Fire Management today

Volume 72 • No. 4 • 2013

Getting It Done

United States Department of Agriculture
Forest Service

Fire Management Today is published by the Forest Service of the U.S. Department of Agriculture, Washington, DC. The Secretary of Agriculture has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department.

Fire Management Today is for sale by the Superintendent of Documents, U.S. Government Printing Office, at:
Internet: bookstore.gpo.gov Phone: 202-512-1800 Fax: 202-512-2250
Mail: Stop SSOP, Washington, DC 20402-0001

Fire Management Today is available on the World Wide Web at <http://www.fs.fed.us/fire/fmt/index.html>.

Tom Vilsack, Secretary
U.S. Department of Agriculture

Melissa Frey
General Manager

Thomas L. Tidwell, Chief
Forest Service

Tom Harbour, Director
Fire and Aviation Management

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

April 2013

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

Fire Management today

Volume 72 • No. 4 • 2013

On the Cover:

The Mormon Lake Hotshots eating a late night dinner back at spike camp after completing a burn operation on a section of line on the Whitewater-Baldy Complex. This is the Prior Cabin Coyote Spike in the Gila Wilderness, New Mexico, June 06, 2012.
Photo by Kari Greer

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.

Contents

Short Features

Anchor Point

by Tom Harbour
Director, Fire and Aviation Management
Forest Service

Wildland Fire Management Organization—Part of a Great Organization!

When I talk about the wildland fire management organization, what do I mean? Am I talking about the Forest Service wildland fire and aviation management organization? Sure. But, it is so much more.

The national wildland fire organization has a base that surpasses the Forest Service where success is predicated on the profound foundation of partnerships between Federal, Tribal, State, and local agencies; nongovernmental partners; and the public. We cannot be successful without our partners; we cannot be successful without looking at the bigger picture, outside our national forests and grasslands.

The national wildland fire organization has a base that surpasses the Forest Service where success is predicated on the profound foundation of partnerships between Federal, Tribal, State, and local agencies; nongovernmental partners; and the public.

Regardless of agency or level of the government, budgets are austere at best. If we are to make a difference to change and improve conditions at a national scale, our future will go far beyond funding. The future crosses over to the work there is to do across jurisdictions and at a landscape level. We have all heard the adage, "we need to learn to do more with less." What is true is that together, we can do more.

We have a great foundation–there is no better example of agencies working together as one than the wildland fire organization where when the fire bell rings, we come together on the fireline or during an all-hazard incident. We are exemplary and are recognized as world leaders. But, we can do better. We need to think "outside the box." We need to leverage upon each other's successes and look for opportunities to work together with our partners off the fireline.

In recent years, we've gotten a good start. A few examples include:

- Implementing the Wildland Fire Suppression Doctrine: The implementation of the fire doctrine has enhanced our ability to make good decisions by using knowledge, experience, awareness, and the essential use of judgment.
- Creating and improving analytical tools: Analytical tools such as Fire Program Analysis (FPA) and the Wildland Fire Decision Support System (WFDSS) tools provide fire managers with the ability to make better, risk-informed decisions.
  – The FPA has a new, more defined scope and provides managers with a common, interagency process for strategic fire management planning and budgeting. FPA will be used to evaluate the effectiveness of alternative fire management strategies to support land management goals and objectives.
  – The WFDSS assists fire managers and analysts in making strategic and tactical decisions for fire incidents. It has replaced the Wildland Fire Situation Analysis (WFSA), Wildland Fire Implementation Plan (WFIP), and Long-Term Implementation Plan (LTIP) processes with a single process that is easier to use, more intuitive, linear, scalable, and progressively responsive to changing fire complexity.
  – Continuing National Cohesive Wildland Fire Management Strategy: The strategy is ongoing and has enabled collaboration at an all-time enhanced

level. The cohesive strategy has identified three major factors to successfully addressing the Nation's wildland fire management problems. They are to restore and maintain resilient landscapes, create fire-adapted communities, and respond to wildfire. The strategy recognizes that there is no one single answer and that no one particular agency, regardless of the level of government, can be successful alone.

> The problems experienced by this Nation are an "all-lands" problem–we cannot be successful alone; together we can do more.

Important to our continued success is the commitment of folks to work together to make our fire program an example of "good government" in action. We have the boots on the ground to make it work; we have the fire doctrine to help us make the good risk-informed decisions; and we have the analytical tools to help us, with science and practitioners engaged in the program. We have the "tools in the toolbox" to make us successful into the future. Now, it is up to us to look for opportunities to capitalize on our relationships, and by working together, achieve success. We are part of a great organization. I am proud of it and look forward to the challenges the future will bring. ■

Did You Know

The Forest Service headquarters building was first used by the U.S. Bureau of Engraving and Printing in 1880 to house the production of currency. Having outgrown the building, the bureau left in 1914 and, in the following years, several government agencies would call it home. Auditors from the Navy, Treasury, and State Departments were the first to use it, which gave this structure its name—the Auditors' Building. For many years during World War II, it was home to the Office of War Information.

In 1990, the Forest Service moved its headquarters into the newly renovated building. In October of 1994, the Forest Service opened the Information Center. In honor of Congressman Sidney R. Yates of Illinois and his support for environmental programs, Congress redesignated the building as the Sidney R. Yates Federal Building in 1999.

Fire Control Notes Offers Its Services

Roy Headley
Forest Service, Washington, DC

Fire Control Notes Offers Its Services (a *Fire Management Today* reprint from December 1936, Volume 1, Issue 1.)

Fire Management Today began in December 1936 as *Fire Control Notes*. As we approach our 77th year of existence, we would like to take a moment to republish part of the first article of Volume 1, Issue 1, which introduces *Fire Control Notes*. Many things have changed over the years, as you will see in reading this piece (such as authors and readers of 1936 being primarily addressed as men). However, we in Fire and Aviation Management and at *Fire Management Today* still endeavor to serve as a medium for the exchange of information and ideas between all groups and individuals who are doing creative work in wildland fire management.

The Fire Control Meeting at Spokane, Washington, in February, 1936 gave the Forest Service Division of Fire Control in Washington, D.C., a mandate to issue from time to time a publication which would serve as a medium for exchange of information and ideas between all the groups and individuals who are doing creative work in forest fire control. On the assumption that readers will respond with ideas and information to publish, the mandate is accepted.

Over a period of 30 years since the inception of the organized effort to stop the fire waste of American natural resources, impressive advances have been made. Considerable body of knowledge of the arts and sciences involved has accumulated. Systems of organizing and managing human forces and mechanical aids have in some instances attained dramatic efficiency. Fire research has won the respect of owners and managers of wild land. The advancement to date in technique entitles fire control to a place among the amazing technologies which have grown up in recent decades.

The advance of the technology of forest fire control is not, however, a completed thing. Its forward march has not even begun to slow down. On the contrary, there is good reason to anticipate a period of broader and more rapid growth. Fire control has won a large measure of public interest. Its relation to conservation of wild land resources is better understood. Financial support is increasing. A growing number of men are making technical contributions from a wider range ability and training. More men know more about how to climb to new plateaus of efficiency in stopping this fire waste.

Future advances will come not from the work of small groups, but from the experience, thinking, and experiments of the larger number of men now engaged in pushing back the frontiers of fire control. The integrated experience and study of such a body of interested men may easily yield results overshadowing all that has been gained so far.

The surprising thing is that the need for a vehicle for interchange of ideas among such men has not been recognized before. Widely scattered as they necessarily are, the creative efforts of individuals and separate groups cannot be fully effective without the aid of something which will serve as a common meeting ground, a clearing-house of developments. *Fire Control Notes* aspires to render that service. It hopes to be a carrier of whatever men need to know to keep abreast of developments and trends in fire control.

Fire Control Notes will seek to act as a channel through which useful or suggestive information may flow to each man in the field, whether he be a fire research worker attacking some fundamental of combustion, or a fire fighter, facing flame and smoke, who discovers some new device for organizing a crew of laborers. These pages will also hope to be used as a mouthpiece of every man, whatever his job, who discovers something which would be useful to others, or who has a criticism to make, a question to raise, or an unusual fire experience to relate….

The only requirement imposed upon contributions to *Fire Control Notes* is that they be interesting or helpful to some group of people concerned with some phase of fire control. ■

Ember Production During the Bastrop Complex Fire

Sean Rissel and Karen Ridenour

This study looks to build upon the already extensively studied area of firebrand (ember) generation in a wildfire setting. This phenomenon consists of firebrands lofted from burning vegetation and/or burning buildings, transported ahead of the propagating fire, and deposited on unburned fuel with some potential for igniting new fire (Foote et al. 2008). This event has been extensively studied by many different organizations across the globe and has been identified as an important mechanism for movement of fire in an uncontrolled setting (Koo et al. 2010, Pagni et al. 2000). While this mechanism of movement has been studied more elaborately in a controlled laboratory setting, there is less evidence of those findings to actual firebrand protection in an uncontrolled wildfire (Babrauskas 2003). This study is one of the few instances where actual data from a wildfire event has been collected to help understand their relationship to laboratory findings. While there is a great wealth of research concerning ember production, home susceptibility to ember intrusion is still considered to be a large factor in home loss during a wildfire event (Cohen 1991). Historically, firebrand ignition events in large-scale fires have been documented and recorded (Fradkin 2006, U.S. Department of Defense 1973).

As the human population expands and builds into previously uninhabited and densely vegetated areas, we've seen increased risk and realization of potential disastrous fire in this wildland-urban interface (WUI) setting (Manzello et al. 2006). The WUI currently has two accepted definitions. The Federal Register defines this event as follows: "The Urban Wildland Interface exists where humans and their development meet or intermix with wildland fuel." The National Wildfire Coordinating Group defines WUI as "the line, area, or zone where structures and other human development meet or intermingle with undeveloped or vegetative fuel." Unlike urban settings where residences are in the middle of a large city or town, these communities are nestled inside of large vegetative areas to the point where they are part of the "fire landscape," not separated from it. This setting increases the risk of larger impacts on these communities should a wildfire in the surrounding area occur (Foote and Cole 1993). The Texas Forest Service (TFS) in Bastrop, TX, is particularly focused on the quantifying of elements that increase the potential for home ignition in a WUI setting. The findings indicate there is a complex interaction of multiple factors about how susceptible a structure is to ignition from a wildfire. Included in these are physical landscape parameters such as slope and vegetative fuel loadings of the surrounding area. There are also homeowner-controlled factors such as proximity of vegetation to the primary structure, building materials of the structure, and aspects making the structure more susceptible to ember intrusion, such as vent and eave type. The National Institute of Standards and Technology (NIST) and the TFS have developed a two-tiered approach to enable the collection of reliable WUI post-fire data. The first tier, called WUI 1, is used to collect widespread fire data across the entire fire perimeter, while the second tier, WUI 2, focuses on specific communities of interest. By collecting and analyzing data from disparate WUI fire-affected communities across the United States, key vulnerabilities and common attributes in WUI fires might be identified. Trained TFS personnel implemented the WUI 1 methodology on the Bastrop Complex Fire. This team found

> While there is a great wealth of research concerning ember production, home susceptibility to ember intrusion is still considered to be a large factor in home loss during a wildfire event.

Karen Ridenour worked for the Texas Forest Service for 10 years doing fire research regarding home loss in the Wildland-Urban Interface. She currently teaches 8th grade science in hopes to educate future homeowners.

Sean Rissel is currently a FRAC field supervisor with Thomas Petroleum and was previously a Type I firefighter for the Texas Forest Service.

numerous instances where homes with masonry walls, metal roofs, and little direct fire impingement were still destroyed. These findings are contributing to the increasing belief that structure ignition from firebrands is much more numerous than previously thought (Foote et al. 1991, McArthur and Lutten 1991, Mitchell and Patashnik 2007).

Even with the soundest and most "fireproof" construction, exposure to overwhelming amounts of ember wash can compromise a structure. In theory, it only requires one small ember to pass through a vent into an area with combustibles (e.g., an attic with insulation or the drapes in a room) to ignite those combustibles and potentially destroy a home.

Recently, Manzello et al. developed the NIST Firebrand Generator (NIST Dragon) to investigate ignition vulnerabilities of structures to firebrand exposure (Foote et al. 2008). These detailed experiments are considered as a foundation for performance-based building standards with the intent of making structures more resistant to firebrand attack (Foote et al. 2008). The experiments developed and tested by NIST are helping to better quantify firebrand generation and mechanisms of firebrand attack. This information, however, needs data from real wildfire events to solidify their findings. The data collected for this paper will build upon previous findings, both in the lab and in the field, to better characterize firebrand size and density.

Bastrop Complex Fire Study Area, Weather, Fuels and Fire Behavior

The Bastrop Complex Fire was the most destructive fire in Texas history, and the third most destructive in the history of the United States. It was actually the result of three different ignitions in Bastrop County, TX, approximately 35 miles east of Austin, TX. This area is composed of sandy soils, drought-resistant subspecies of many plants, and topography from flat to rolling hills. The lost pines area, as it is called, is the westernmost distribution of loblolly pine (*Pinus taeda),* separated from most of its counterparts by 100 miles of agricultural land. All three ignitions occurred in the same vegetation type, Loblolly pine overstory and understory dominated by yopuan (*Ilex vomitoria*). All three reported ignitions occurred within 2 hours of each other and burned together over the course of 48 hours. By the end of the event, more than 32,000 acres were burned, an estimated 1.8 million trees were burned, and 1,696 structures were destroyed. The burned areas included a number of WUI subdivisions, unmanaged private lands, and 96 percent of Bastrop State Park. The impacted communities represented most conditions in any setting; some areas had extremely high-density of homes while others were more spread out. Among all of the communities, there were undeveloped and unmanaged lots that had higher fuel loadings than the surrounding lots.

The *Tropical Storm Type* critical fire weather pattern during the Bastrop Complex Fire was intensified by one of the worst drought seasons in recorded Texas history. On the morning of September 3, 2011, Tropical Storm Lee was just south of the central Louisiana coast and the counter-clockwise circulation was just beginning to result in northeast surface wind across most areas east of I-35 in Texas. Meanwhile, a well-defined, mid-level trough was moving across the Northern Plains States with an associated cold front having moved

Table 1.—*Field measurements surrounding each of the collected trampolines and information compiled from the Bastrop Complex Fire Case Study. * Denotes that this was where two flanking fires came together, acting like a head fire.*

Address	Slope in direction of the fire (%)	Distance to nearest structure (ft)	Direction of structure from trampoline	Distance to vegetation (ft)	Fire intensity	Canopy cover	Fire type
111 West Hilo Ct.	0	42.7	Northwest	13.12	Low	Open	Flanking
332 Kaanapali Ln.	5	27.2	Southwest	6.7	High	Medium	Flanking*
268 McAllister Rd.	0	14.4	West	3.3	Medium	Dense	Direct
350 McAllister Rd.	7	26.6	South	6.7	Medium	Medium	Flanking
104 Oak Shadows Dr.	5	39.7	East	16.4	High	Open	Flanking
126 Pine Shadows Ln.	0	27.2	South	90.9	High	Open	Direct
103 Poole Rd.	0	29.9	North	3.3	High	Medium	Flanking

east of the Rocky Mountains. Ahead of the front, temperatures were able to climb into the lower 100s, driving minimum relative humidity (RH) down to 20 percent in the Bastrop area. Tropical Storm Lee moved inland by late afternoon on September 4, but all precipitation remained east of I-45. High temperatures climbed, again, into the triple digits, and sustained winds of 12 to 14 miles per hour (mph) with gusts of 25 to 31 mph occurred near the time the fire started in Bastrop (Greg Murdoch, National Weather Service-Midland).

Live fuel moistures are measured every month across the State to help track changes in plant moistures. This information is also used by predictive services to predict increased probabilities of wildfires. During the Bastrop Complex Fire, the live fuel moistures were trending down to below historic lows in all vegetation types within the county.

- Pine—92 percent (August 15), 83 percent (September 15)
- Yaupon—62 percent (August 15), 52 percent (September 15)
- Juniper—78 percent (August 15), 54 percent (September 15)
- Post Oak—76 percent (August 15), 81 percent (September 15)

(Fuel moisture content is the percent of the fuel weight represented by water, based on the dry weight of the fuel.)

Because of reduced moisture, all vegetation would be more susceptible to combustion during a wildfire.

The Bastrop Complex Fire would experience intense spotting with reports coming in through 911 dispatch service of fires starting up to distance of 3 miles from the main fire front. Vertical vortex rolls were observed by on the ground firefighters and horizontal vortex rolls were visible in aerial reconnaissance showing characteristic long strips of unburned (or scorched) tree crowns within areas of severally burned vegetation throughout the fire perimeter. The main fire front traveled at a rate of 5 mph through pine, cedar yaupon mix mid-story, during the first several hours of the event. There was heterogeneous burning across the fire with some areas being lightly scorched and other areas completely consumed to the point that all nutrients were leached from the soil.

Methods

To date, only one other group has developed and utilized this methodology of ember measurement in the field. Foote et al. in 2008 used ember burns in lawn furniture and scarred trampoline surfaces to estimate ember production during the Angora Fire of 2007. In an effort to elaborate and build upon their techniques, this methodology is similar to theirs.

The team conducting post-fire assessments on structures within the burned area collaboration between NIST and TFS was also able to collect information on firebrand distribution and density. Because of the scale of this fire, post-fire assessments could not reasonably be conducted on all of the homes within the fire perimeter. Instead, four subsets within differing communities were selected based on a number of goals by the research team. For more information on these selections and other aspects of the Bastrop Complex Fire, please refer to the case study conducted by Ridenour et al. in 2012. The generation of this case study included a fire progression map for the first 12 hours from the time of fire ignition. As post-fire data was being collected, homeowners with trampolines were asked to donate their destroyed trampolines for measurement. Because of the material, firebrand burns (holes) in trampolines leave an identifiable footprint that can be counted and measured.

The team took panoramic photographs around the trampolines prior to their removal and after receiving the homeowner's approval. These photographs consisted of three sets of 360-degree photographs, with the first photo of each set taken while the photographer was facing north. The team shot photographs in overlapping frames so that in post-processing they could be threaded together into one picture. The team took one panorama looking at the canopy surrounding the trampoline and another looking at eye level. The team took the last photo after the trampoline was removed, standing inside of the frame and, again, looking at eye level. Not only are these photographs useful in documenting the location of the trampoline, they can also be used later to better describe the environment around the trampoline, even after clearing and reconstruction events have taken place. The team recorded other environmental factors at the time of trampoline collection and photo documentation. These include slope in direction of the fire, distance to structure, distance to trees/vegetation, fire intensity, and distance to steep slopes. They also recorded distance from the ground to the trampoline surface and a description of the framing material. All of the collected trampolines were 3 feet (0.9 meters (m)) from the ground and supported by metal springs attached to a metal frame. The team collected seven trampolines from locations across the fire. All of the trampolines were of the same material, and all had diameters of 12 feet (3.8 m). Condition of the trampolines ranged from good, where the entire border was intact, to poor, where anywhere up to almost half of the trampoline was destroyed beyond consistent measurement.

Site Description. As already mentioned, the team measured and photographed extensively each of the seven sites. For the sake of conciseness, all of measurements are condensed in table 1. The fire intensity and fire type are from information published in the Bastrop Fire Case Study. Also, these measurements are on a microscale, they only refer to the immediate area surrounding the trampoline. The lot and landscape-scale are most likely different from those reported here. Interestingly, four of the trampolines' addresses are almost in a straight line running from north to south, the same direction of the fire. The other three run relatively straight east to west (figure 1).

Post-Processing. After documentation and collection, the team took all of the trampolines back to a large area where they could be spread out completely. In order to achieve enough clarity of hole for image analysis, the trampolines had to be subdivided into quadrants. The team performed initial testing to determine what combination of light and level of zoom could be used to measure firebrands. After initial testing, they established that firebrands could be accurately measured within an area of 2.7 square feet (feet^2) (.25 m^2). Beyond that, the angle of the camera and its flash made the holes' photographed size unrepresentative of the actual size. Accordingly, the team segmented each trampoline into 54 quadrants using measuring tape and line chalk to create the quadrants, as seen in figure 2. They placed a large sheet to white paper underneath each trampoline to aid in photographing and developed a technique to help eliminate not only the glare of overheard fluorescent light, but also the patterns created by the trampoline weave on the ground. Photographers required two people: one used the digital camera and the other slightly elevated the trampoline segment so that it was just above the white paper. Using the flash on the camera highlighted the holes with the white paper and helped reduced the "dummy" holes caused by the trampoline weave. The photographers positioned the digital camera (Nikon D90) approximately 4.17 feet (1.27 m) above each quadrant and took three photographs of each. This process was repeated to help resolve focus issues that can sometimes arise when taking pictures. The team included a ruler on the border of each quadrant to give the image scale for analysis.

Image Recognition Software. In order to count and measure the firebrand marks in the most objective and repeatable manner, the team used ImageJ recognition software. This software is very powerful and has an immense variety of functions that can be used to edit, modify, and measure photographs. While the toolbar and its dropdown menus may seem daunting, the team created a relatively simple methodology and then repeated it for each picture. First, the team imported each photo into the ImageJ software using the "Open" function. Using the line tool and increasing the zoom, they created a line of known distance and set the scale under the "Analysis" function. By selecting "Global," this scale would be automatically set for all future pictures imported while the program is running. Because some pictures did require small adjustment based on changes in lighting or particular problematic frames, the analyst confirmed or readjusted the scale on every image. The ana-

Photo © Sean Rissel, Texas Forest Service. 2012

Figure 1.—*Map of fire perimeter with trampoline locations and ember count at each location.*

lyst then cropped each photograph cropped so that only the desired quadrant remained and is then converted to an 8-bit grayscale image. The most laborious part was adjusting the threshold so that only the firebrand scars were highlighted and not the woven material or other blemishes on the quadrant. The threshold works on the premise of identifying changes in color from one pixel to the next. The toolbar for adjusting the threshold of the photo is a sliding scale from 0 to 254. At a maximum, the team set the threshold for each photo to 51. However, other marks not resulting from firebrand burns will sometimes still be highlighted. Combined with verification from the original photographs, the analyst cropped these instances out as to not be included in the analysis and skew the results (figure 3). Because each photo has different properties, such as hole arrangement and folding creases, each image had to be treated separately and edited accordingly.

Depending on the amount of reflected light and other factors, some images prove to be more time consuming than others. After the team edited the image and confirmed that it represented the true image, they analyzed each quadrant and counted all thresholded firebrand scars and measured their areas. Testing prior to the experiment also demonstrates burns under.0003 square inches (inch^2) (.002 square centimeters (cm^2)) were uncommon and could not be distinguished from the holes created by the mesh threading of the trampoline. Therefore, the team filtered out any measured images below.0003 inch^2 (.002 cm^2) during analysis. The output also included outlines of all the measured firebrand marks; these were helpful in verifying that “true” holes were measured accurately (figure 4). The team copied outputs for each quadrant into Microsoft Excel© and combined them to create a single spreadsheet for each of the seven trampolines.

Results

The embers counted and measured by ImageJ analysis software ranged from a minimum of 882 to a maximum of 6,147. In four instances, the team documented extremely large holes whose origin of cre-

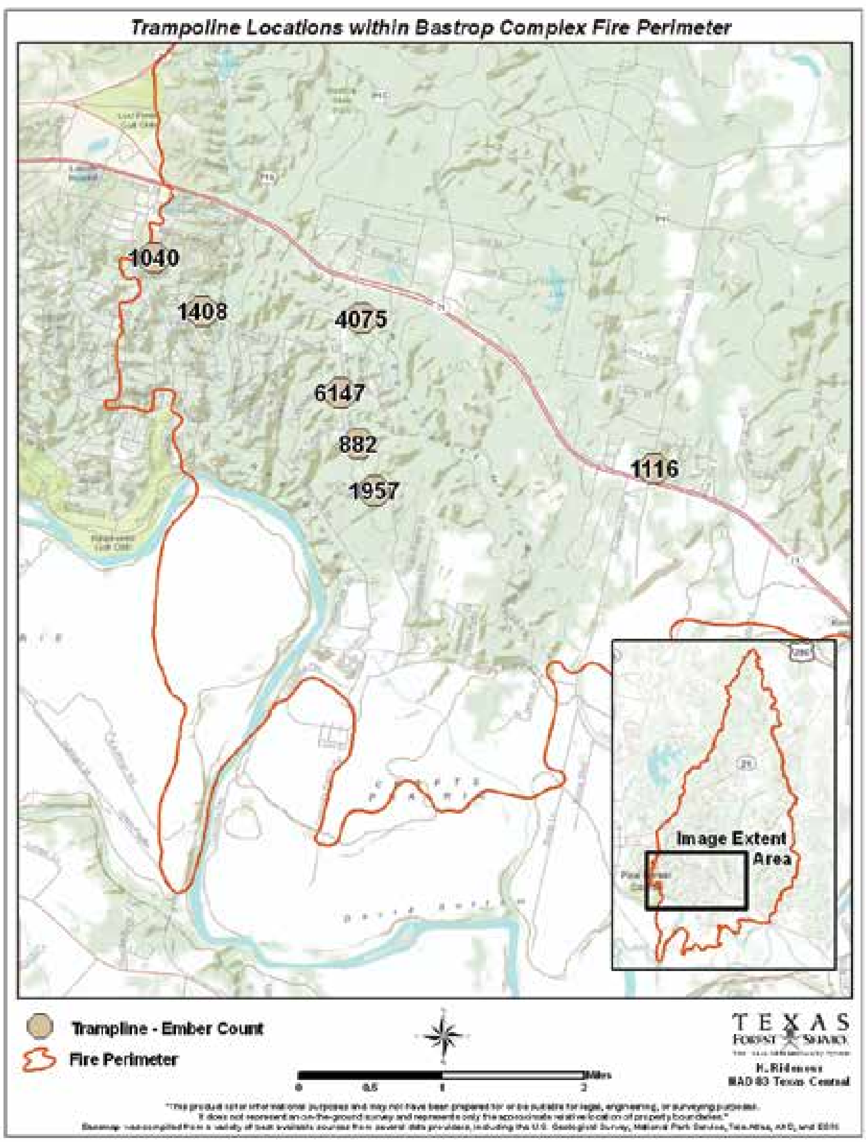


Figure 2.—*Image of trampoline divided into 54 quadrants.*

Photo © Sean Rissel, Texas Forest Service. 2012

Figure 3.—*Trampoline segment inverted and cropped to remove unwanted signatures from trampoline mesh.*

ation could not be determined. While they could have been the result of a large firebrand, they also could have resulted from burning debris underneath the trampoline or radiant heat exposure. Because of this, the team subtracted those measured areas from the calculated area of each trampoline when estimating ember density. In all seven cases, anywhere from 91 to 99 percent of measured firebrand holes were less than 0.5 cm. Figure 5 shows the pooled results of all of the data with more than 90 percent of the holes less than 0.5 cm^2 in size. The single largest hole in a trampoline base measured 27.25 $inch^2$ in total area, measured from the trampoline collected at 332 Kaanapali. Firebrand density ranged between 9 and 68 holes per square foot. Note that some of the trampolines had adjusted areas; firebrand density is believed to be an underestimate in some instances.

Photo © Sean Rissel, Texas Forest Service. 2012

Figure 4.—*Example of outlines of measured images generated by ImageJ.*

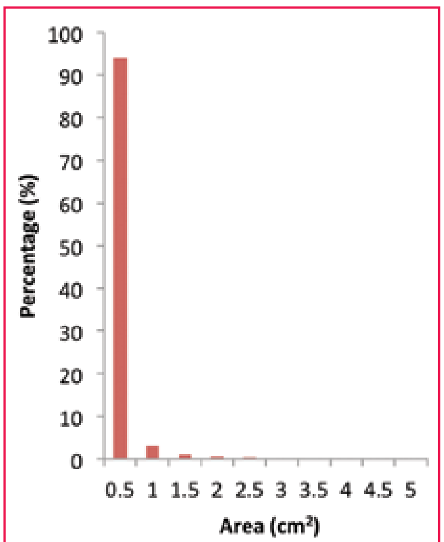


Figure 5.—*Distribution of burn patterns for all seven trampolines collected from Bastrop Complex Fire.*

Current wildfire building construction regulations recommend screens intended to protect against firebrand entry range in size from 1/16 inch (.03 cm^2) to 1/4 inch (.40 cm^2). There are no nationally recognized American building construction test standards or design practices for exterior wildfire or interface fire exposure protection (Foote et al. 2008).

Conclusions and Discussion

Although this study was only limited to the seven collected trampolines, the research results are able to give researchers more scientifically grounded estimates of ember production during the Bastrop Complex Fire. Similarly, these results confirm the findings by Foote et al. for the Angora Fire, where more than 85 percent of all ember holes measured were less than .05 cm^2 in area. Their study also included firebrands generated in the lab, where the majority of the firebrand sizes fell in this same range. Although these findings cannot be applied to every location of the fire, the location of the measured trampolines across the burned area does show that there was high production of firebrands at numerous locations across the fire. Differing amounts of ember production are consistent with the fire severity map; areas with more severe fire intensity also had more firebrands. The only home on the same parcel as the trampoline that was not destroyed was 350 McAllister, which also had the lowest recorded ember production.

The trampoline from 126 Pine Shadows Lane had the second highest amount of measured firebrands, yet it was located along a power line easement that was cleared of vegetation prior to the fire. Given what has been reported as fire spread from the north, firebrands would have traveled at least 90.9 feet from the woodline to land on the trampoline. Given the fire behavior during that fire, this estimate is well within the range of possibility. Evidence of large firebrands, fire whirls, and vortex rolls has all been documented for the Bastrop Complex Fire. Cold embers were reported as far as 15 miles from the fire, so ember production and subsequent fire spread were undoubtedly instrumental in home loss.

There are some limitations in both the image recognition software and conclusions from this study that must be addressed. Due to the nature of photo processing, ember holes that an individual may have seen as one ember were broken down and counted as different ember marks. The image recognition software works based on changes from one pixel color to the next. Small strands of material would be enough to show this difference even if each piece seemed to be part of the same ember hole. While care was taken to eliminate this noise from the images, it did undoubtedly occur. Also, because the lowest size measured was .0003 $inch^2$ (.002 cm^2), due to the trampoline mesh, any firebrands smaller than this were discounted. However, these misreading are believed to be negligible when compared to the relative amounts of each firebrand size. The firebrand holes measured do not take into account how long the embers were sitting on the trampoline. Because of this, measured firebrand holes could be slightly larger than the actual embers. Presence of other combustibles could also account for the inflated firebrand estimate, although it is believed that production of embers by vegetation is an order of magnitude greater than production by structures and other combustibles. Due to current methodology, this is still the most accurate and repeatable way to measure firebrand production in an actual wildfire event.

Despite the limited scope from which conclusions can be made, this research can be helpful in fire event recreation and future fire planning. Based upon this new approach to measuring ember production in the field, estimates of ember production in distinct habitats could one day influence building construction and allocation of suppression resources during a major wildfire event. Current recommendations for things such as vent screen size and shapes of roofs may need further modification to accommodate such high numbers of extremely small firebrands. Further measurement of firebrands in different vegetation types may lead to a more thorough understanding of ember production.

Acknowledgments

We are very grateful for the support of the TFS, the Bastrop County Office of Emergency Management, and the Bastrop Fire Department in providing resources and locations for data collection. We would also like to thank all of the homeowners who allowed us to use their trampolines for this study and all of the people affected by the Bastrop Complex Fire. From such tragedy, we hope to create the means to keep it from happening again. Thanks to R. Gray and B. Woods from the TFS for support and review. We would also like to thank A. Maranghides, at National Institute for Standards and Technology/Forest Service and J. Leonard, The Commonwealth Scientific and Industrial Research Organisation, for helping format our ideas and the direction of this paper. All data collection and processing was performed by the authors from TFS, thanks to W. Powell for his assistance in measurement and collection.

References

Babrauskas, V. 2003. Ignition Handbook. Issaquah, WA: Fire Science Publishers. 952-954.

Cohen, JP. 1991. A site-specific approach for assessing the fire risk to structures at the wildland/urban interface. In: Nodvin, S.C.; Waldrop, T.A., eds. Fire and the environment: ecological and cultural perspectives: proceedings of an international symposium, Knoxville, TN, March 20–24, 1990. Gen. Tech. Rep. SE-69. Ashville, NC: USDA Forest Service, Southeastern Forest Experiment Station. 5 p.

Foote, E.I.; Liu, J.; Manzello, S.L. 2011. Characterizing firebrand exposure during wildland-urban interface fires. In: Proceedings of Fire and Materials 2011 Conference, 12th International Conference and Exhibition. London, Interscience Communications: 479–491.

Foote, E.I.; Cole, D. 1993. Making a case for “the interface.” Fire Chief Magazine. 37: 59 p.

Foote, E.; Martin, R.; Gilless, J.K. 1991. The defensible space factor study: a survey instrument for post-fire structure loss analysis. In: Proceedings of the 11th Conference on Fire and Forest Meteorology. Missoula, MT: Society of American Foresters. 606 p.

Fradkin, P.L. 2006. Great earthquake and firestorms of 1906–How San Francisco nearly destroyed itself. Berkeley, CA; University of California Press. 2005. 481 p.

Koo, E.; Pagni, P.J.; Weise, D.R.; Woycheese, J.P. 2010. Firebrands and spotting ignition on large scale fires. International Journal of Wildland Fire. Victoria, Australia: CSIRO Publishing. 19: 818-843.

Manzello, S.L.; Cleary, T.G.; Shields J.R.; Yang, J.C. 2006. On the ignition of fuel beds by firebrands. Fire and Materials. Maiden, MA: Wiley and Sons, LTD. 30: 77-87.

Manzello, S.L.; Shields, J.R.; Yang J.C.; Hayashi, Y.; Nii, D. 2007. On the use of a firebrand generator to investigate the ignition of structures. In: WUI Fires, Proceedings of the 11th International Conference on Fire Science and Engineering (INTERLFAM). London: Interscience Communications. 861–872.

McArthur, N.A.; Lutton, P. 1991. Ignition of exterior building details in bushfires: An experimental study. Fire and Materials. Maiden, MA: Wiley and Sons, LTD. 15: 59–64.

Mitchell, J.W.; Patashnik, O. 2007. Firebrand protection as the key design element for structural survival during catastrophic wildfire fires. In: Proceedings of the 10th International Conference on Fire and Materials Conference. San Francisco, CA. Science 313. 940–943

Pagni, P.J.; Woycheese, J.P. 2000. Fire spread by brand spotting in: 15th Meeting of the UJNR Panel on Fire Research and Safety. NISTR 6588. Gaithersburg, MD: National Institute of Standards and Technology, Building and Fire Research Laboratory: 373–380.

Ridenour K.; Rissel, S.; Powell, W.; Gray, R.; Fisher, M.; Sommerfeld, J. 2012. Bastrop complex wildfire case study. College Station, TX: Texas Forest Service, Texas A&M University and Bastrop County Office of Emergency Management. http://www.co.bastrop.tx.us/bcdisaster/index.php/wildfire-case-study. (22 February 2013). 205 p.

U.S. Department of Defense. 1973. DCPA attack environment manual: Chapter 3, What the planner needs to know about fire ignition and spread. Washington DC: Civil Defense Preparedness Agency. 2 p.

Colorado State Forest Service Upgrades Fire Engine Fleet

Ryan Lockwood

Editor's Note: On July 1, 2012, the Colorado State Forest Service (CSFS) fire-management functions for command and control transferred from Colorado State University to the Colorado Department of Public Safety. This transfer included the CSFS fire equipment shop. The State of Colorado made the move as part of an effort to centralize all of the State's fire-management functions into a single, statewide point of contact. The forest management, research, education, and outreach aspects of the CSFS remain at Colorado State University.

With firefighter and public safety in mind, the Colorado State Forest Service (CSFS) recently completed a 4-year goal to upgrade 40 of the wildland fire engines in its 140-engine fleet. The newer engines offer improvements such as advanced safety equipment and lower profile designs less prone to tipping. One of these newer engines is headed to a fire department in Yuma County. In this county, the Heartstrong Fire burned 24,000 acres and injured three firefighters trying to escape from a stranded fire truck.

"Firefighter safety has always been our No. 1 concern," said Matt O'Leary, lead mechanic at the CSFS fire equipment shop. "So, our primary goals were to make sure these engines have better stability for fighting fires in rugged terrain and to provide the best safety features we can."

Today, O'Leary will help deliver a new CSFS engine to the Wauneta Fire Protection District near Wray, CO. Rather than retire the department's older engine, the CSFS instead will loan it to the Wages Volunteer Fire Department in nearby Yuma, CO, to replace the engine it lost to the Heartstrong Fire.

Since 2008, CSFS fire equipment shop mechanics in Fort Collins have worked to swap out dozens of wildland fire engines in the State fleet that had an older chassis or outdated equipment. Over the past year, the final 13 of 40 earmarked engines were replaced; the last of these are being delivered in March 2012 to fire protection districts around Colorado.

Upgrades Include Newer Chassis, Increased Stability

One of the most significant improvements is the replacement of dumptruck-sized, 6x6 Type-4 engines with newer models offering a low-profile, 880-gallon water tank design that drops the vehicle's center of gravity and greatly reduces rollover risk on rough terrain. The newer engines also have automatic transmissions, air-assist power steering, three-point seat belts, and better braking systems. Additionally, the water pumps on the engines run on diesel instead of unleaded gasoline, allowing them to draw fuel from the main tank.

To replace many aging 1967 chassis, many of the smaller, pickup truck-sized Type-6 engines were swapped out with newer Chevrolet and Ford truck chassis. One of these replacement engines recently arrived at the Western Fremont Fire Protection District in Coaldale, CO.

"Our engine desperately needed to be replaced," said John Walker, Western Fremont's fire chief. He

Ryan Lockwood is the public and media relations coordinator for the Colorado State Forest Service, the lead State agency providing forest stewardship and wildfire mitigation assistance to private landowners in Colorado. He previously served as the agency's lead fire information officer.

The newer engines offer improvements such as advanced safety equipment and lower profile designs less prone to tipping.

said the most important upgrade to the new vehicle is the addition of side-discharge water nozzles. Water now can be sprayed from both sides of the moving vehicle, rather than from a hand-held hose at the rear of the engine. This allows the engine to lay down a "wet line" as it drives across the path of an oncoming fire, which works well in grasses and other light fuels.

"A wet line can help reinforce and widen other fuelbreaks, such as roads," Walker said. "Having these new nozzles is quicker, more efficient, and safer than putting firefighters on foot in front of a fire."

Federal Program Makes Engines Available

To build and maintain an engine fleet in Colorado, the CSFS fire equipment shop obtains retired vehicles through the Federal Excess Personal Property (FEPP) Program. The program allows the CSFS to acquire used vehicles from the U.S. Department of Defense and other Federal entities, which become property of the Forest Service and are loaned to rural fire departments.

Together, the CSFS and Forest Service absorb nearly all costs of the engine fleet program to ensure that fire departments around the State have the necessary equipment to fight fires. The CSFS fire equipment shop converts the vehicles to functional fire engines and provides ongoing major vehicle maintenance on the fleet. Recipient fire departments are only required to contribute $200 annually to help cover travel costs for CSFS fire shop mechanics, who must complete annual inspections on the vehicles. "This program is absolutely essential," said Walker. "It's great to see a State and Federal partnership that produces such excellent results."

Starting with the chassis of a retired military vehicle, CSFS mechanics O'Leary, Nate Taggatz, Paul Rodriguez, Jakob Bonser, Kevin Podvin, and Reed Hanlon first perform a full-scale overhaul of the vehicle at the CSFS State Office in Fort Collins. They replace hoses, belts, brakes, fluids, filters, and shocks. They then make necessary modifications, such as mounting a low-profile water tank and attaching a pump, hose reel, and tool boxes before delivering the refurbished vehicle to its new home. O'Leary says it takes about 6 weeks to build a new fire engine.

Engines Benefit Fire Departments All Over Colorado

From Yuma County in the northeast to Montezuma County in the southwest, CSFS fleet engines are made available to fire departments throughout Colorado.

"We use this vehicle and one other CSFS Type-4 on a variety of fire incidents," said Erik Johnson, fire chief at the Tallahassee Volunteer Fire Department in Fremont County, who received one of the upgraded engines last October. "They fit very well into our current fleet of fire engines, and give us a year-round tool to use with the limited budget we have." ■

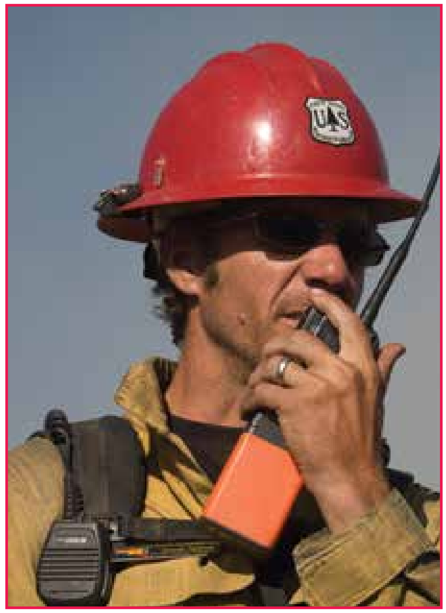
Squirrel Channels

By Rex Hambly

The colloquialism "secret squirrel channel" has been used for decades in wildland firefighting. Salty captains and battalion chiefs have long denounced the use of channels not assigned to the fire. In fact, Finding Number 34 of the Esperanza Fire Investigation states that, "While monitoring the incident assigned frequencies, all five Forest Service engines maintained radio communications with each other on [a] Forest Service tactical radio frequency not assigned to the fire." Page 83 of the same reports also notes, "Excessive communication demands." So the long burning questions remains: Is the use of a channel not assigned to an incident ever okay, and, if it is deemed okay, what are the best operating procedures?

Hotshot crews have long used a "crew net." In more complicated terms, it is a simplex channel, almost never officially assigned to the fire. If one were to listen in, he or she might overhear chatter amongst crew members regarding bumping of the jerry cans, breaking of a tool, and miscellaneous grumblings such as how many more chains to tie in. Most important is what the eavesdropper *won't* hear on the crew net. Tactical messages that affect the entire division or fire are always transmitted over the assigned incident frequency in order to share the operational information with everyone.

Rex Hamby is a firefighter on Engine 58 for the U.S. Fish and Wildlife Service at the San Diego National Wildlife Refuge in California.



Radio use on the Little Bear Fire. Photo by Kari Greer

Another good example of appropriate use of a "crew net" or "squirrel channel" occurs frequently when a strike team or task force designates a travel channel to facilitate travel to and from the incident. Often times when radio waves become hectic and overloaded on the incident assigned frequency, members of the unit can still maintain emergency communications on the predesignated travel channel–just enough to pull everyone back and regroup–when this would be impossible on the assigned tactical frequency.

While there are many examples of the success of "crew net" type channels, we must also examine their pitfalls and limitations. The Jesusita Fire of 2009 illustrates what can go wrong with miscalculated use of a crew net. A municipal strike team of engines assigned to triage and preparation of structures in advance of a wildfire near Santa Barbara, CA, experienced multiple burnovers and destroyed equipment. They were using an 800 megahertz radio system and did not have a very high frequency (vhf) radio compatible with the incident assigned frequencies. On page 35, the investigation states: "The strike team leader did not have an incident tactical radio." Despite the fact that all members of the strike team could communicate with each other, they did not have communications outside their strike team. While the use of their crew net did not directly cause the burnovers, it certainly did limit their ability to make sense (i.e., situational awareness) of the rapidly changing world around them.

To safely use a crew net in addition to the incident assigned frequencies, several layers of radio proficiency must be present. The user must have an authorized Federal Communications Commission (FCC) frequency and the frequency must not interfere with other operations, both on and off the fire. For several years, heavy use of a Forest Service Pacific Southwest Region project/travel frequency by helideck operations on large fires caused problem for both users.

The radio user must additionally understand how the radio operates, from scan and priority settings to frequency programming. To be brief, the tactical frequency should always be designated as priority. That way, if there is chatter on crew net, the lookout message will override the crew chatter, such as when the division lookout orders crews into safety zones.

When asked his opinion on the topic of crew nets, Lee Rickard, former Bureau of Land Management smokejumper and current fire management officer of the Southern California Fish and Wildlife Refuges, had a few things to say: "Crew nets play an important role in keeping radio traffic to a minimum on the assigned tactical frequency. Back in the early 1990s, we gabbed on a few different unused frequencies as crew nets.   We used them all around the Western United States. Looking back, they may not have always been authorized for use in the various geographic areas that we operated in." Rickard also notes that using a frequency without authorization is considered pirating by the FCC and can carry legal and monetary penalties.

To safely use a crew net in addition to the incident assigned frequencies, several layers of radio proficiency must be present.

Crew nets and "squirrel channels" play a vital role in facilitating smooth communications on an incident. Using these channels requires discipline and a depth of radio knowledge. Most importantly, we must remember not to exclude others on the fireline from important operational information. Someday, our culture will learn to safely utilize crew nets. Until that happens, it's a safe bet to change your batteries, monitor tac, and switch to crew net. ■

Contributors Wanted!

Fire Management Today is a source of information on all aspects of fire behavior and management at Federal, State, tribal, county, and local levels. Has there been a change in the way you work? New equipment or tools? New partnerships or programs? To keep up the communication, we need your fire-related articles and photographs! Feature articles should be up to about 2,000 words in length. We also need short items of up to 200 words. Subjects of articles published in *Fire Management Today* may include:

Aviation
Communication
Cooperation
Ecosystem management
Equipment/Technology
Fire behavior
Fire ecology
Fire effects
Fire history
Fire science
Fire use (including prescribed fire)
Fuels management
Firefighting experiences
Incident management
Information management (including systems)
Personnel
Planning (including budgeting)
Preparedness
Prevention/Education
Safety
Suppression
Training
Weather
Wildland-urban interface

Fire Weather Case Study– Mann Gulch Fire, Montana

Paul Werth

Background Information

The Mann Gulch Fire burned in August 1949 approximately 20 miles north-northeast of Helena, MT (figure 1). The fire was ignited by lightning on August 4 near the top of an east-west oriented ridge between Mann and Meriwether Gulches. It was 1 of 10 lightning fires that started that day on the Canyon and Helena Ranger Districts of the Helena National Forest. A group of Forest Service smokejumpers, attached to the Missoula Smokejumper Base, initially attacked the fire the afternoon of August 5. The fire was about 50 to 60 acres in size when 15 smokejumpers jumped the fire at 4:00 p.m. A local district fire guardsman joined them at 5:00 p.m. Extreme fire behavior (spotting, rapid rate of spread, and a sudden increase in fire intensity) developed around 5:45 p.m., overrunning the firefighters and resulting in the deaths of 12 smokejumpers and the local fire guardsman. Controversy surrounding the events of that afternoon continued for many years. Increased research into wildland fire behavior and the eventual development of a national fire danger rating system were products of this incident.

Paul A. Werth is a fire weather meteorologist with Weather Research and Consulting Services, LLC, in Battle Ground, WA. He served 30 years as a fire weather forecaster with the National Weather Service in Medford, OR, and Boise, ID. He retired from the Northwest Interagency Coordination Center in Portland, OR, as the fire weather program manager for Predictive Services.

Figure 1.—*Mann Gulch Fire location.*

> Increased research into wildland fire behavior and the eventual development of a national fire danger rating system were products of this incident.

Case Study Objective

Although topography and fuel conditions (Rothermel 1993) contributed to extreme fire behavior on the Mann Gulch Fire, the intent of this report is to analyze weather conditions to determine if a "critical fire weather pattern" also contributed to the "blowup." A "blowup" is defined as a sudden increase in fireline intensity or rate of spread of a fire sufficient to preclude direct control or to upset existing suppression plans. It is often accompanied by violent convection and may have other characteristics of extreme fire behavior. "Critical fire weather patterns" are defined as atmospheric conditions that encourage extreme fire behavior resulting in large and destructive wildland fires.

Weather Discussion

A record-setting heat wave gripped much of the Western United States, including Montana, in early August 1949. The heat wave actually began on July 30 when a strong high pressure aloft pushed northward from the Desert Southwest into the Canadian Rockies. Hot, dry weather persisted for the next week. Maximum temperatures climbed well into the 90s at Helena, MT, while minimum relative humidity dropped to as low as 12 percent.

The August 5 upper level pattern at 500 millibars (approximately 18,000 feet mean sea level (msl)) is graphically displayed in figure 2. The 00Z chart time correlates to late afternoon, within an hour or two of the Mann Gulch blowup. For clarification purposes, the Canadian, Washington, Oregon, and California coastline is shown. Just to the southeast of the low pressure center is Vancouver Island.

High pressure aloft was centered over Utah with a ridge axis through eastern Montana and central Canada. Meanwhile, a low pressure center was located near the northern tip of Vancouver Island with a trough off the Washington and Oregon coasts.

The Mann Gulch area was situated between these two pressure centers, west of the high pressure ridgeline through eastern Montana and east of the upper trough. The upper trough was advancing toward the coast, pushing the high pressure ridge east. The winds at 18,000 feet msl over the fire were from the southwest (parallel to the contour lines in figure 2). While the strongest upper level winds (jet stream) were over Washington and Oregon, upper level winds over Mann Gulch were on the increase. Cooler air aloft was also moving into Montana ahead of the upper trough.

At the same time, the surface pressure pattern (figure 3) indicated a low pressure system (heat low)

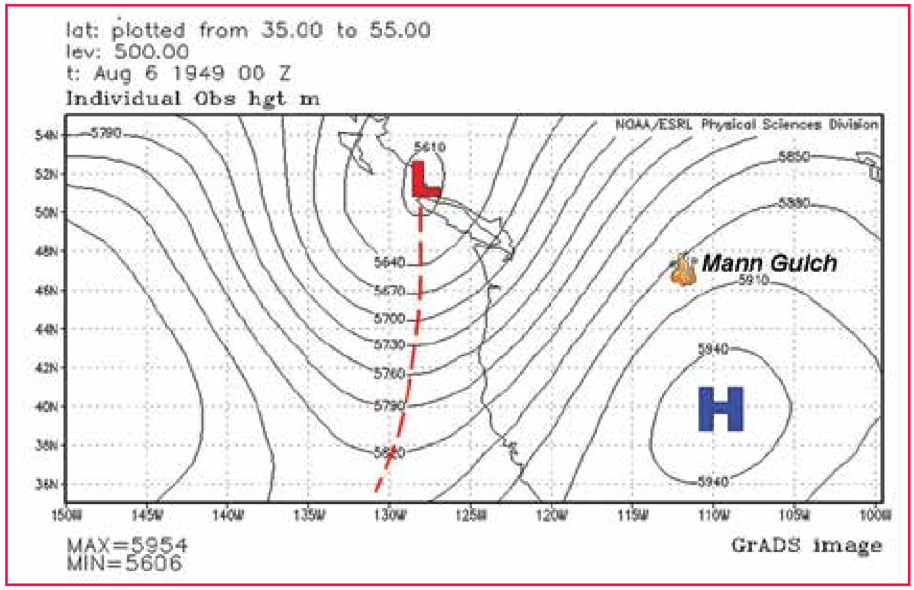


Figure 2.—*Afternoon 500MB map, August 5, 1949.*

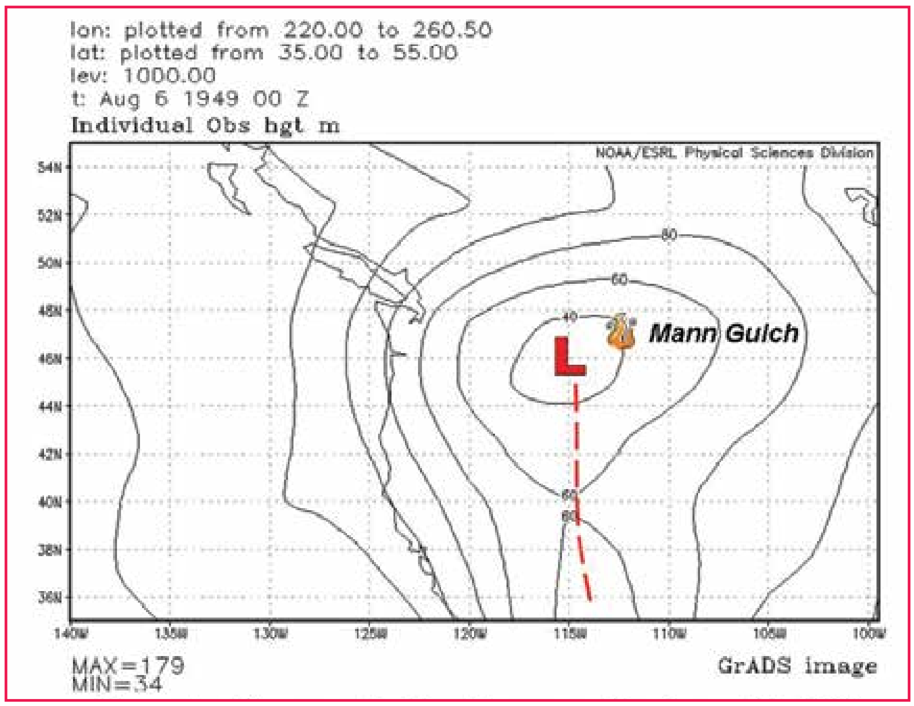


Figure 3.—*Afternoon surface pressure map, August 5, 1949.*

over western Idaho, with a thermal trough southward through Nevada (indicated by the dotted line). Heat lows and thermal troughs are quite common during the summer in the Western United States. They form under strong high pressure aloft due to intense heating of the air near the surface. The surface wind is typically light during the morning near the thermal trough; however, the air can become very unstable during the afternoon, resulting in gusty and shifting winds. Strong up and downward drafts often result in very turbulent air and erratic fire behavior. The Mann Gulch area was located just to the east of the heat low during the time of the blowup.

The afternoon relative humidity pattern over the Western United States (figure 4) indicated a tongue of very dry air extending from the Great Basin into the Northern Rockies (the shaded area). Within this area, surface relative humidity ranged from 10 to 20 percent. The Mann Gulch area was located near the 15 percent contour line within this area.

Thus, at about the time of the Mann Gulch Fire blowup and the resulting entrapment of the smokejumpers, the weather pattern at the fire site was dominated by an upper level ridge of high pressure, a surface heat low (or thermal trough), and very dry air near the surface.

Critical Weather Elements

There are four critical weather elements common to large and destructive wildland fires: low atmospheric moisture/relative humidity, strong wind, unstable air, and drought. Low relative humidity (regional values can vary between 15 and 40 percent depending upon fuel model) must always be present for the development of large and intense wildland fires. In addition to low relative humidity, either strong wind or unstable air must also be present. Drought is often associated with large timber fires, but is not necessary for large grass fires. We will now examine how many of these elements were present during the Mann Gulch blowup.

> The concept of critical fire weather patterns has been around for many years, but has been underused in fire weather forecasting.

Low Atmospheric Moisture

Dry air in the lower levels of the atmosphere (i.e., low relative humidity) significantly lowers the moisture content of fuels, making them easier to ignite and carry fire. Low relative humidity also increases the probability of spotting.

Figure 5 graphs the daily maximum temperature and minimum relative humidity at Helena during August. On August 5, the high temperature was 97 degrees Fahrenheit and the minimum relative humidity (RH) was 16 percent. This was much warmer and drier than usual. Helena averages 85 degrees Fahrenheit and a minimum relative humidity of 30 percent in early August. The 16 percent RH correlates well with the tongue of dry air over the Great Basin and northern Rockies displayed earlier.

Conclusion

Low atmospheric moisture was a critical element in the blowup of the Mann Gulch Fire.

Strong Wind

Extreme burning conditions have been associated with strong frontal, thunderstorm, and foehn winds.

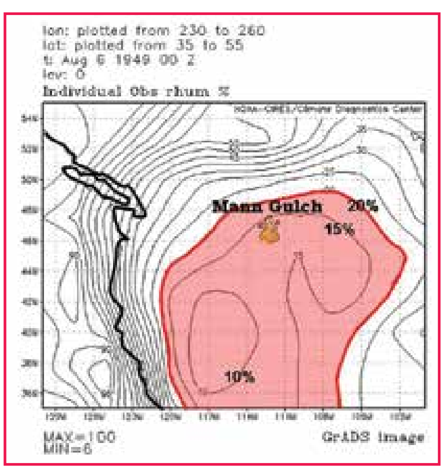


Figure 4.—*Afternoon RH map, August 5, 1949.*

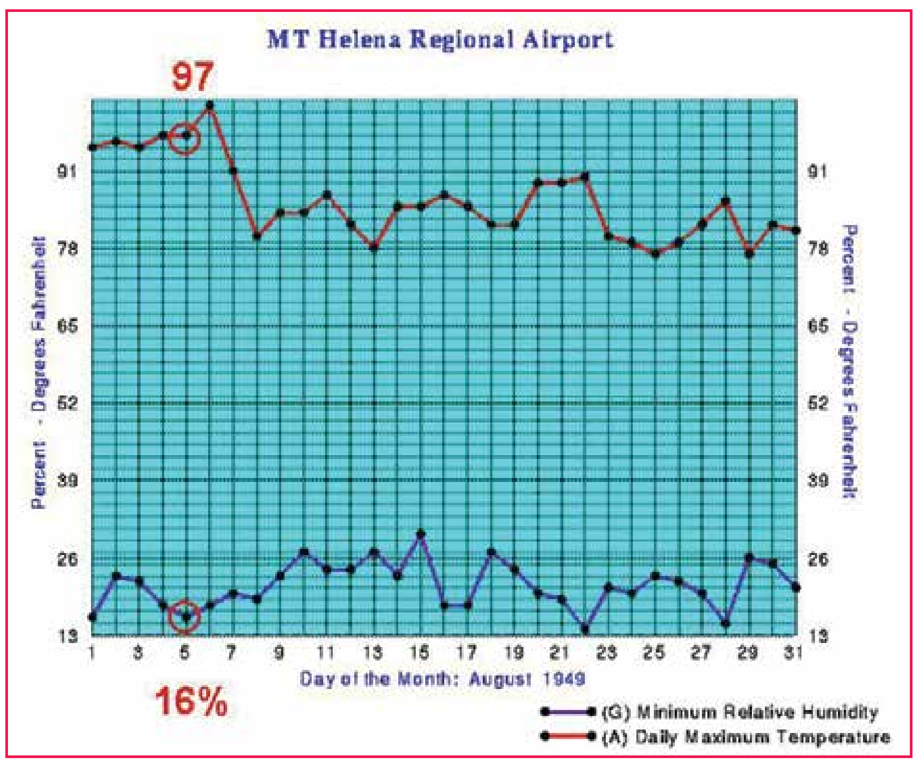


Figure 5.—*Helena, MT, August 1949 temperature and RH.*

Wind affects wildland fires in a number of ways. Wind: (1) supplies additional oxygen to the fire, increasing fire intensity; (2) preheats the fuels ahead of the fire; and (3) increases rate of spread by carrying heat and burning embers to new fuels. Strong wind produces wind-driven fires.

The wind at Helena was reported at 5 to 8 miles per hour (mph) during the morning. At noon, the wind increased to 15 mph, the temperature jumped from 81 to 91 degrees, and the relative humidity dropped from 40 percent to 24 percent. The morning surface-based inversion had broken and cumulus clouds started to form. Then at 3:30 p.m., the wind switched to the south and increased to 24 mph. Cumulonimbus clouds (CBs) and virga were visible to the west and south of Helena. Although no thunderstorms or distant lightning were reported at Helena that afternoon, CBs and strong, gusty southerly winds at 14 to 32 mph continued the remainder of the afternoon and evening. Eyewitness accounts of smoke drift at the Mann Gulch fire suggests a wind shift to strong southerly winds occurred between 4:15 and 4:50 p.m. This is consistent with the wind shift at Helena due to cumulonimbus downdraft and outflow winds. The upper level wind speed and direction would have moved the CBs at Helena into the Mann Gulch area at about 4:30 p.m., causing the sudden increase in wind speed and a shift in direction from the south rather than the southwest. The wind at Helena continued to blow strongly from the south at 14 to 22 mph throughout the remainder of the afternoon and evening and this was most likely the case at Mann Gulch.

At about 5:00 p.m., Canyon Ferry District Ranger Robert Jansson reached the mouth of Mann Gulch by boat and attempted to walk up the gulch to reach the smokejumpers. He estimated the wind at Mann Gulch to be between 20 and 30 mph with gusts to 40 mph. Because of the orientation of the canyons and ridges, a strong southerly wind created extreme turbulence at the mouth of Mann Gulch, producing strong winds that blew up the gulch (from the southwest) toward the smokejumpers (Rothermel 1993). Two fire weather stations in the vicinity also reported strong wind at 5:00 p.m.—Canyon Ferry Ranger Station at 16 mph and Hogback at 15 mph.

Over the years, there have been conflicting theories as to what caused the fire to move from the ridge on the south side of Mann Gulch to the mouth of the gulch and then to the north side. One explanation may be that thunderstorm downdrafts caused the fire to spot across the gulch. The other theory is that fire whirls developed on the lee (north) side of the ridge due to southerly winds down the Missouri River that caused the fire to spot on the north side. In order to determine which theory is the more plausible, the Great Falls, MT, upper air (radiosonde) wind, temperature, and dew point data were evaluated to determine the cause of the strong wind observed at Mann Gulch. To accomplish this, two relatively new analysis programs were used: ANALYZE (Werth J.A. and Horton 1991) and WINDEX (McCain 1994). Figure 6 displays the August 5, 1949, vertical wind profile near Mann Gulch at 8:00 a.m. and 8:00 p.m. The 8:00 a.m. profile showed increasing wind aloft (south to southwesterly in direction) with a speed maximum of 30+ mph at 15,000 feet msl, or about 10,000 feet above the elevation of Mann Gulch. This is much stronger than the usual upper level summer wind in the northern Rockies. At 8:00 p.m., the strongest wind (20+ mph) had descended (or surfaced) to the same elevation as Mann Gulch and the vertical profile showed decreasing

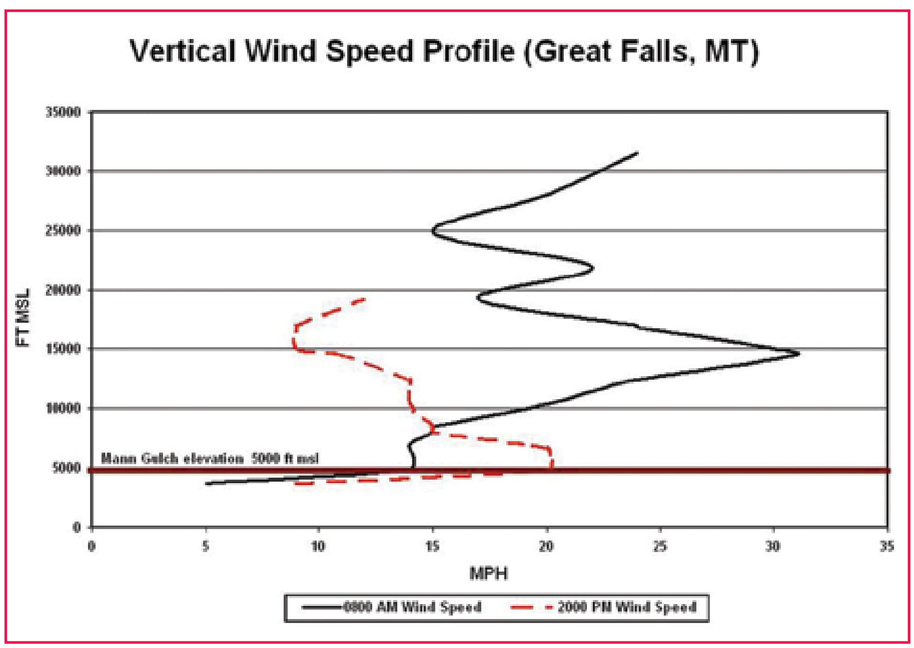


Figure 6.—*Great Falls, MT, August 5, 1949, wind profile.*

wind aloft. Byram (1954) described this profile of strong surface wind with decreasing wind speed aloft as one of the most dangerous for blowup fires. The strong upper level winds over the fire area during the morning surfaced later that day due to very unstable air mixing these winds downward to the surface. Southerly winds at 20 mph would have produced eddy winds and fire whirls strong enough to cause the spot fires north of the gulch. However, this isn't the complete story. ANALYZE and WINDEX also indicate the airmass over Mann Gulch was unstable enough for convection and the formation of CBs and possible thunderstorms with a downdraft/outflow potential of 40 to 50 mph. Although neither Helena nor eyewitness accounts from Mann Gulch mentioned thunderstorms when describing the weather that day, Helena did report CBs and downdraft winds of up to 32 mph from mid-afternoon through early evening. Thus, it is also likely that Mann Gulch received strong downdraft winds from CBs in addition to the surfacing of strong upper level winds. So, both theories are correct. The strong wind that caused the fire to spot across Mann Gulch and overrun the smokejumpers was the result of both strong surfacing wind and convective downdraft/outflow wind. In any event, the topography of the area resulted in strong eddy winds and fire whirls at the mouth of Mann Gulch.

Conclusion

Strong wind was a critical element in the Mann Gulch Fire blowup.

Unstable Air

Unstable air enhances vertical motion in the atmosphere. As with wind, upward movement of air increases combustion by supplying more oxygen to the fire. It also enhances the vertical growth of the smoke column. As the height and strength of the smoke column increases, the potential for gusty surface winds, dust devils, and fire whirls also increases. Spotting may become profuse all around a fire as large firebrands are lifted in the smoke column. Unstable air increases the probability of plume-dominated fires.

There are many indications that the air over Mann Gulch was very unstable that afternoon. One of the surviving smokejumpers recalled that, on the flight to Mann Gulch, "The air was so turbulent that we were all half sick and were trying to be in the stick to jump and get on the ground." (MacLean 1992). The DC-3 aircraft encountered heavy turbulence over Mann Gulch and had to climb to a higher-than-usual altitude to drop the cargo. Ranger Jansson also reported seeing a number of vortices at the lower end of Mann Gulch at about the same time the fire spotted across to the north side of the gulch. At 6:00 p.m., and at a distance farther from the fire, Jansson described the smoke column as, "One big whirl and one little whirl side by side. The little whirl came right off the big whirl." (Mann Gulch Fire Board of Review 1949).

The Haines Index (Haines 1988) is another indicator of unstable air. It combines the stability and dryness of the lower atmosphere into an index that correlates well with large fire growth. The Index ranges between 2 and 6. Values of 2 and 3 are indicative of moist, stable air. Values of 5 and 6 indicate dry, unstable air. The calculated high elevation Haines Index for the Mann Gulch Fire, using the Great Falls 8:00 a.m. and 8:00 p.m. 700 and 500 millibars temperature and dew point data, was a solid 5 and a borderline 6. The Haines Index climatology for Great Falls (Werth and Werth 1997) indicates a Haines Index of 6 occurs only 2 percent of the days in August. Thus, a Haines Index this high is relatively rare. All indications point to a very unstable and dry airmass over Mann Gulch that day.

Conclusion

Unstable air was a critical element in the blowup of the Mann Gulch Fire.

Drought

Drought affects fuel availability by lowering the moisture content of both live and dead fuels, making them more combustible. Drought conditions are NOT a prerequisite for fires to occur and spread, but there is a close relationship between drought conditions, large wildland fires, and extremely difficult fire suppression. The Palmer Drought Index (PDSI) has been extensively used to measure

Critical elements in the blowup of the Mann Gulch Fire:

- Low atmospheric moisture
- Unstable air
- Strong wind
- Drought (may or may not have been)

drought throughout the United States. Although primarily developed for agricultural use, the PDSI is also a good indicator of fire season severity, especially in forest fuels.

Figure 7 displays the August 1949 PDSI by climate zone. While most of eastern Montana was in severe to extreme drought, near normal conditions were indicated for the Mann Gulch area. However, the adjacent climate zone to the north indicated extreme drought.

Figure 8 displays Helena's precipitation from November 1948 through July 1949. Helena received above normal precipitation during the winter months (November through February). April was drier than usual, but May was again wet. June was a little drier than normal, but July was much drier. Thus, while the long-term PDSI did not indicate drought in this part of Montana, short-term dryness was a factor.

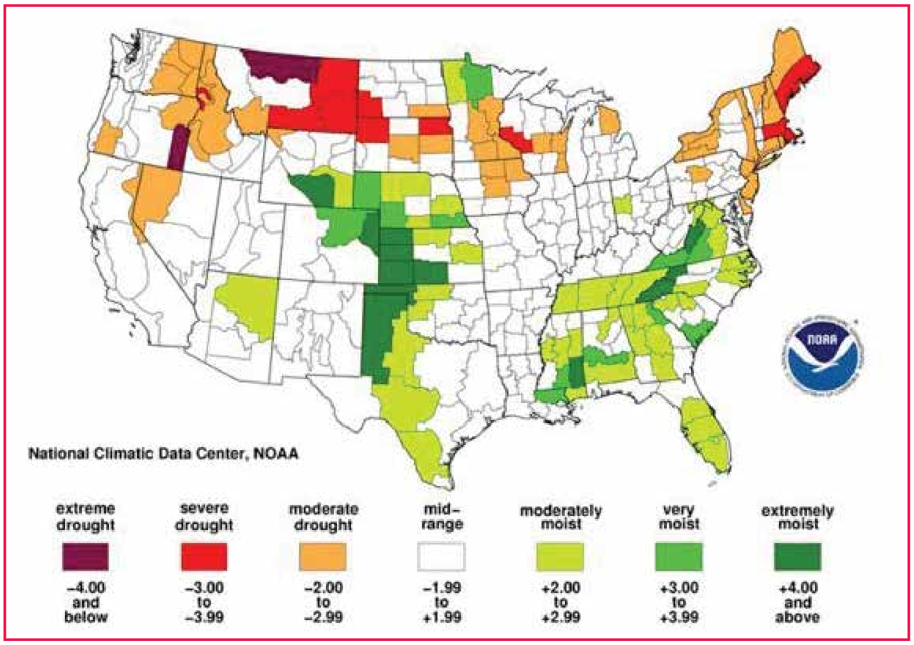


Figure 7.—*Palmer Drought Severity Index, August 1949.*

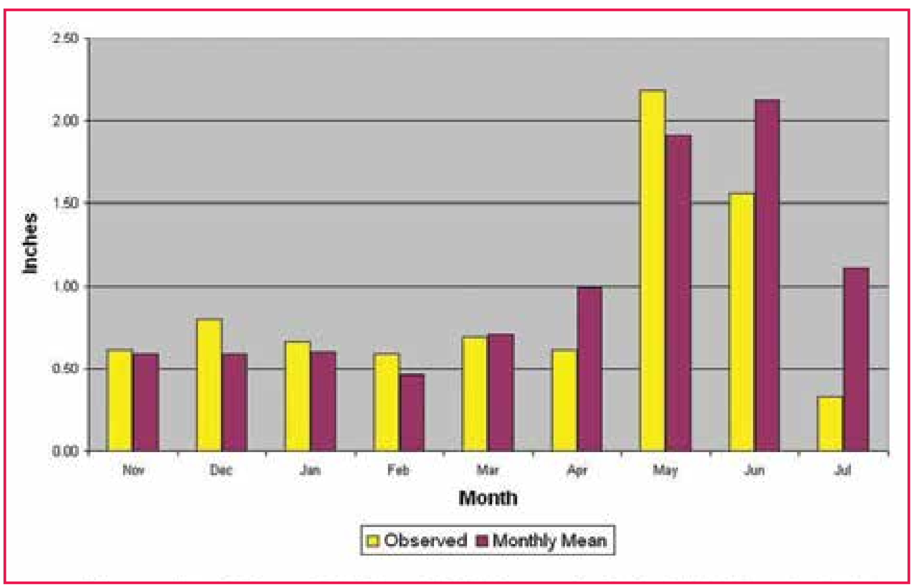


Figure 8.—*Helena, MT, November 1948 through July 1949 precipitation.*

Conclusion

Drought may or may not have been a critical element in the blowup of the Mann Gulch Fire.

In summary, at least three of four critical weather elements (low relative humidity, unstable air and strong wind) were present during the Mann Gulch Fire.

Critical Fire Weather Pattern

Let me define "critical fire weather pattern" one more time. It occurs when atmospheric conditions encourage extreme fire behavior resulting in large and destructive wildland fires. In this section, we will determine which, if any, critical fire weather pattern significantly contributed to the Mann Gulch blowup.

The concept of critical fire weather patterns has been around for many years, but has been under-used in fire weather forecasting. While individual weather elements are highlighted in fire weather forecasts, they are seldom tied to cyclical large-scale atmospheric patterns that continually change on a daily and seasonal basis.

The first publication concerning critical fire weather patterns was "Synoptic Weather Types Associated with Critical Fire Weather" by Schroeder et al. (1964). This study covered the lower 48 States and concluded that "**periods of critical fire weather are associated with relatively few weather patterns.**"

"Predicting Major Wildland Fire Occurrence" by Brotak and Reifsnyder (1977) detailed the relationship of Central and Eastern United States wildland fires to surface frontal systems and upper level troughs and ridges.

"Wildfire Behavior Associated with the Upper Ridge Breakdown" by Nimchuk (1983) documents the relationship of the breakdown of an upper level ridge to extreme fire behavior conditions in Western Canada.

Figure 9 illustrates a critical fire weather pattern: Breakdown of the Upper Ridge (Werth and Ochoa 1990). There are three defining factors of this pattern: an upper level ridge at 500 millibars moving off to the east, a surface thermal trough (or surface low) on the west side of the upper ridge, and dry air. The highest risk of explosive fire behavior occurs when these factors converge. This summer weather pattern typically produces hot temperatures, very low relative humidity, unstable air, strong gusty wind, and possible dry lightning. Any one of these weather elements can cause fire problems but, when combined, can frequently produce large and destructive fires.

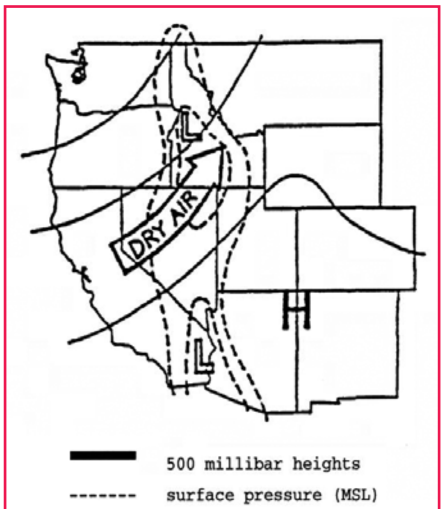


Figure 9.—*Idealized "Breakdown of the Upper Ridge" pattern.*

The reconstructed upper level and surface weather maps for Mann Gulch on August 5, 1949, are markedly similar to those shown for the "Breakdown of the Upper Ridge" critical fire weather pattern. The weather elements described by survivors of the burnover and other firefighters in the vicinity are consistent with this pattern.

Thus, based on eyewitness accounts and the reconstructed weather pattern of the day, we can conclude with a high level of confidence that a "Breakdown of the Upper Ridge" critical fire weather pattern significantly contributed to the Mann Gulch Fire blowup.

Summary

Thirteen firefighters tragically perished on August 5, 1949, shortly after the initial attack on the Mann Gulch Fire, 20 miles north-northeast of Helena, MT. Twelve of the fatalities were members of a group of 15 smokejumpers. Prior to jumping the fire, one of the survivors and the jump spotter stated that the fire was relatively quiet and wasn't burning much. Yet only 2 hours later, with little warning, extreme fire behavior developed, trapping and overrunning the firefighters. Little did they know that their destiny was tied to a critical fire weather pattern: the "Breakdown of the Upper Ridge."

References

Brotak, E.A.; Reifsnyder, W.E. 1977. Predicting major wildland fire occurrence. Fire Management Notes. 38: 5-8.

Byram, G.M. 1954. Atmospheric conditions related to blowup fires. Sta. Pap. 35. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeast Forest Experiment Station. 34 p.

Haines, D.A. 1988. A lower atmospheric severity index for wildland fire. National Weather Digest. 13: 23-27.

Mann Gulch Fire Board of Review, September 26–28, 1949. Washington, DC: U.S. Department of Agriculture, Forest Service

MacLean, N. 1992. Young men and fire. The University of Chicago Press. 301 p.

McCann, D.W. 1994. WINDEX–A new index for forecasting microburst potential. Weather and Forecasting. Vol. 9. 10 p.

Nimchuk, N. 1983. Wildfire behavior associated with upper ridge breakdown. Report No. T/50. Edmonton, AB: Alberta Energy and Natural Resources, Forest Service. 45 p.

Rothermel, R.C. 1993. Mann Gulch Fire: a race that couldn't be won. Gen. Tech. Rep. INT-299. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 10 p.

Schroeder, M.J.; Glovinsky, M.; and Hendricks, V. 1964. Synoptic weather patterns associated with critical fire weather. Contract OCD-05-62-143. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station.

Werth, JA; Werth, PA 1997. Haines index climatology for the western United States. Salt Lake City, UT: National Weather Service, Western Region. Technical Attachment No. 97. 17 p.

Werth, J.A.; Horton, A. 1991. ANALYZE. Salt Lake City, UT: National Weather Service, Western Region. Programming Note No. 91.

Werth, P.A.; Ochoa, R. 1990. The evaluation of Idaho wildfire growth using the haines index and water vapor imagery. In: Proceedings of the Fifth Conference of Mountain Meteorology. Boulder, CO: American Meteorological Society. 223–234. 12 p.

Characterizing Wildfire Hazard and Risk in Mountain Pine Beetle-Affected Stands and How To Identify Those Characteristics at the Landscape-Scale

Robert W. Gray

The suddenness, intensity, and extent of the mountain pine beetle (MPB) epidemic in Western North America has left fire researchers scrambling to determine if and when this new fuelbed will become an issue for fire managers to deal with. The transformation of fuels resulting from the mountain pine beetle epidemic is unprecedented in its large geographic extent and the rapid pace of the transformation. The epidemic is estimated to have affected more than 18 million hectares of forest in British Columbia and Alberta, Canada, and 2 million hectares of forest in five States in the United States. Confounding the issue for managers is the lack of consensus within the fire management and academic communities on what constitutes risk and hazard in beetle-affected stands. In this paper, risk is defined as fire start and spread, while hazard is defined as the consequence, in the form of increasing fire intensity and severity.

This leads to two main issues: how do we describe wildfire risk and hazard in the context of mountain pine beetle affected stands and how do we assess risk and hazard across broad landscapes. First, the characteristics of the fuelbed are key to identifying potential wildfire hazard and risk. From there we can then describe how a number of processes may be responsible for producing those characteristics, and how we might use that knowledge to identify fuel characteristics at the landscape-scale. The guiding hypothesis is that fuelbed characteristics associated with the antecedent stand and the disturbances it experienced exert a significant influence on post-MPB wildfire risk and hazard. The key fuelbed characteristic is surface fuels, especially heavy loading of large fuels. This leads to a generalized model of risk and hazard associated with three broad stand types that are a product of previous disturbance agents and processes: (a) mature, single-storied stands of lodgepole pine with low accumulations of surface fuels; (b) mature, single-storied stands of lodgepole pine with high accumulations of surface fuel; and (c) mature, multistoried stands of mixed-conifers with high accumulations of surface fuels.

> The transformation of fuels resulting from the mountain pine beetle (MPB) epidemic is unprecedented in its large geographic extent and the rapid pace of the transformation. This paper describes a proposed fire risk and hazard characterization system, as well as methodology for locating certain stand types on the landscape.

Efforts to characterize and map stands based on surface fuel conditions are difficult absent a large-scale fuel inventory effort using either field crews or Lidar technology. In place of a physical or remote- sensing-based inventory and characterization system, we could rely on a proxy such as antecedent disturbance.

Stand Type 1: Mature Single-Storied Stands of Lodgepole Pine With Low Accumulations of Surface Fuels

This stand type is comprised of almost pure stands of mature lodgepole pine (may contain small proportions of spruce, subalpine fir, or Douglas-fir) with a very light loading of surface fuels. Aerial fuels are characterized by moderate to heavy loading of foliage and

Robert W. Gray is a fire ecologist and the president of R.W. Gray Consulting, Ltd., in British Columbia, Canada. He has more than 30 years of experience in the research and application of many facets of fire science, including fire regime reconstruction, wildfire risk and hazard assessment, international fire management policy, and hazardous fuel management. Gray has served as a fire ecologist at the San Carlos Apache Tribe and a forest technician with the Forest Service.

fine branches, moderate to high canopy bulk density, and a significant canopy base height separating surface fuels from aerial fuels. Surface fuels consist of compacted short-needle pine litter, moss, and minor amounts of scattered woody fuels (figure 1a). Fire risk and hazard, pre-beetle attack, is low in this type due to stand and fuelbed conditions, resulting in a poor fire environment: general lack of heavy surface fuels; canopy closure that shades fuels, suppresses the growth of herbaceous fuels, and holds in surface and ground moisture; and a stand density that greatly reduces wind speed below the canopy.

Fire managers need tools to enable them to identify and prioritize the most hazardous stands within their jurisdictions and begin the process of treating them.

Following attack by the MPB, during what has been described as the "red attack" phase, lodgepole pine canopies are highly flammable even under conditions of high relative humidity. During this stage, the risk of canopy ignition is high leading to a high hazard of independent crown fire. Active crown fire runs in this type are difficult without the sustained input of high-intensity surface fire (figure 1b). Immediately after the red needles fall, the risk of surface ignition increases due to increased solar radiation at the surface drying fuels, coupled with a moderate to high loading of fine surface fuels (grasses, forbs, and shrubs responding to the decreased canopy cover) and a significant reduction in wind friction. Fire hazard, however, at this stage of fuelbed transformation is low due to the lack of heavy fuels (figure 1c). Over time, as the dead overstory decays and falls to the surface, both hazard and risk are high. The surface fuelbed is characterized by a heavy loading of mostly elevated and air-dryed lodgepole pine, mixed in with grasses, forbs, shrubs, and regenerating conifers. Surface fuels dry out sooner in the summer due to a lack of canopy and wind friction. This stage could persist for several decades until a new forest canopy covers the surface fuelbed suppressing the growth of fine surface fuels and increasing the decomposition of heavy fuels (figure 1d).

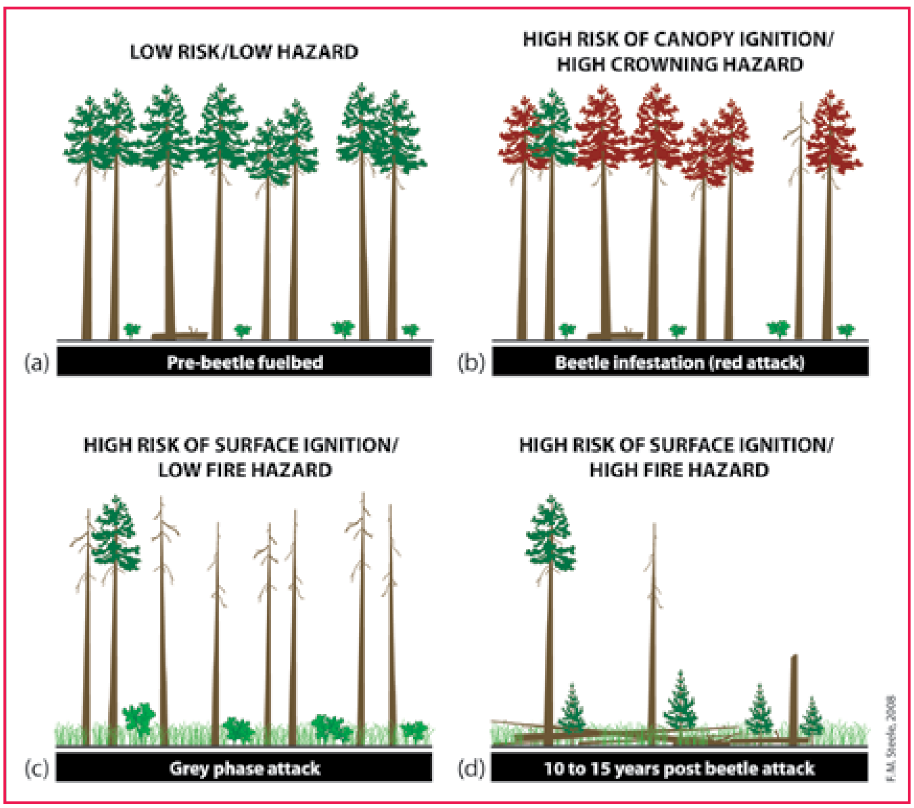


Figure 1.—*Wildfire risk and hazard for various stages of fuel succession before and after a beetle epidemic in mature, single-storied lodgepole pine stands with low accumulations of large fuels.*

Stand Type 2: Mature Single-Storied Stands of Lodgepole Pine With High Accumulations of Surface Fuels

This stand type differs from Type 1 in that it contains a high accumulation of surface fuels, especially large fuels, prior to the current pine beetle epidemic. In the pre-attack phase (figure 2a), the stand containsn a high loading of large surface fuels. A fine fuel layer of herbaceous material may or may not be present depending on canopy conditions. Fire risk is relatively low due to canopy cover, but fire hazard is high due to the presence of elevated, dried large fuels. During the red attack phase (figure 2b), fire risk and hazard are both high as the dead foliage is highly flammable and there are abundant heavy surface fuels.

The immediate post-red attack stand (figure 2c) and the same stand 10 to 15 years later (figure 2d) both exhibit high fire risk and fire hazard. With the loss of the forest canopy understory, plants get established resulting in a fine fuel layer that aids in fire ignition and rapid spread. These two phases are also characterized by increased solar radiation hitting the forest floor, decreased large fuel moisture, and decreased wind friction. Fires in these forest types are easily ignited, spread fast, and exhibit high fire intensity and severity.

Mitigating these conditions takes a long time, especially on dry sites. A closed forest canopy is once again needed to suppress the fine fuel layer, increase surface fuel moisture, and increase the decomposition of large fuels.

Stand Type 3: Mature Multistoried Stands of Mixed Conifers With High Accumulations of Surface Fuels

This stand type also contains a high pre-epidemic loading of heavy fuels and a well developed herbaceous fuel complex. Fire risk and hazard are high in the pre-attack stage (figure 3a) due to the surface fuel complex combined with an open canopy. As the beetle epidemic progresses through the stand, the conditions of risk and hazard do not change. The canopy becomes more flammable during the red attack stage (figure 3b) but conditions are already quite volatile. As the dead lodgepole pine loses its needles, the surface fuels are exposed to more direct sunlight and wind resulting in more herbaceous growth and drier large fuels (figure 3c). A subcanopy of shade-tolerant conifers,

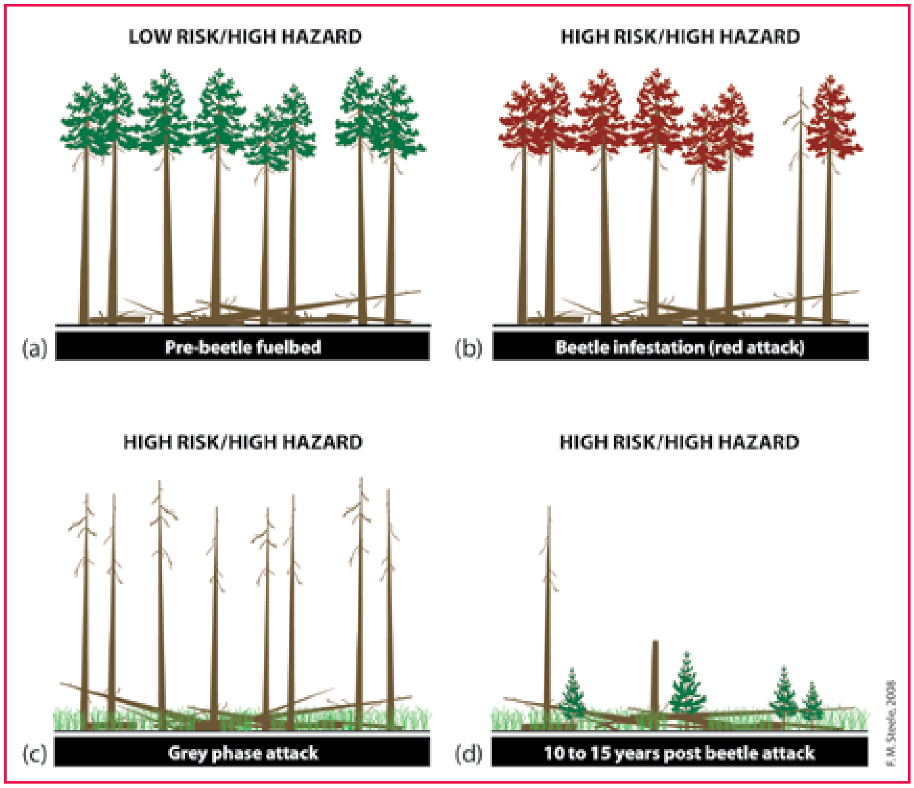


Figure 2.—*Wildfire risk and hazard for various stages of fuel succession before and after a beetle epidemic in mature, single-storied lodgepole pine stands with high accumulations of large fuels.*

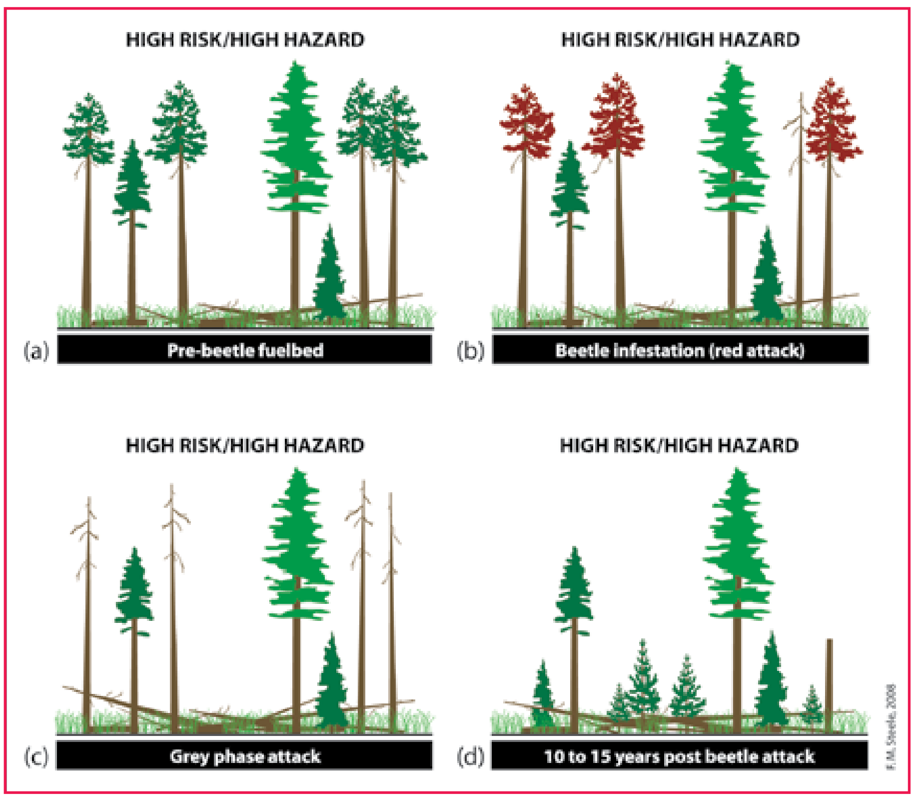


Figure 3.—*Wildfire risk and hazard for various stages of fuel succession before and after a beetle epidemic in mature, multistoried stands of mixed conifers with high accumulations of large fuels.*

most notably Douglas-fir and grand fir, becomes established and generates a ladder fuel component to the fuelbed. A decade or more out from the current epidemic and surface fuel loading has increased substantially as has the density of regenerating conifers (figure 3d). This condition of high risk and hazard can persist until the canopy closes and surface fuels decompose. This stand type is associated with lower elevation mixed conifer forests where lodgepole pine is a minor, but still critical, stand component.

How Do We Identify These General Stand Types on the Broader Landscape?

Characterizing the potential risk and hazard of these broad stand types is not very useful to fire managers if they can't identify where they are on the landscape. The following is a potential process for identifying where these stand types are located based on a Geographic Information Systems (GIS) exercise using antecedent fire history and forest inventory data. Stand type 1, with its low volume of large surface fuels, can often be the product of a reburn occurring within a decade or two of a previous fire. Multiple back-to-back fires, with the first fire killing the stand and the second fire consuming most of the dead and downed material, would produce this type of lodgepole pine stand. Across the landscape of the West, this stand type is commonly associated with 19th and 20th century railroad and mining activity. For example, large areas of lodgepole pine forest in the Canadian Rockies were affected by back–to–back railroad fires at the turn of the century that produced single-storied pine stands with very little in the way of large surface fuels. Overlapping fires in fire history data bases can also reveal the presence of this stand type (figure 4).

Figure 4.—*This image is of a mature, single-storied stand of lodgepole pine with a very low loading of large surface fuels. The 2006 Tripod Fire in central Washington State ran into this stand and stopped due to a lack of surface fuels. Evidence of the antecedent stand and disturbance pattern is found in the widely scattered remnant charred stumps and logs.*

Stand type 2, with its high loading of large surface fuels, is a product of both stand dynamics and antecedent disturbance. Overly dense lodgepole pine stands will often go through a process of "self-thinning" that can result in a large input of heavy surface fuels. Unfortunately, there is no easy way to predict where this activity has occurred. We can, however, with some general GIS datasets, predict where this stand type is located if the fuel characteristics are the product of past insect epidemics or wildfire. The current MPB epidemic was preceded by a number of previous epidemics; the most notable of which occurred in the 1980s. This particular epidemic, while not as intense as the current one, did result in large amounts of lodgepole pine mortality across Western North America. This mortality, coupled with forest inventory, provides us with two key GIS datasets that can enable us to predict where this stand type is located. Federal land management agencies in both countries have carried out insect damage surveys for a number of decades. These agencies, and their provincial and State counterparts, have also conducted regular forest inventories. Pre-1980s forest inventory will provide an estimate of lodgepole pine volume or stand density by polygon. The 1980s forest insect surveys will identify which polygons have been infested, while the post-1980s forest inventory will reveal what proportion of lodgepole pine was affected (changes in stand density or volume). We know from snag fall rate studies and the many "shelf-life" studies carried out in British Columbia that the majority of those trees killed in the 1980s epidemic are no longer standing. Beyond a certain minimum threshold of stand density or volume change between pre- and post-1980s lodgepole pine inventory, we can conclude that the current stand contains a large loading of large surface fuels.

This stand type can also originate due to past wildfires, with the current lodgepole pine stand growing up through a forest of dead pine. In this case, the prediction is that the large fuel hazard is a function of time since the last wildfire and the general decomposition rate associated with that particular ecosystem. For example, if the antecedent disturbance occurred more than 100 years ago and the decomposition rate is high, chances are that those fuels are no longer an issue. If the antecedent disturbance occurred 50 years ago and the decomposition rate is slow, chances are that those fuels are still an issue. Identifying stand type 3 follows a very similar process as used to identify stand type 2. In this exercise, it is the proportion of lodgepole pine in mixed-species stands between the pre-1980s forest inventory and the post-1980s inventory.

In summary, the current MPB epidemic is creating a wildfire risk and hazard situation across the West that is unprecedented. Fire managers need tools to enable them to identify and prioritize the most hazardous stands within their jurisdictions and begin the process of treating them. This paper describes a proposed fire risk and hazard characterization system, as well as methodology for locating certain stand types on the landscape. ■

Success Stories Wanted!

We'd like to know how your work has been going! Provide us with your success stories within the State fire program or from your individual fire department. Let us know how the State Fire Assistance (SFA), Volunteer Fire Assistance (VFA), the Federal Excess Personal Property (FEPP) program, or the Firefighter Property (FFP) program has benefited your agency. Feature articles should be up to about 2,000 words in length; short items of up to 200 words.

Submit articles and photographs as electronic files by email or through traditional or express mail to:

Melissa Frey
USDA Forest Service
Fire and Aviation Management
1400 Independence Ave., SW
Mailstop 1107
Washington, DC 20250

Tel. 202-205-1090
E-mail: mfrey@fs.fed.us

If you have any questions about your submission, you can contact one of the FMT staff at the email address above or by calling 202-205-1090.

Eating for Health and Performance: *The Wildland Firefighter*

A Forest Service, Missoula Technology and Development Center Brochure

This Forest Service brochure, originally printed in 2006, will help firefighters balance food intake with energy demands before, during, and after the fire season. Copies of the brochure (number 0651-2833P-MTDC) can be downloaded at <http://www.fs.fed.us/t-d/pubs/htmlpubs/htm06512833/index.htm>.

Heli drop foods on Little Bear Fire, photo by Kari Greer

Part I. Energy for Work: Calories

Firefighting is a physically demanding occupation that may require 6,000 calories (kilocalories) per day. Firefighters who do not consume enough calories will become fatigued and will lose body weight and muscle. Consuming too few calories over the weeks and months of a busy fire season can impair immune function and lead to illness. This is not the time to lose weight. Firefighters should check their weight every 2 weeks to monitor their energy balance. The best time to weigh is in the morning before breakfast (but after urination). Energy (calories) comes from carbohydrate, fat, and protein.

Firefighters who do not consume enough calories will become fatigued and will lose body weight and muscle.

Carbohydrate

Carbohydrates are converted to glucose and stored in the liver and muscles as glycogen (branched chains of glucose molecules). Muscle glycogen fuels the muscles during work; liver glycogen maintains blood glucose, the **primary fuel for the brain and nervous system**. When blood glucose levels drop due to extended physical activity, carbohydrates from the food we eat can be used to produce blood glucose. If the body does not receive enough carbohydrates through the diet, it will make glucose from muscle protein, a poor alternative because the muscle protein is needed for the work at hand.

Carbohydrate Requirements

High levels of continuous physical activity, such as digging fireline for hours, increase the daily carbohydrate requirements. Each gram of carbohydrate provides 4 calories of energy.

The following example shows how to calculate the carbohydrate requirement for a 154-pound firefighter:

Weight (in pounds) 154/(2.2 pounds/kilogram) = 70 (weight in kilograms)

***Moderate Work*—5 to 7** grams of carbohydrate/kilogram/day x 70 kilograms (body weight) = 350 to 490 grams of carbohydrate/day

Hard Work—7 to 10 grams of carbohydrate/kilogram/day x 70 kilograms (body weight) = 490 to 700 grams of carbohydrate/day

For ultraendurance activities or very hard work, such as a long, hard day on the fireline, the carbohydrate requirement could be even higher.

Carbohydrate-rich foods include whole-grain products, beans, rice, corn, peas, potatoes, fruit, fruit juice, milk, yogurt, energy bars, and most sport drinks.

Food	Carbohydrate content (grams)
1 slice bread	12
1 cup beans	48
1 cup rice	37
1 cup corn	41
1 medium apple	21
1 energy bar	25
1 cup sports drink	15
1 cup milk	12
1 cup yogurt	14 to 44

During work, firefighters need 40 grams of carbohydrates each hour from snacks and sport drinks. An energy bar may contain 25 grams of carbohydrates, and 1 cup of a sports drink may contain 15 grams, for a total of 40 grams of carbohydrates. Field studies on firefighters show that *eating carbohydrates improves* work output, immune function, blood glucose, ability to think clearly, and mood.

Fat

Fat should provide no more than 20 to 35 percent of daily calories.

MRE, Whitewater-Baldy Complex, photo by Kari Greer

No more than one-third of the fat should come from saturated and trans fats (such as butter, lard, dairy fat, and some processed fats—read the labels). The balance of fat should come from monounsaturated and polyunsaturated fats (such as olive, canola, and peanut oils or from nuts such as almonds, hazelnuts, and olives). If a firefighter needs 4,000 calories per day for heavy work, one-quarter can come from fat (1,000 calories). Because each gram of fat has 9 calories, that's 111 grams (4 ounces) of fat per day.

Protein

Athletes and wildland firefighters require **1.2** to **1.8** grams of protein per kilogram of body weight per day, with **1.2** grams required for moderate work and **1.8** grams required for prolonged hard work under adverse conditions. For this example, we will use a *154*-pound (*70*-kilogram) firefighter who requires **1.5** grams of protein each day for each kilogram of body weight.

1.5 grams of protein/kilogram/day x *70* kilograms (body weight) = *105* grams (*3.7* ounces) of protein/day.

Shift Food—Eating throughout the shift maintains blood glucose and work output.

Part II. Nutrients and Hydration

Nutrition Needs

Firefighters should determine their caloric and nutrient needs by using the Web site <http://www.choosemyplate.gov>. The firefighter may enter his or her age, gender, and level of physical activity. Although the site will provide daily nutrition requirements, the protein and carbohydrate requirements underestimate the needs of wildland firefighters, who are more physically active. Additional information is available by clicking the food group. The following table illustrates the requirements for light and arduous work.

Wildland fire breakfast, Little Bear Fire, photo by Kari Greer

Protein in Foods

Food	Portion	Grams of protein
Almonds	¼ cup	5
Beans	½ cup cooked	8
Beef	4 ounces	35
Cheese	1 ounce	7
Chicken	4 ounces no skin	37
Chili	1 cup	20
Corn	½ cup cooked	3
Egg	1	6
Fish	4 ounces	31
Hamburger patty	4 ounces	20
Milk	1 cup	8
Peanut butter	1 tablespoon	4
Pizza	1 slice	10
Pork	4 ounces lean	35
Rice	½ cup cooked	2.5
Sunflower seeds	¼ cup	8
Tofu	1 cup	6 to 9
Veggie burger	4 ounces	5

Firefighters do not need vitamin and mineral supplements if their diets include a variety of nutrient-rich foods and beverages and provide enough energy to maintain their body weight.

For information on vitamin and mineral needs, see Wildland Firefighter Health and Safety Report: No. 9 on the Missoula Technology and Development Center (MTDC) Web site.

Hydration

Fluid requirements vary from person to person and change with environmental stress. Wildland firefighters should drink enough water throughout the day so that they don't lose more than 2 percent of their weight while working. The U.S. Army and American College of Sports Medicine recommend drinking 1 liter of fluid for every hour of hard work to maintain blood volume and the body's ability to cool itself by sweating.

The work of wildland firefighting generates about 400 calories of heat per hour, while the firefighter receives another 180 calories of heat from the environment and the fire (400 + 180 = 580 calories of heat gain/hour). Complete evaporation of 1 liter of sweat will remove those 580 calories of heat.

Sweat rate and fluid loss differ among individuals. Urine color is a reasonably accurate gauge of hydration—urine should remain pale yellow or wheat colored throughout the day. Daily fluctuations in weight can be monitored to track hydration (weigh in the morning after urination but before eating or drinking).

A firefighter should consume:

	Light work (2,200 calories)	Arduous work (4,400 calories)
Fruit	4 servings (2 cups)	12 servings (6 cups)
Vegetables	4 to 5 servings (2 to 2 ½ cups)	8 servings (4 cups)
Whole Grains	6 servings	12+ servings
Milk or yogurt	1 to 2 cups	5 cups
Meat, fish**	6 ounces	10 ounces

*Whole grains and enriched or whole-grain products.
**Meat, fish, or meat substitute.

Hydrate before work	Drink 1 to 2 cups of fluid
Hydrate during work	Drink 1 cup of fluid every 15 minutes (1 quart/hour)
Hydrate after work	Drink 2 ½ cups of fluid for each pound of weight lost

For more information on heat and hydration, see Wildland Firefighter Health and Safety Report: No. 3 or Fitness and Work Capacity (1997) on the MTDC Web site (see page 7).

Electrolytes

Electrolytes are minerals (sodium and potassium) that are important for nerve/muscle function, and for the body's fluid and acid/base balances.

To replace electrolytes lost in sweat:

- Use the salt shaker at meals
- Eat salty foods (pickles, olives, jerky) during hard work
- Drink carbohydrate/electrolyte drinks (sport drinks) during hard work
- Drink milk at breakfast or after work

Sport Drinks

Carbohydrate/electrolyte drinks (sport drinks) help maintain blood glucose, work output, immune function, mood, and the ability to make decisions. The electrolytes help to maintain blood volume and reduce loss of fluid in the urine. Lightly flavored sport drinks encourage drinking. For more information on sport drinks, see Wildland Firefighter Health and Safety Report: No. 8 on the MTDC Web site.

Part III. Related Issues

Immune Function

Psychological stress, exhaustion, smoke exposure, sleep deprivation, and dehydration can degrade immune function. A well-balanced diet with adequate calories, meat, shellfish, fruits, and vegetables enhances immunity. Research has demonstrated that eating snacks and drinking sport drinks to provide extra carbohydrates during work help to maintain the immune function of wildland firefighters.

Incident Management Teams

Incident management team members do less arduous work than wildland firefighters. Their dietary needs are based on the daily energy expenditure required to maintain the body mass index (BMI) in the normal range (20 to 24.9). Nutritional needs can be determined at <http://www.choosemyplate.gov>. The BMI chart is at <http://www.cdc.gov/nccdphp/dnpa/bmi/>.

Weight Management

When fire season is over, firefighters need to eat less because their energy needs will be lower. To lose weight during the off season, firefighters may:

- Increase physical activity
- Decrease caloric intake by
  - Decreasing intake of sweets and fats
  - Decreasing portions of all foods
- Record body weight every 2 weeks to monitor progress.

Firefighters should begin the fire season **physically fit** with a **sound nutritional base.** ■

Additional copies of this document may be ordered from:

USDA Forest Service, Missoula Technology and Development Center
5785 Hwy. 10 West
Missoula, MT 59808–9361
Phone: 406–329–3978
Fax: 406–329–3719
E-mail: wo_mtdc_pubs@fs.fed.us

Leadership Development for Wildland Fire Management

William Ott

Introduction and Background

Leadership is considered the most essential element in determining the success or failure of institutions (Vecchio, 2008). Organizations need effective leaders to assist their employees in attaining goals and objectives. To do so, many organizations invest heavily in the development of leaders (Robbins and Coulter, 2007). The Forest Service expends nearly 50 percent of its budget on wildfire management activities and invested $29.5 million in 2005 in firefighter training and leadership development, according to the U.S. Department of Agriculture, Office of Inspector General (USDA OIG) (2010). The purpose of this study was to identify successful leadership development programs (LDP) and compare these programs' activities to the Forest Service program to determine if the Forest Service LDP is adequate to meet current and future (5 to 10 years) needs.

Problem Statement

The Forest Service is a Federal land management agency responsible for managing 193 million acres of national forests and grasslands and protects an additional 20 million acres of adjacent State and private property. According to the U.S. Government Accountability Office (GAO), at about 30,000 employees, the Forest Service is the largest organization within the USDA (GAO 2009). More than half of the leadership for this workforce will be eligible to retire by 2014 (USDA OIG 2010). In 2010, the USDA OIG found that the Forest Service "... has not taken the necessary steps to ensure it has a sufficient number of qualified staff to meet its future wildland fire management responsibilities." In 2009, approximately 26 percent of critical firefighter leadership personnel were eligible to retire. The rate is expected to increase to 64 percent by 2014 and 86 percent by 2019 (USDA OIG 2010). As senior firefighter leadership continues to retire, there are an insufficient number of individuals to assume fireline leadership positions.

> As senior firefighter leadership continues to retire, there are an insufficient number of individuals to assume fireline leadership positions.

The Forest Service estimates that 40 percent of employees who take fire training never follow through to qualify for a firefighter position, representing a potential waste of $12 million annually (USDA OIG 2010). This is a problem because the Forest Service finds itself "... fighting larger fires with fewer available critical firefighters" (USDA OIG 2010). The intent of the research project was to review successful leadership programs and compare programs with the Forest Service firefighter LDP to determine if the Forest Service LDP was current and adequate to meet projected leadership needs. The findings from this study served as a framework for recommendations to the Forest Service.

Theoretical Framework

The study is based on Lewin's Field Theory of Social Science (Spector 2010). Within this framework, organizations are considered as open systems and are in a constant interactive state with external and internal environmental forces. The change process model includes unfreezing how an organization operates (including establishing the need for change), changing or moving how the organization operates (e.g., new behaviors), and refreezing the changes into the organization's operations (e.g., integration of new behaviors into organizational relationships) (Palmer, Dunford, and Akin 2009). The diagnostic step falls within the first stage of unfreezing and involves learning how an organization is functioning. Diagnosis identifies gaps between actual and desired organizational performance (Mohrman and Cummings 1989). Therefore, diagnosis has been used in this study and involved acquiring relevant data and information, conducting analysis, and drawing conclusions about organizational design and performance.

William A.R. Ott is the deputy director of Safety, Fire, and Aviation Management and the acting deputy director of Cooperative Forestry and Tribal Relations in the Forest Service, Rocky Mountain Region.

This research project draws upon Lewin's change model by considering the driving forces that may indicate a need for change from the status quo (Robbins and Coulter 2007). Additionally, this research project draws upon work done by Mohrman and Cummings (1989) on a self-design strategy that "… is a process for changing the organizational design components to achieve high performance."

Research Design

The study utilized quantitative measures to identify successful LDPs for subsequent comparison of their best practices with Forest Service practices. The methodology involved diagnosing the functionality of the Forest Service LDP. Diagnosis involved acquiring relevant data, analyzing it, and drawing conclusions about organizational design and performance. Additionally, we examined a qualitative review of best practices of other organizations for the purpose of comparison with Forest Service LDP practices.

Forest Service

Established in 1905, the Forest Service manages and protects 193 million acres of national forests and grasslands and protects an additional 20 million acres of adjacent State and private property (USDA OIG 2010). The Forest Service fields over 10,000 firefighters each fire season and provides training and development of leadership positions for this workforce (USDA OIG 2010).

Definition of Terms

Retirement. Many firefighters face mandatory retirement at 57 years of age, while other Forest Service employees do not have mandatory retirement. While employees in dedicated fire positions may be required to qualify for firefighting positions, Forest Service employees in nonfire positions must volunteer to do so if they choose to participate in firefighting activities. Identifying whether employees belong to fire staff or to the general employee population that may be involved in firefighting allows the Forest Service to forecast its replacement needs due to mandatory retirement (USDA OIG 2010).

For training delivery, the Forest Service uses its own agency professionals as subject matter experts to serve as both developers of curricula as well as instructors.

Lewin's Change Process Model. The three-stage model for how change occurs includes (1) unfreezing or establishing the need for change, (2) moving to a new way of behavior and operations (typically involves restructuring of organizations), and (3) refreezing and integrating changes into operations (including behaviors into social and organizational relationships) (Palmer, Dunford, and Akin 2009). The model views organizations as open systems designed to achieve specific goals within a given environment (Mohrman and Cummings 1989).

Topic and Problem Information

Leadership development of Forest Service personnel for firefighter leadership is elusive in terms of efficiency and effectiveness. Data underscoring this as a problem include:

1. There are more than 300 different Forest Service firefighter qualifications and 54 positions considered critical leadership positions. Of the 24,000 Forest Service employees holding at least 1 qualification, more than 4,300 are also qualified for critical leadership positions (USDA OIG 2010). In 2009, 26 percent of incumbents of these positions were eligible to retire. This rate is expected to increase to 64 percent in 5 years and 86 percent in 10 years (USDA OIG). Refer to figure 1.

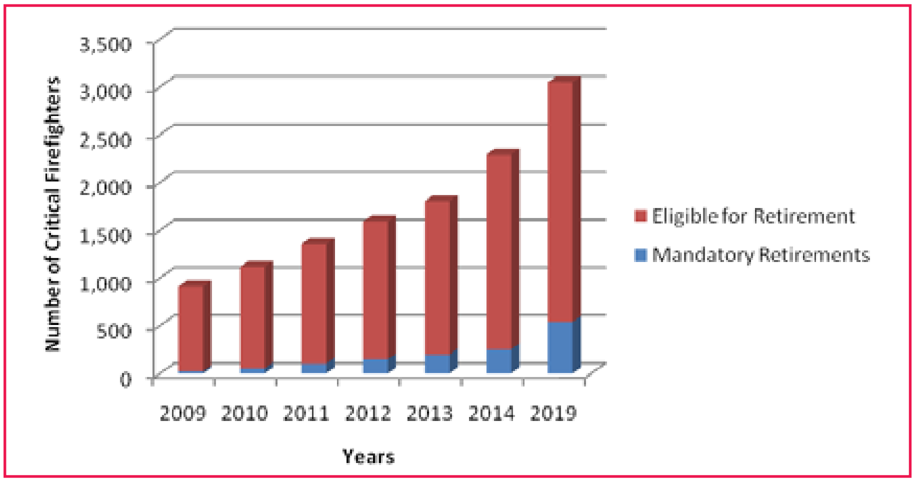


Figure 1.—*Retirement projections of Forest Service firefighters*
Note: Adapted from USDA OIG 2010.

2. The current firefighter LDP relies on voluntary participation (refer to figure 3) and this "… model cannot be sustained due to a lack of sufficient incentives and accountability measures" (National Wildfire Coordinating Group 2011).
3. Forest Service participation and graduation rates from the upper command and general (C and G) staff training program are insufficient to provide for leadership positions, now and into the future (USDA OIG 2010). Refer to figure 4.
4. The Forest Service LDP relies on voluntary participation, which may not coincide with agency needs. Thus, there is no system in place for ensuring that the training investment ($29.5 million in 2005) will yield adequate replacement of incumbents retiring from leadership positions (USDA OIG 2010). Additionally, the Forest Service estimates that 40 percent of employees who undertake fire training "…never follow through to qualify for a firefighter position, a potential waste of $12 million annually" (USDA OIG 2010). Refer to figure 5.

The data indicates that the Forest Service may not be well positioned for meeting its strategic goal of maintaining one of the "basic management capabilities" (USDA Forest Service 2007) of the organization. Declining firefighter leadership is a problem for the Forest Service because it is finding it increasingly difficult to meet its strategic objective of suppressing wildfires efficiently and effectively (USDA Forest Service 2007).

Methodology

The intent of this study was to identify successful LDPs and compare these programs' activities to the Forest Service program to determine if the Forest Service LDP was adequate for meeting current and future needs. The findings from this study served as a foundation for recommendations to the Forest Service. This research project followed a standard approach to applied research (Clark and Creswell 2010). This chapter outlines the methodology used to locate, organize, and review data and information.

Method of Inquiry

Both quantitative and qualitative data provided better insight into the research problem than either approach by itself (Clark and Creswell 2010). Initially, we used an analysis of quantitative data to provide a general understanding of the Forest Service LDP. Government publications and Web sites of the Forest Service, the National Wildfire Coordinating Group, and the USDA OIG served as primary sources of information. We collected additional qualitative data about the LDPs of high-performing, benchmark organizations for comparison and to uncover opportunities (e.g., best practices) for resolving any systemic issues within the Forest Service program. For selected comparison (benchmark) organizations, we used respective corporate Web sites to identify best practices for LDPs. Benchmark organizations included the Internal Revenue Service (IRS), U.S. Navy, General Electric (GE), Motorola, and Federal Express (FedEx).

> Cooperation amongst Federal land management agencies and their State partners will be necessary to leverage scarce human resources and talent.

Steps in Finding and Evaluating Information

Mohrman and Cummings (1989) describe "laying a foundation" as a means by which organizations prepare themselves for change from the status quo. Initial (foundational) steps included investigating the basic principles, structures, and systems of the Forest Service LDP and opportunities for innovation in this program; clarifying the values and outcomes the Forest Service is trying to promote; and diagnosing the current functioning of the organization's LDP. Next steps involved drawing conclusions about organizational design and performance and identification of any potential need for change. The data collected for analysis of the Forest Service LDP included (1) training program activities, (2) accession and attrition rates, (3) LDP participation levels, and (4) post-LDP program participation in firefighting. We compiled this data and organized it into graphs and tables, and analyzed it to seek relationships between inputs, activities, and outputs. A review of leadership development program best practices in government and for-profit organizations was also conducted.

Findings

Components of the Forest Service Leadership Development Programs

A review of the literature led to sorting activities into five strategic components as described in figure 2. The five strategic program components represent key areas of training and development. The current state of the Forest Service LDP was described within each component and subsequently compared to that of strategic LDP practices of five benchmark organizations.

Career and Leadership Development

The Forest Service has a well-developed guide (Forest Service Handbook 5109.17, Fire and Aviation Management Qualifications Handbook) to assist employees with understanding requirements for qualifying and becoming certified for firefighter leadership positions. The focus of this guide is on fire suppression leadership. From a programmatic standpoint, the Forest Service allows employees to self-select target leadership positions based on personal preferences rather than on the needs of the organization (USDA OIG 2010). The Forest Service has a number of intake programs that offer accelerated training. However, there are a limited number of openings, and program costs are considered to be rather expensive (FFTTG 2002).

Training Coordination and Management

The current Forest Service LDP lacks a vision for how to provide systemwide coordination of training and development efforts (FFTTG 2002). As noted by USDA OIG (2010), the organization "does not have a national plan (e.g., succession plan) to manage its future firefighting workforce needs." The current system for developing and scheduling leadership courses is based on wants (i.e., personal preferences) rather than the strategic needs of the organization (FFTTG 2002; USDA OIG 2010). Subgeographic areas of the Forest Service and its sister Federal agencies have developed regional training centers. However, there has been no evaluation about the effectiveness of such training centers as the best model for training delivery (FFTTG 2002).

Curriculum Definition and Innovation

Most of the training provided by the Forest Service is focused on management of wildland fire incidents and the logistical support functions necessary to support these incidents. The organization has only recently recognized the need for improving leadership proficiency (FFTTG 2002). Fireline leadership courses are now sanctioned by the NWCG and offered by a limited number of academies (NWCG 2007). However, a curriculum that offers a full range of leadership development subject matter

Program component	Description
1. Career and Leadership Development	Progress in establishing career tracks for fire leadership positions
2. Training Coordination and Management	Progress in developing a national planning and coordination system
3. Curriculum Definition and Innovation	Progress in establishing new curricula for leadership training
4. Training Delivery and Technology	Progress in establishing new methods and technologies for training delivery and learning
5. Learning Evaluation and Financial Management	Progress in establishing new approaches to evaluating training for learning, return on investment, and organizational performance

Figure 2.— *Strategic components of firefighter leadership development. Note: Adapted from Federal Fire Training Task Group (FFTTG), 2002.*

Critical incident position	Ordered	Unfilled	Percent unfilled
Helicopter coordinator	32	23	72%
Strike team leader, dozer	30	21	70%
Helibase manager (Type 1)	168	110	65%
Safety officer, line	250	156	62%
Strike team leader, crew	315	172	55%

Figure 3.—*Voluntary participation rate for select firefighter positions. Adapted from USDA OIG, 2010, p. 25. Percentage of unfilled orders for critical fire positions (July 19 to August 29, 2007).*

is not available at any one academy. As a result, employees take several years to complete a specific series of leadership development courses (FFTTG 2002). As leadership curriculum was developed, modified, or redesigned, there was no coordination by any accreditation body (FFTTG 2002).

Training Delivery and Technology

For training delivery, the Forest Service uses its own agency professionals as subject matter experts to serve as both developers of curricula as well as instructors. In many cases, this work was collateral to the employees' primary duties. As noted by FFTTG (2002), "the success of this approach is dependent on management's commitment to make these employees available along with the skills and abilities these individuals possess to provide professional instruction." Most training was delivered locally and in a classroom setting (Management Analysis, Inc., 2008). Typically, training techniques involved instructors presenting lectures from lesson plans. Technology included the use of slides, overhead projectors, and electronic slide presentations. Some training centers were beginning to develop and use Web-based training (FFTTG 2002).

Although there is a wide range of fire academies and training centers co-sponsored by the Forest Service and other wildland fire agencies, there are no centrally coordinated programs. Lack of coordination and use of collateral duty instructors who are often poorly trained in knowledge delivery has resulted in a patchwork approach to the development of training and delivery methods (FFTTG 2002). The lack of a systematic and comprehensive approach has engendered a number of issues, of which the most problematic is the length of the training cycle. An early finding by FFTTG (2002) noted that "many employees see the lengthy training cycle to

Critical firefighter position	No. of qualified	Average age of qualified	No. of trainees	Average age of trainees	Difference
Command staff					
Incident commander, Type 1	27	55.7 yrs	3	49 yrs	-24 (89%)
Incident commander, Type 2	66	54.5 yrs	33	51.3 yrs	-33 (50%)
Incident commander, Type 3	817	48.3 yrs	456	41.7 yrs	-361 (44%)
Safety officer, Type 1	32	57.5 yrs	20	54.5 yrs	-12 (38%)
Safety officer, Type 2	274	55.8 yrs	125	51.7 yrs	-149 (54%)
Safety officer, Line	131	52.3 yrs	226	44.2 yrs	+95 (73%)
Public information officer, Type 1	60	56.7 yrs	48	51.3 yrs	-12 (20%)
Public information officer, Type 2	191	54.5 yrs	115	52.7 yrs	-76 (40%)
Total no. and average age—command staff	1,598	51.5 yrs	1,026	45.7 yrs	
General staff					
Operations section chief, Type 1	70	53.8 yrs	27	52.5 yrs	-43 (61%)
Operations section chief, Type 2	287	53 yrs	168	48.6 yrs	-119 (41%)
Planning section chief, Type 1	45	57.9 yrs	6	54.6 yrs	-39 (87%)
Planning section chief, Type 2	95	57 yrs	19	57.5 yrs	-76 (80%)
Logistics section chief, Type 1	46	58 yrs	10	53.8 yrs	-36 (78%)
Logistics section chief, Type 2	114	58.2 yrs	19	54.9 yrs	-95 (83%)
Finance section chief, Type 1	37	56.5 yrs	11	56.2 yrs	-26 (70%)
Finance section chief, Type 2	73	55.9 yrs	24	53.8 yrs	-49 (67%)
Total no. and average age—general staff	767	55.3	284	51.0	

Figure 4.—*Qualified leadership positions versus number of trainees. Adapted from USDA OIG, 2010, p. 39. Calculated totals reflect weighted averages as of July 18, 2008.*

Course number	Course description	Target position	Number attending class	Projected number not obtaining certification	Estimated training inefficiency
S-403	Incident information officer	Incident information officer (Type 2)	43	43	100%
S-470	Air operations branch director	Air operations branch director	11	11	100%
S-460	Finance section chief	Finance section chief (Type 2)	1	1	100%
S-330	Task force/strike team leader	Task force/strike team leader	900	783	89%
S-400	Incident commander	Incident commander (Type 2)	10	9	87%
S-378	Air tactical group supervisor	Air tactical group supervisor	41	31	76%
S-430	Operations section chief	Operations section chief (Type 2)	36	27	75%
S-404	Safety officer	Safety officer (Type 2)	111	81	73%
S-450	Logistics section chief	Logistics section chief (Type 2)	7	4	57%
S-300	Incident commander extended attack	Incident commander (Type 3)	187	101	54%

Figure 5.—*Training completion rate for select leadership positions. Adapted from USDA OIG, 2010, p. 42.*

be a barrier to pursuing a career in fire management…" Eight years later, the USDA OIG (2010) found there had been little improvement and noted that "since employees set their own training pace, they take an average of 23 years to qualify for critical incident management positions such as section chiefs and incident commanders (refer to figure 6); this is an average of 12 years longer than the optimal timeframes that Forest Service estimates are possible with more focused training."

Learning Evaluation and Financial Management

Currently, the Forest Service and its Federal partners do not have a systematic approach for evaluating specific courses of instruction in terms of the value of training or for conducting an assessment of overall programs of study (FFTTG 2002). The organization has focused most of its efforts on collecting costs on such items as curriculum development, delivery, and management and administration. However, little effort has been placed on evaluating

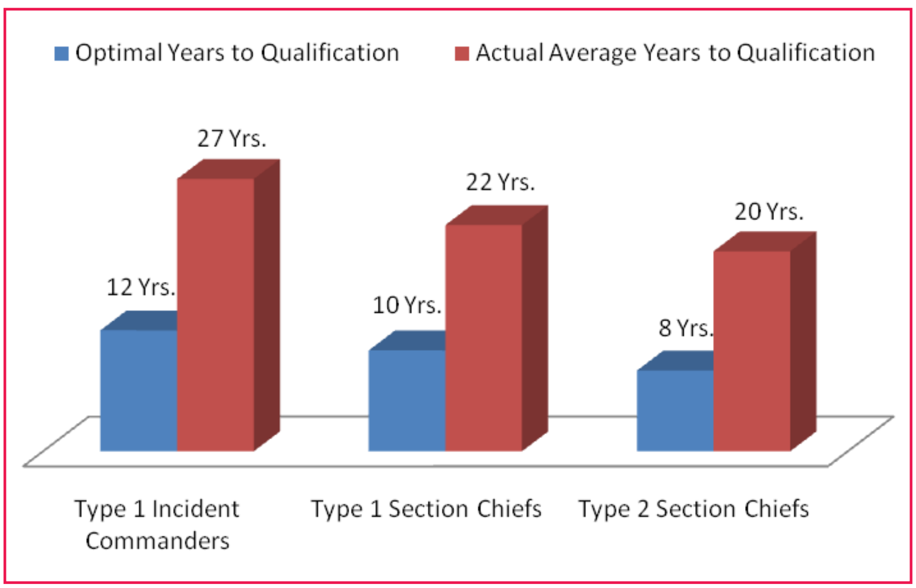


Figure 6.—*Actual versus optimal time to qualify for leadership postions. Adapted from USDA OIG, 2010, p. 16.*

benefits and return-on-investment (ROI) (Management Analysis, Inc. 2008). A general sense of the value placed on firefighter leadership development by the organization has been that when there were budget cuts, training was one of the first items to receive less funding (FFTTG 2002).

Components of Successful Leadership Development Programs

To be competitive for a fixed to diminishing talent pool, organizations need to understand the connection between strategic development of human resources and organizational success (American Society for Training and Development 2003). For this study, five organizations were selected as benchmarks for best practices. Two organizations from the Federal sector included the IRS and the U.S. Navy. The Office of Personnel Management (OPM) recognized the IRS for its advances in strategic management of human capital and, in particular, as an example of moving forward in leveraging the power of standardized information technology to gain efficiencies in employee training and development (OPM 2005). *Leadership Excellence* magazine recognized the U.S. Navy as being in the top 10 Government/military organizations in 2010 for its leadership program (Leadership Excellence 2011). *Leadership Excellence* magazine also recognized three large (over 2,000 employees) for-profit organizations for best leadership development practices including GE, FedEx, and Motorola. Following is a summary of best practices from each organization.

Over a quarter of the organization's critical firefighter leadership is currently eligible to retire, and over half are eligible to do so in 5 years.

Internal Revenue Service

The IRS set out to implement a new approach to employee development that would increase the availability of training materials, reduce expenditures associated with travel and time related to traditional training delivery programs, provide an accessible corporate database for monitoring employee development, and ensure consistency and reusability of a wide range of training processes and procedures (Howard 2007). Several best practices adopted by the IRS included:

- Developing and capturing learning content in a reusable format to be used in both classroom and online settings.
- Providing training to content developers and vendors to assure that they were aligned with the IRS' Learning Content Management System.
- Conducting cost-benefit analysis estimates for course development in order to make decisions about the feasibility of preparing courses in-house or contracting for courses.

U.S Navy–Naval Aviation System

According to the FFTTG, the U.S. Navy's Naval Aviation System (NAVAIR) Career Development Program exemplifies a successful effort in significantly reducing the cycle time for processing employees through a training system (2002). The NAVAIR LDP prepares sailors and marines for greater effectiveness in abilities to lead large and small teams (Comprint Military Publications 2009). The focus of the LDP has been on building executive core qualifications and continuous process improvement. Through these two focus areas, the Navy weaves in functional and technical knowledge, skills, and abilities (KSAs), team skills' management KSAs, and leadership KSAs. Additionally, the Navy's best practices include providing:

- An extensive and formal mentoring program.
- An online career mapping tool for preparing individual development plans (FFTTG 2002).

General Electric

GE continues to be recognized for its success in developing leadership talent (Stewart 1998; Robbins and Judge 2010). Among GE's best practices for leadership development are the following:

- Aligning initiatives with core values.
- Providing continuous succession planning.
- Assuring successful cultural transformation through creating, identifying, and transferring organizational learning.
- Assuring alignment of human resource management with core business objectives.
- Basing individual development needs on five key traits that are highly valued by GE: imagination, clear thinking, inclusiveness, external focus, and having a domain expertise (Knudson 2011).

- Coaching.
- Action learning (Day and Halpin 2001).

Federal Express

FedEx has a strong commitment to involving its employees in its quality improvement program and in its training, professional development, and advancement programs (Baldrige Performance Excellence Program 2002). The guiding philosophy at FedEx is that "…when people are prioritized first, they will provide the highest level of possible service, and profits will follow (People-Service-Profits, or PSP)" (Day and Halpin 2002). FedEx has a comprehensive LDP in which leaders at all levels are expected to cultivate the company's people-first culture. The company established a leadership institute based on applying principles of leadership drawn from Hersey and Blanchard's Situational Leadership Theory and Greenleaf's servant leadership model (Day and Halpin 2002). Another best practice included using the organization's *Leadership Evaluation and Awareness Program* (Casestudyinc.com 2008) to introduce the company's nonmanagerial employees to opportunities to move into management positions.

Motorola

Originally established as the Motorola Training and Education Center in 1980, the Motorola University is a key component of Motorola's leadership development program. Leadership training focuses on developing managers into catalysts for continuous improvement (Day and Halpin 2001). Motorola University is considered a *Prototype III: Drive and Shape* (Fresina 1997) model in that the company uses it as a primary force to drive and shape the organization. Motorola University is at the core of the company's senior executive leadership development program (Fresina 1997). Another innovation includes Motorola's strategy for developing and sustaining leadership supply. The company identified the top 1,000 individuals in the organization and "…created position profiles, talent profiles on current and potential leaders, and put the entire system into a talent management data base" (FFTTG 2002). Additionally, the company conducts rigorous reviews of its executives and reassigns 10 percent of these leaders to assure that there is room for new talent to move into this cadre (Day and Halpin 2001). Motorola has worked towards accelerating the development and delivery of the Six Sigma quality improvement program. Other leadership development initiatives included tailoring training to different leadership levels (supervisors, beginning managers, and executives). Much of the company's leadership program content for lower level managers was based on Hersey and Blanchard's Situational Leadership Theory (Day and Halpin 2001).

Comparison of Leadership Development Programs

Figure 7 provides a summary of key activities within each of the five leadership program components of the Forest Service and the five benchmark organizations. Although each organization is unique in the way it has designed its LDP, there are commonalities across programs as well as several distinguishing features. Features common to two or more of the benchmark organizations and the Forest Service include the presence of coaching and/or mentoring and training centers. Features common to two or more benchmark organizations but not present at the Forest Service include having executive level commitment, monitoring (e.g., tracking) employee development, providing a centralized coordination and management of LDPs, establishing a continuous improvement process for curriculum development and innovation, identifying key leadership attributes (i.e., executive core qualifications), evaluating return on investment, and reducing the training cycle time. Several features unique to some benchmark organizations and not present at the Forest Service included online career mapping and efforts to reduce the cost of training delivery.

Analysis

Relationship of Findings to Research Question

As noted, over a quarter of the organization's critical firefighter leadership is currently eligible to retire and over half are eligible to do so in 5 years. Currently, there are an insufficient number of individuals ready and available to keep up with this rate of attrition (USDA OIG, 2010). The findings led to a diagnosis of potential underlying causes for a shortfall in leadership development and for financial losses associated with the Forest Service LDP.

Analysis

Although the Forest Service has a well-developed guide for employees seeking a career path toward firefighter leadership positions, the agency defers to employees' personal preferences rather than guiding employees toward meeting critical organizational leadership needs. As a result, scheduling of courses has been driven by employee demand

Program component	Forest Service	IRS	U.S. Navy	General Electric	Federal Express	Motorola
Career and leadership development	Tailored to different leadership levels Coaching and mentoring program Action learning	Monitoring and tracking of employee development	Online career mapping Mentoring program	Action learning Coaching Executive level commitment	Leadership evaluation and awareness program Executive level commitment	Tailored to different leadership levels Talent management data base Executive level commitment
Training coordination and management	Decentralized	Centralized	Centralized	Continuous succession planning		Sustaining leadership supply Succession plan
Curriculum definition and innovation	Focus on technical skills		Executive Core Qualifications Continuous Improvement Process	Development based on key leadership traits	Continuous Improvement Process	Continuous Improvement Process
Training delivery and technology	Training centers	Reduce cost of training delivery Online availability of training materials Consistency in training delivery	Training centers Reduced training cycle time		Training centers	Training centers Reduced training cycle time
Learning evaluation and financial management	Track cost only	Cost-benefit analysis			Links profits to people	Rigorous review of executives

Figure 7.—*Comparison of leadership development programs. Adapted from Howard, 2007; FFTTG, 2002; Knudson, 2011; Day and Halpin, 2001; casestudyinc.com, 2008; Fresina, 1997.*

rather than by the strategic needs of the organization (USDA OIG 2010). Because personal preferences were not necessarily aligned with organizational needs, this practice has led to inefficient use of financial resources.

Further compounding the issue has been the lack of a Forest Service succession plan to guide financial investments (USDA OIG 2010). Coordination of leadership development was distributed not only across the organization but has also been shared with four other Federal agencies (FFTTG 2002). Decentralization of efforts has led to a lack of unity and focus with no systemwide coordination or succession planning. Lack of coordination has also contributed to an excessively long training cycle (FFTTG 2002; USDA OIG 2010). With the decentralized approach to leadership development, many different forms of training delivery have manifested themselves across the broad geographic reach of the many regions of the Forest Service. Additionally, firefighter leadership training has not kept up with technology innovations such as Internet and Web-based delivery (FFTTG 2002). The analysis offered here led the author to conclude that, from a financial management standpoint, the Forest Service LDP has been very poorly managed in terms of providing an adequate supply of firefighter leaders in a cost effective and timely manner. Much of the Forest Service investment in training future firefighter leaders has been lost with too little return.

Best Practices

Many of the best practices of the benchmark organizations have application for improving the Forest Service LDP (refer to figure 7). Executive level commitment to an organization's LDP appeared to be a critical element for sustaining a successful program. A systematic approach to career development including career mapping, coaching and mentoring, indentifying talent, and monitoring, and tracking high-potential employees was one of a few of the best practices exhibited by benchmark organizations.

Successful models for training coordination and management at high-performing organizations were characterized by a centralized approach. Additionally, continual attention to succession planning and monitoring of progress appeared to be a prerequisite. Monitoring and evaluation of progress in succession coupled with adjustments were required to assure sustainability of leadership from the beginning through the end of the LDP pipeline.

With respect to curriculum development and innovation, a characteristic of successful LDPs was the presence of a continuous improvement process. Attention to the identification of key leadership traits and executive core qualifications was another best practice that assures continual improvement and innovation. Shifting focus from technical skills to both leadership and managerial skills (e.g., organizational leadership, human relations, communications, decisionmaking, financial management, etc.) was an important characteristic found in several benchmark organizations that would have applicability for the Forest Service LDP.

Several benchmark organizations have centralized training centers through which training delivery was coordinated and executed. In this fashion, the organizations maintained continuity and quality assurance in the development and delivery of training, as well as in the application of emerging technologies (e.g., Web-based training). Although the Forest Service has relied on the training center model, it has many training centers that pursue different delivery methods, most of which continue to be conventional classroom settings and which exhibit a high degree of variability from one center to another. A number of benchmark organizations have made significant strides toward reducing training cycle times through such practices as online availability of courses, integrated planning (e.g., succession planning), and coordinated execution (e.g., scheduling of course development and delivery) of their respective LDPs.

In contrast to the Forest Service practice of tracking costs only, a number of benchmark organizations have linked costs to the outputs resulting from their investments in leadership development. One organization conducted cost-benefit analyses of its training development to make decisions about how to invest its financial resources for the best return. Another organization has devised a system for linking organization performance (e.g., profits) to its LDP.

Recommendations

The analysis (diagnosis) portrayed above indicates a need for change or, as described in Lewin's change model as the first stage, unfreezing (Spector 2010). As noted in Spector (2010), Lewin's second stage involves movement of the Forest Service operations for managing its LDP. Recommended changes were anchored to the underlying causes of the Forest Service's inability to bring its LDP's rate of output in line with or ahead of its leadership attrition rate. Additional recommendations focused on resolving the financial management issue associated with the waste of millions of dollars annually (USDA OIG 2010).

Because the Forest Service has exhibited a tendency to study the issues surrounding the performance of its LDP at length (FFTTG 2002; Management Analysis, Inc. 2008; USDA OIG 2010; NWCG 2011) followed by minimal action for improvement, the catalyst for change will most likely have to come from outside the organization (e.g., from the USDA, U.S. Congress, or the Executive Branch of the U.S. Government). At best, the organization has pursued a change strategy of "tinkering, kludging, and pacing" as described by Palmer, Dunford, and Akin (2009). Although, this approach to change can be effective, particularly with respect to managing resistance to change, it has been ineffective in improving the success and effectiveness of the Forest Service LDP. Strong and sustained leadership from the top echelons of the Forest Service as well as its sister agencies in the U.S. Department of the Interior (DOI) (e.g., Bureau of Land Management, U.S. Fish and Wildlife Service, National Park Service, and Bureau of Indian Affairs) will be required to affect and sustain successful change. Additional support and direction will most likely be required at the higher Departmental level (USDA and DOI). A recommended means for focusing and applying executive leadership to the Forest Service and to cooperating organizations' efforts for improving LDPs would be to establish a governing body that is interagency in nature and would be delegated the authority to strategically leverage the LDP resources of all five agencies. The goal of this body would be to integrate the planning of financial investments in training and development as well as assuring coordinated execution of the LDP. This proposal was first surfaced by FFTTG (2002). However, the idea has never been fully implemented and is indicative of limited leadership commitment by the organization and its partners to strengthening a coordinated, effective, and efficient firefighter LDP.

Career and Leadership Development

Recommendations for career and leadership development include development of a process for screening and evaluating high-potential leadership candidates and the establishment of a database to track employees' progress in order to assure key milestones are achieved. Critical milestones would include establishing short- and long-term career tracks and associated individual development plans, scheduled action learning experiences, coaching and mentoring, and monitoring and feedback mechanisms.

Training Coordination and Management

We recommended the Forest Service develop an updated and comprehensive workforce analysis and succession plan. The effort should be coordinated at a high organizational level to assure a systematic and systemwide approach. The present practice of distributing coordination efforts across multiple geographic areas has failed to lead to the desired results (e.g., sustained, timely and efficient development of leadership). The governing body described above would serve as an initial first step. Continuous succession planning on a biennial or quadrennial basis would assure that plans do not go stale and that leadership supply is sustained on a continual basis.

Curriculum Definition and Innovation

Only recently have the Forest Service and its Federal partner agencies begun to shift from providing technical training to a more broad-based approach to leadership training. A number of the newer leadership courses have not been sanctioned by an accrediting body. The recommendation is that the Forest Service identifes key leadership attributes necessary to successfully lead its firefighting workforce. At the highest firefighter leadership positions, executive core qualifications should be established and a curriculum of study and action learning developed and sanctioned to meet leadership performance requirements.

Training Delivery and Technology

USDA OIG and others (FFTTG 2002, Management Analysis, Inc. 2008, NWCG 2011) have identified several key issues that would serve as a basis for examining the flow of individuals through the organization's training and development cycle. Undertaking a value stream mapping exercise as described by Stevenson (2009) of the training and development cycle is recommended. In doing, so the identification of process bottlenecks and where waste occurs (e.g., investments with no return, non-value-added requirements, etc.) would afford the opportunity to make process improvements. An example of a process improvement opportunity would be to shift from a traditional classroom setting for delivery of instruction to a more reusable online, Web-based format for content and delivery.

Learning Evaluation and Financial Management

Elements of a lean operations philosophy as described by Stevenson (2009) have applicability for matching capacity with demand for leadership positions. The overarching goal of a lean approach is to achieve a smooth and rapid flow of employees through a training and development system that yields a sufficient number of skilled employees to assume critical leadership positions. Concurrently, the agency must establish a systematic approach for assuring that these individuals are readily available when needed.

Metrics for providing an improved financial management system that assures a better return on investment should include monitoring of the number of employees that enter the LDP and the number of employees that successfully complete the program. Rather than just measuring cost elements such as instructor and student salaries and travel and facilities costs, actual outputs (e.g., benefits) should be measured so that a unit cost can be established and compared (trend) over time. Presently, firefighters face a mandatory retirement age of 57 years. Another metric would include identifying the shelf life of employees coming out of the LDP as qualified leaders who are assigned to leadership positions. This metric would provide information about the organization's leadership inventory, the cost of maintaining the inventory, and the shelf life of the leaders in the inventory.

> Critical milestones would include establishing short- and long-term career tracks and associated individual development plans, scheduled action learning experiences, coaching and mentoring, and monitoring and feedback mechanisms.

In other words, how many years of service are obtained from qualified leaders before they face mandatory retirement? The first step would be to better refine the current inventory of leadership personnel by eliminating those employees who, although trained, are unavailable to be mobilized due to other agency priorities. By doing so, the agency would have a more accurate count of inventory as well as its shelf-life. Additionally, the agency must cease investing training and development resources into personnel at the unit leader level who are either unavailable for mobilization or do not have the personal commitment and/or support from their managers to advance toward higher level leadership positions. Concurrently, Forest Service leaders must hold their managers accountable for investing in and making the broader inventory of fire personnel (both dedicated and collateral duty) available for fire duty.

Future Research Efforts

The recommendations described above highlight opportunities for future research. Perhaps the greatest value-added opportunities would flow from the recommendations to apply a lean philosophy and to undertake an exercise in value mapping of the current leadership training and development cycle. Additional research on the range of leadership development models currently available with respect to their applicability to emergency response leadership would benefit the Forest Service and other organizations. For example, an evaluation of the LDPs of other emergency response organizations, such as the military service branches of the U.S. Department of Defense (e.g., U.S. Coast Guard) and the U.S. Department of Homeland Security's many emergency response agencies (e.g., Federal Emergency Management Agency) might inform the Forest Service decisions on how to improve its LDP model.

Conclusion

In 2010, the USDA OIG conducted an evaluation of the Forest Service firefighting succession planning process (USDA OIG, 2010). USDA OIG found that the agency's efforts have been ineffectual and, in many cases, resulted in a waste of resources. A fundamental conclusion was that the Forest Servivce's projected demand for firefighter leadership exceeds the organization's capacity. As found by the USDA-OIG (2010), the Forest Service has allowed for the creation of imbalances between employee's chosen firefighter career paths and the agency's strategic needs. The Forest Service has allowed its employees to self-select firefighting courses and to determine the pace of their own progress. Rather than an optimal training cycle of 12 years, an average of 23 years has been required to reach upper level leadership qualifications. The agency has failed to ensure an efficient return on its investment ($12 million wasted of $29.5 million invested in 2005) (USDA-OIG 2010).

The Forest Service has an opportunity (as well as direction) to resolve a leadership development program for providing leaders of its wildland firefighting workforce. Forest Service leadership must not only engage its interagency partners but also the employees that staff its incident management teams in designing a more efficient and effective LDP. Cooperation amongst Federal land management agencies and their State partners will be necessary to leverage scarce human resources and talent. The recommended governing body described earlier would be a way for facilitating such interagency cooperation.

References

American Society for Training and Development. 2003. The human capital challenge: A white paper by the ASTD Public Policy Council. 27 p.

Baldrige Performance Excellence Program. 2002. Malcolm Baldridge national quality award 1990 recipient Federal Express Corporation. http://www.baldrige.nist.gov/FederalExpress_90.htm. (22 February 2013).

Casestudyinc.com. 2008. HR Best practices at FedEx, a best company to work for. http://www.casestudyinc.com/hr-best-practices-at-fedex-best-company. (8 January 2010).

Clark, V.P.; Creswell, J.W. 2010. Understanding research: A consumer's guide. Upper Saddle River, NJ: Pearson Education, Inc. 288 p.

Comprint Military Publications . 2009. NAVAIR to brief new leadership development program. http://ww2.dcmilitary.com/stories/022609/tester_28167.shtml. (25 February 2009).

Day, D.V.; Halpin, S.M. 2001. Leadership development: A review of industry best practices. Technical Report 1111. Alexandria, VA: U.S. Army Researh Institute for the Behavioral and Social Sciences. 77 p.

Federal Fire Training Task Group. 2002. Federal fire training strategy training and development for the next generation of Federal wildland fire managers. Tucson, AZ: National Advanced Fire and Resource Institute. 81 p.

Fresina, A. J. 1997. The three prototypes of corporate universities. Hanover, IN: Executive Knowledge Works. Corporate University Review. 4 p.

Government Accountability Office. 2009. Forest Service emerging issues highlight the need to address persistent management challenges. GAO–09–443T. Washington, DC: Government Accountability Office. 22 p.

Howard, Chris. 2007. Large-scale e-learning: IRS increases training efficiency. ID–2804. Oakland, CA: Bersin and Associates. 22 p. http://www.bersin.com/Practice/Detail.aspx?id=5804. (25 February 2013).

National Wildfire Coordinating Group. 2011. Evolving incident management: An analysis of organizational models for the future. Boise, ID: National Wildfire Coordinating Group, Incident Management Organization Succession Planning Team. 71 p. http://www.nwcg.gov/imosp/docs/binder.pdf. (25 February 2013).

Knudson, L. 2011. Generating leaders GE style. HR Management. Issue 4: 4. http://www.hrmreport.com/article/Generating-leaders-GE-style/. (25 February 2013).

Leadership Excellence. 2011. 2010 best in leadership development. http://www.leaderexcel.com/best_ranking.html. (12 November 2011).

Management Analysis, Inc. 2008. Management efficiency assessment of the interagency wildland fire training and related services. Washington, DC: The Fire Executive Council. 1 p.

Mohrman, S.A.; Cummings, T.G. 1990. Self-designing organizations–learning how to create high performance. Reading, MA: Addison-Wesley. 189 p.

Office of Personnel Management. 2005. OPM hosts Internal Revenue Service's learning management system. Washington, DC. 1 p.

Palmer, I.; Dunford, R.; Akin, G. 2009. Managing organizational change (2nd ed.). New York, NY: McGraw-Hill Irwin. 432 p.

Robbins, S.P.; Coulter, M. 2007. Management (9th ed.). Upper Saddle River, NJ: Pearson Prentice Hall. 672 p.

Robbins, S.P.; Judge, T.A. 2010. Organizational behavior (14th ed.). Upper Saddle River, NJ: Pearson Prentice Hall. 720 p.

Spector, B. 2010. Implementing organizational change: Theory into practice (2nd ed.). Upper Saddle River, NJ: Prentice Hall. 224 p.

Stevenson, W. 2009. Operations management (10th ed.). New York, NY: McGraw-Hill Irwin. 944 p.

Stewart, T.A. 1998. America's most admired companies why leadership matters. Fortune Magazine (March 2). http://money.cnn.com/magazines/fortune/fortune_archive/1998/03/02/238547/index.htm. (25 February 2013).

U.S. Department of Agriculture (USDA), Forest Service. 2007. USDA Forest Service strategic plan: FY 2007–2012. FS-880. Washington, DC: Forest Service. 34 p.

USDA Forest Service. 2008. Fire and aviation management qualifications handbook. FSH 5109.17. Washington, DC: Forest Service. 251 p.

USDA Forest Service. 2011. Fire Management. FSM 5100. Washington, DC: Forest Service. 116 p.

USDA Office of Inspector General (OIG). 2010. Forest Service's firefighting succession planning process. Audit Report 08601-54-SF. Washington, DC: U.S. Department of Agriculture, OIG. 54 p.

Vecchio, R.P. 2008. Leadership: Understanding the dynamics of power and influence in organizations (2nd ed.). Notre Dame, IN: University of Notre Dame Press. 583 p.

Fire Management today

2013 Photo Contest

Deadline for submission is 6 p.m. eastern time, Friday, December 6, 2013

Fire Management Today (FMT) invites you to submit your best fire-related images to be judged in our photo competition. Entries must be received by close of business at 6 p.m. eastern time on Friday, December 6, 2013.

Awards

Winning images will appear in a future issue of *FMT* and may be publicly displayed at the Forest Service's national office in Washington, DC.

Winners in each category will receive the following awards:

- 1st place: One 20- by 24-inch framed copy of your image.
- 2nd place: One 16- by 20-inch framed copy of your image.
- 3rd place: One 11- by 14-inch framed copy of your image.
- Honorable mention: One 8- by 10- inch framed copy of your image.

Categories

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

Rules

- The contest is open to everyone. You may submit an unlimited number of entries taken at any time, but you must submit each image with a separate release/application form. You may not enter images that were judged in previous *FMT* contests.
- You must have the authority to grant the Forest Service unlimited use of the image, and you must agree that the image will become public domain. Moreover, the image must not have been previously published in any publication.
- *FMT* accepts only digital images at the highest resolution using a setting with at least 3.2 mega pixels. Digital image files should be TIFFs or highest quality JPGs. Note: *FMT* will eliminate date-stamped images. Submitted images will not be returned to the contestant.
- You must indicate only one category per image. To ensure fair evaluation, *FMT* reserves the right to change the competition category for your image.
- You must provide a detailed caption for each image. For example: *A Sikorsky S-64 Skycrane delivers retardant on the 1996 Clark Peak Fire, Coronado National Forest, AZ.*
- You must submit with each digital image a completed and signed Release Statement and Photo Contest Application granting the Forest Service rights to use your image. See http://www.fs.fed.us/fire/fmt/release.pdf.

Disclaimer

- A panel of judges with photography and publishing experience will determine the winners. Their decision is final.
- Images depicting safety violations, as determined by the panel of judges, will be disqualified.
- Life or property cannot be jeopardized to obtain images.
- The Forest Service does not encourage or support deviation from firefighting responsibilities to capture images.
- Images will be eliminated from the competition if they are obtained by illegal or unauthorized access to restricted areas, show unsafe firefighting practices (unless that is their expressed purpose), or are of low technical quality (for example, have soft focus or camera movement).

To help ensure that all files are kept together, e-mail your completed release form/contest application and digital image file at the same time.

E-mail entries to: firemanagementtoday@fs.fed.us

Postmark Deadline is 6 p.m., Friday, December 6, 2013

Superintendent of Documents **Subscription** Order Form

Order Processing Code: S3

*

☐ **YES,** enter my subscription(s) as follows:

Charge your order. It's easy!

To fax your orders: 202-512-2104

To phone your orders: 202-512-1800 or 1-866-512-1800

For subscription cost and to Order on Line: http://bookstore.gpo.gov

The total cost of my order is $__________. Price includes regular shipping and handling and is subject to change.
International customers please add 25%.

Company or personal name (Please type or print)

Additional address/attention line

Street address

City, State, Zip code

Daytime phone including area code

Purchase order number (optional)

For privacy protection, check the box below:

❑ Do not make my name available to other mailers

Check method of payment:

❑ Check payable to Superintendent of Documents

❑ GPO Deposit Account ☐☐☐☐☐☐☐ – ☐

❑ VISA ❑ MasterCard

(expiration date)

Thank you for your order!

Authorizing signature

Mail To: U.S. Government Printing Office - New Orders
P.O. Box 979050
St. Louis, MO 63197-9000