken by homeowners (Absher and others 2009). According to Absher, trust is always identified by Federal agencies as a critical component in working with communities and individuals on fire risk mitigation on their homes and properties, but

*The piece, published in spring 2011, is adapted from *Advances in Fire Practice*, a website maintained by the interagency Wildland Fire Lessons Learned Center.

it is important to link the abstract concept of trust to specific actions and behavior on the ground.

“Trust is complex and the situations in which it acts are complex,” said Absher. “It is important to pull back and see which aspects of trust are important, and in what ways.”

Absher and Vaske conducted a mail survey of rural landowners in heavily forested counties along the Front Range of Colorado. They asked questions designed to measure respondents’ trust in (1) the information that the Forest Service provided regarding forest fires, and (2) the agency’s competency in responding to fires and conducting other land management activities (specifically, prescribed burns and thinning).

Trust in Forest Service information and competence was relatively high among the respondents.

Next, respondents were asked about (1) the perceived effectiveness of a set of Firewise actions, (2) previous Firewise actions they had taken, and (3) their intentions to complete Firewise actions in the future. The Firewise actions covered

steps designed to increase the fire resistance of the home (such as using fire-resistant building materials, cleaning roofs and gutters of ignitable material, and moving firewood and lumber away from the structure) and to protect their properties (such as planting fire-resistant species, moving plants away from the home, and increasing spacing between plants).

The survey yielded an interesting set of results. First, trust in Forest Service information and competence was relatively high among the respondents: between 82 percent and 87 percent trusted the information, and between 64 percent and 85 percent agreed that Government agencies competently handled fires and fuels projects. Second, respondents perceived the surveyed Firewise actions as effective in reducing fire risk, and most had taken at least a few of the steps and intended to take further actions.

However, Absher and Vaske went further and analyzed the relationship between the trust factors and past and intended actions. They found that the perceived effectiveness of actions predicted most of the recent Firewise actions and that past Firewise actions were the greatest predictor of future actions. As measured, trust factors had little observable influence on either past actions or intended actions.

Getting people to take minimal Firewise steps can lead to further, more significant actions in the long term.

Absher said that the practical lesson to be drawn from this study is that efforts designed to get people to take at least the minimal Firewise steps can lead to further, more significant actions in the long term. He also said that the findings do not discount the value of trust in affecting homeowner decisions. Specific communities may have very different pathways to mitigating losses of homes to wildfires.

“This study shows that residents’ trust of agency recommendations is often strong,” said Absher. “If you don’t have trust, you may need to establish it before you can convince people of the effectiveness of some of these actions. But once you have it, you still have work to do in order to change behaviors.” ■

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50TH MEETING OF THE NORTHEAST FOREST FIRE SUPERVISORS



Maris G. Gabliks

In June 2016, the Northeast Forest Fire Supervisors (NFFS) held their 50th annual meeting in King of Prussia, PA. The NFFS, made up of State forest fire supervisors from the 20 Northeastern States, operates as a committee of the Northeastern Area Association of State Foresters. The group works closely with the Forest Service and other Federal partners in coordinating and encouraging forest fire protection and management activities across the 20-State area.

In their 2016 meeting, the attendees discussed critical wildland fire management issues. They also participated in a wildland fire leadership staff ride in Pennsylvania's Valley Forge National Park that culminated in a visit to historic Philadelphia. The staff ride and Philadelphia visit were both facilitated by the U.S. Army Combat Studies Institute and the Forest Service's Northeastern Area.

Created in 1966, the NFFS held its first meeting in Philadelphia, PA, on January 17–19, 1967. The organization was originally named the Northeast Forest Fire Control Supervisors, and its members were the forest fire control supervisors from the 20 Northeastern

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State wildland fire supervisors—members of the Northeast Forest Fire Supervisors (NFFS)—pose for a photo during a 2012 meeting in Connecticut under the theme “Improving Fire Management Programs.” Photo: Maris Gabliks, Forest Service.

States—the lead individuals in the State forestry programs who oversaw wildland fire control and fire management. The original executive committee consisted of three State forest fire supervisors, the Forest Service's Chief of Fire Control for the Eastern Region, and the Chief of Fire Control from the Northeastern Area's office for State and Private Forestry.

The original purpose of the organization was to improve efficiency in the protection of rural areas and wildlands from damage by fire.

The original purpose of the organization was to improve efficiency in the protection of rural areas and wildlands from damage by fire. Its objective was the least number of fires possible, with the least damage and cost. Accordingly, the organization stimulated the development and use of specialized forest fire equipment; better techniques in fire prevention, presuppression, and suppression; and improved training and safety methods.

In the mid-1970s, the organization changed its name to the Northeast Forest Fire Supervisors to better reflect its responsibilities in forest fire management beyond just fire control. In 2006, the NFFS became a committee of the Northeastern Area Association

In the mid-1970s, the organization changed its name to the Northeast Forest Fire Supervisors to better reflect its responsibilities in forest fire management beyond just fire control.

of State Foresters to better coordinate activities among all forest-related committees operating in the Northeast.

Over the years, the NFFS has played a role in developing such wildland fire management programs as the Roscommon Equipment Center partnership with the State of Michigan in 1971; the North East Area Training committee concept in 1984; and the Northeastern Area States Aviation Committee in 1997. All have played a national role in wildland fire management. Since 1967, the NFFS has had various working committees on topics such as film, research,



At the 50th NFFS meeting, the U.S. Army Combat Studies Institute hosted a leadership staff ride at Valley Forge National Park in Pennsylvania. The staff ride included wildland fire management topics and leadership issues related to military leadership and management. Topics included training, logistics, and leadership. The session was based on the Continental Army's encampment during the winter of 1777. Photo: Maris Gabliks, Forest Service.

aviation, railroads, training, mobilization, fire prevention, public information, equipment development and testing, and the wildland–urban interface.

Today, the NFFS Leadership Team consists of four State fire supervisors, a State Forester liaison, and a liaison from the Northeastern Area's Fire and Aviation Management staff. The

NFFS also works closely with representatives from the Western Fire Managers and Southern Fire Chiefs and with the National Association of State Foresters Fire Director in addressing wildland fire management on a national level. For 50 years, the NFFS has been and continues to be a leader in wildland fire protection across the Northeast and the entire United States. ■

GUIDELINES FOR CONTRIBUTORS

Fire Management Today (FMT) is an international quarterly magazine for the wildland fire community. The purpose of FMT is to share information and raise issues related to wildland fire management for the benefit of the wildland fire community. FMT welcomes unsolicited manuscripts from readers on any subject related to fire management.

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