Fire Management *today*

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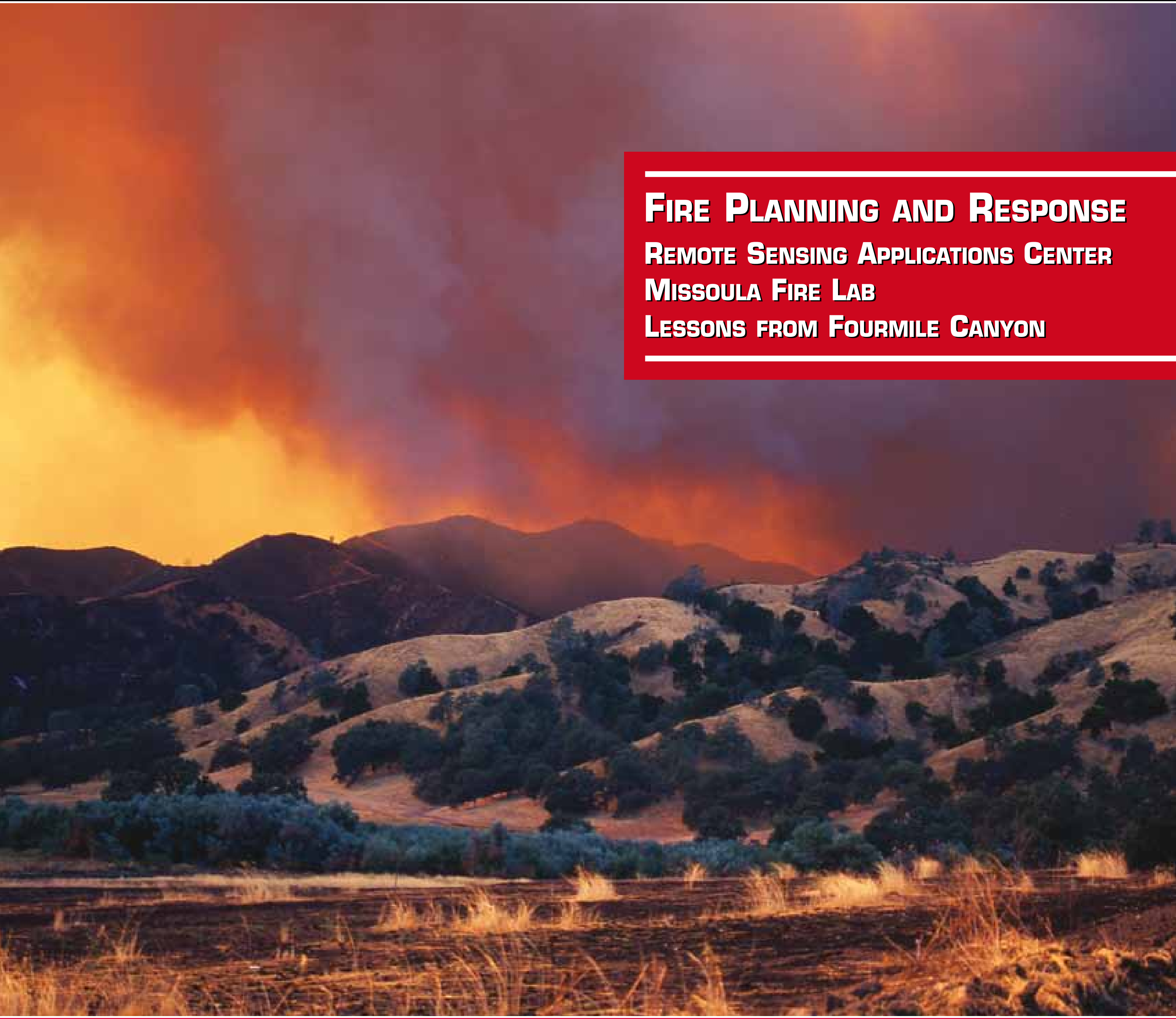

Fire Planning and Response

Remote Sensing Applications Center

Missoula Fire Lab

Lessons from Fourmile Canyon

USDA

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Forest Service

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On the Cover:

Burned grasses mark the foreground of the Kirk Complex, Fort Hunter Ligget, CA. Photo: Kari Greer, National Interagency Fire Center, Castle Rock, CO.

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, Washington, DC

What's in a Legacy?

My focus in the past couple issues of *Fire Management Today* has been on those items that are very important to me as the Forest Service Fire and Aviation Management (FAM) Director—those things that are important to me as the national director and to you as a member of the Fire and Aviation Management team. Two issues ago, I listed them—(1) building a national cohesive wildland fire management strategy; (2) continuing implementation, adaptation, identification, and evolution of doctrine and risk management; (3) building a wildland fire profession with professional ethics, a code of conduct, philosophy, and professional qualifications that creates equity and opportunity in fire and aviation management; and (4) better aligning the expectations of the land with ecologic fire dynamics of vegetation. Two other important items are to continue with our leadership in the Quadrennial Fire Review and take our appropriate role on the world stage. I promised to use Anchor Point to elaborate on each of them—describe what they mean to me as the national director and what they should mean to you as a member of the FAM team.

In the last issue I wrote about the Fires of 1910 and how they ultimately propelled the Forest Service into the fire leaders that we are today. I talked about how we cannot solve the wildland fire management problems facing the Nation alone, and how the Secretaries of Agriculture and of the Interior recently sought the assistance of our other Federal, State, tribal, and local governmental and nongovernmental partners to create a national—not a Federal—cohesive wildland fire management strategy.

The national cohesive strategy provides hope that the framework contained within will afford us the tools we need to work better as firefighters and managers of *all lands* across the United States. Once implemented, the national strategy will help us strengthen our response efforts and enable us, collectively, to focus on broader work activities, contributing to more resilient landscapes and communities that are able to coexist with wildland fire.

Doctrine and Risk Management

This all brings me to the next "legacy" item: implementation, adaptation, identification, and evolution of doctrine and risk management. What does that mean? Doctrine is a body of principles, the foundation of judgment, decisionmaking, and behaviors that guide the actions of the organization and describe the environment in which they are taken. Doctrine is developed from the legal and ethical mandates of the organization and the intent of its senior leaders. Rules cover those things that senior leadership identifies as too important to leave to judgment, while doctrine provides guidance for dealing with the subjective and dynamic parts of the mission that rely on interpretation, judgment, and agility—or the speed, agility, and focus that I talk about.

It is my intention as director that we continue the implementation, adaptation, identification, and evolution of doctrine and risk management. We need to change the way we think about decisionmaking—think about the way decisions are made, from the ground up. We will respect and value thinking minds, and the voices and thoughts of those that challenge the status quo while focusing on the greater good.

Effective command and control relies on the expression of clear intent, confidence in capabilities, acceptance of mutual responsibilities, a specified objective, and freedom to act, all firmly rooted in shared doctrinal principles. We need to make operationally sound decisions, using the science, technology, and tools available to us to develop and apply those decisions.

By the continued implementation and evolution of doctrine and risk management, we will create an organization that is guided by well-stated doctrinal principles, representing the reality of our work, the environment, and our mission. These principles will be understood, meaningful, and accepted by every employee and the public, and will remain at the heart of a safe, effective mission.

The application of doctrinal principles and management of risk are not unique to our fire missions but are relevant to our everyday mission—to every task we encounter, everyday, because at the end of the day, the most important thing to me and your loved ones is that you return home safely. Remember, "To the world you are one person, but to one person you are the world." Be safe. ■

Rapid Assessment of Vegetation Condition After Wildfire

Tony Guay

Following large wildfires, a rapid assessment of postfire conditions is important to support vegetation rehabilitation on Forest Service lands. This is particularly important in areas where active forest management is permitted, such as lands outside of wilderness areas. The Rapid Assessment of Vegetation Condition after Wildfire Program (RAVG) produces data describing postfire vegetation conditions on National Forest System (NFS) lands. RAVG spatial data and summary products are generated using a consistent methodology and facilitate postfire vegetation management decisionmaking by reducing planning and implementation costs. RAVG data serve a variety of agency objectives and provide an effective means of communicating reforestation and restoration needs to Washington Office and congressional decisionmakers.

> RAVG products can reduce the planning and implementation costs associated with postfire vegetation management.

Rapid Postfire Vegetation Condition Assessment

RAVG produces a suite of geospatial and tabular outputs that are delivered to national forest staffs, usually within 30 to 45 days following fire containment. RAVG products include standard vegetation mortality summary tables (fig. 1) and maps (fig. 2), as well as several burn severity data layers. The tables and maps are produced by integrating existing vegetation and burn severity data. The existing vegetation data comes from the existing vegetation type (EVT) layer of the Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) (Rollins and Frame 2006). The burn severity maps are created from prefire and postfire Landsat Thematic Mapper (TM) satellite imagery using the relative differenced normalized burn ratio (RdNBR) (Miller and Thode 2007). The continuous RdNBR data are calibrated to field collected tree mortality data (live and dead by species and size class) to provide estimates of tree mortality. Currently, fires that burn more than 1,000 acres (405 ha) of NFS forest land are analyzed. The RAVG product suite includes the following for each wildfire processed:

- Fire perimeter shapefile: burn scar boundary as visible in the postfire image.

	A	B	C	D
1	2009 Backbone Fire - Six Rivers NF			
2	Rapid Assessment of Vegetation Condition after Wildfire (RAVG)			
3				
4	Vegetation Group (LANDFIRE)*	Ownership / Status	Basal Area Loss	Acres
5	Grassland / Shrubland / Non Veg	USFS	0% - < 25%	3
6			25% - < 50%	0
7			50% - < 75%	0
8			75% - 100%	0
9		USFS Total		3
10		USFS Wilderness	0% - < 25%	768
11			25% - < 50%	140
12			50% - < 75%	148
13			75% - 100%	1,076
14		USFS Wilderness Total		2,133
15	Grassland / Shrubland / Non Veg Total			2,136
16	Deciduous Open Tree Canopy	USFS Wilderness	0% - < 25%	0
17			25% - < 50%	0
18			50% - < 75%	0
19			75% - 100%	0
20		USFS Wilderness Total		1
21	Deciduous Open Tree Canopy Total			1
22	Evergreen Closed Tree Canopy	USFS Wilderness	0% - < 25%	1,479
23			25% - < 50%	241
24			50% - < 75%	220
25			75% - 100%	530
26		USFS Wilderness Total		2,469
27	Evergreen Closed Tree Canopy Total			2,469
28	Evergreen Open Tree Canopy	USFS	0% - < 25%	26
29			25% - < 50%	2
30			50% - < 75%	0
31			75% - 100%	1
32		USFS Total		29
33		USFS Wilderness	0% - < 25%	949
34			25% - < 50%	167
35			50% - < 75%	158
36			75% - 100%	697
37		USFS Wilderness Total		1,972
38	Evergreen Open Tree Canopy Total			2,001
39	Mixed Evergreen - Deciduous Open Tree Canopy	USFS Wilderness	0% - < 25%	98
40			25% - < 50%	7
41			50% - < 75%	6
42			75% - 100%	12
43		USFS Wilderness Total		123
44	Mixed Evergreen - Deciduous Open Tree Canopy Total			123
45	Grand Total			6,730

RAVG Table | Raw Data | RAVG Codes | RAVG - LANDFIRE EVT Master Cros

Figure 1—*RAVG table for 2009 Backbone Fire, California.*

Tony Guay is a remote sensing analyst for the Forest Service, Remote Sensing Applications Center (RSAC), in Salt Lake City, UT.

- RAVG map: basal area loss (percent change in basal area from the prefire condition) within the fire perimeter. Basal area (BA) is the area of the cross section of a tree stem, including the bark, measured at breast height (4.5 feet [1.37 m] above the ground).
- RAVG analysis table: summary of acres of vegetation affected by the fire stratified by ownership/land status and four classes of BA loss.
- Prefire and postfire Landsat TM image subsets.
- Differenced normalized burn ratio (dNBR) image: the differenced NBR image, or change image, is created by subtracting the postfire NBR from the prefire NBR. The dNBR may be used to discriminate burned from unburned areas and identify vegetation burn severity classes. The dNBR is calculated as dNBR = NBR prefire - NBR postfire.
- Relative differenced normalized burn ratio (RdNBR) image: the relative version of the dNBR, which removes the biasing effect of prefire conditions. The algorithm for RdNBR is calculated as RdNBR = dNBR/ SquareRoot(ABS(NBR prefire/1000)).

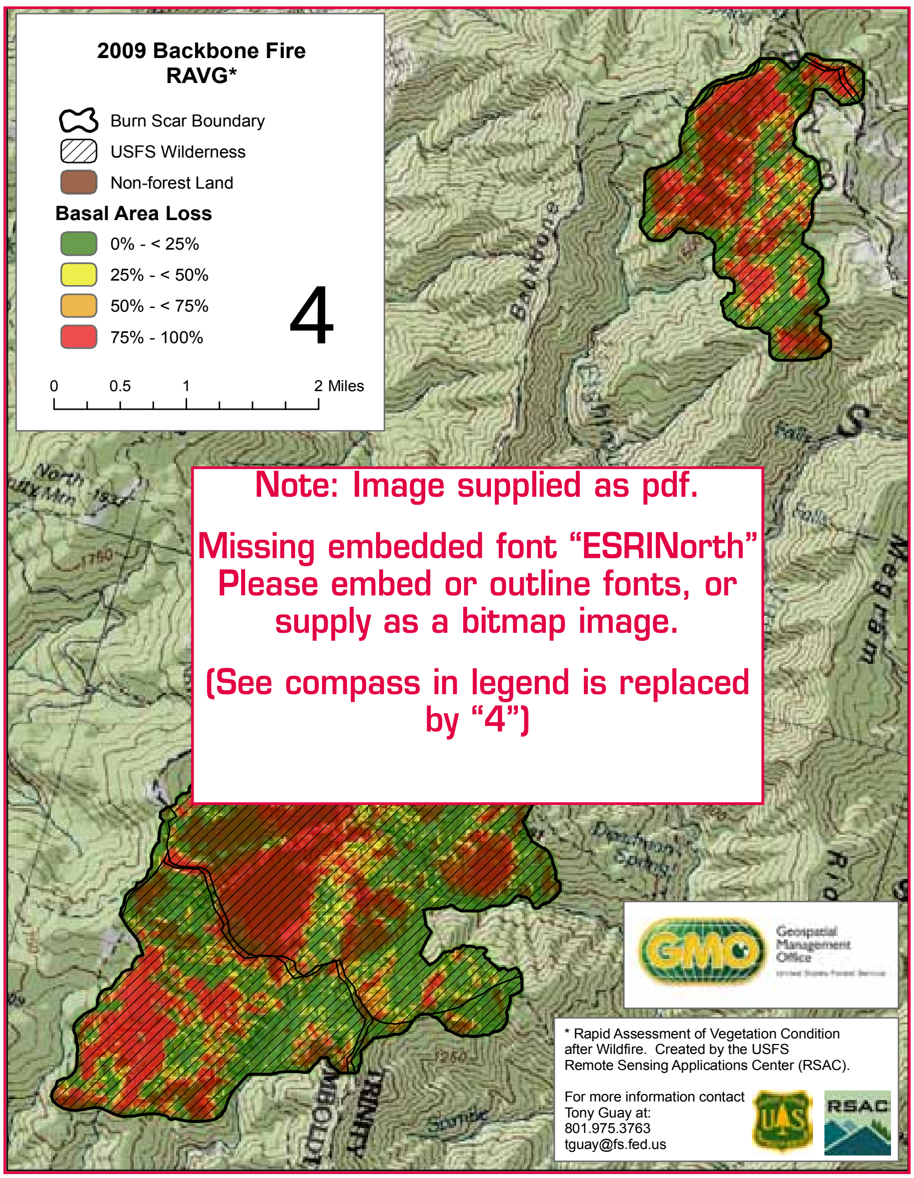

Figure 2—*RAVG map for 2009 Backbone Fire, California.*

- BA image: continuous percent change in basal area from the prefire condition.
- BA4CLASS image: thematic four-class percent change in basal area from the prefire condition.
- BA7CLASS image: thematic seven-class percent change in basal area from the prefire condition.
- Continuous burn severity image: a numerical, synoptic rating of fire effects on individual vegetation strata across the burned area. It is calculated from established relationships between field-based estimates of fire effects and the continuous RdNBR data for the burned area.
- CBICLASS image: a version of the continuous burn severity image split into four thematic burn severity classes.
- Continuous percent change in canopy cover (CC) image: percent change in canopy cover from the prefire condition (canopy cover is defined as the ground area covered by the crowns of trees or woody vegetation as delineated by the vertical projection of crown perimeters). The change on a per-pixel basis in the image is expressed as a percent of total ground area.
- CC5CLASS image: thematic five-class percent change in canopy cover from the prefire condition.
- Metadata text file describing all data layers and processing methods used for a particular wildfire.

RAVG products can assist forest managers' decisionmaking process and reduce the planning and implementation costs associated with postfire vegetation management. In particular, RAVG efficiently and precisely identifies potential resource concern areas following wildfire. Additionaly, RAVG facilitates the consistent assessment and comparison of the postfire conditions and associated reforestation costs, which can guide the prioritization of vegetation treatment needs. RAVG also complements the Burned Area Emergency Response (BAER) Image Support Program, which provides satellite image-based information about fire effects on soils by providing information about fire effects on the existing vegetation. Keep in mind that, while the BAER Image Support Program operates on a by-request basis, RAVG operates on a national level with specific Washington Office requirements; therefore, not all fires mapped for BAER teams will be processed for RAVG and vice versa. Special requests can be made for RAVG analysis of wildfires. However, wildfires that meet the national level mapping requirements receive a higher priority for processing.

How Are RAVG Data Created?

The basal area loss summary table and map products are produced by an image-based change detection process, which uses two Landsat TM images acquired before and after a wildfire and a geographic information system (GIS) overlay analysis. The change detection algorithm used is the RdNBR, which is sensitive to vegetation mortality resulting from the wildfire event. This is a different process from that used for the BAER Image Support Program, which uses the dNBR (Key and Benson 2006) and is better correlated with soil burn severity. The RAVG summary products are based on a seven-class basal area loss layer modeled from the RdNBR (Miller and Thode 2007). The seven-class layer is recoded into four classes for the GIS overlay analysis and subsequent RAVG table and map generation. The data tables and maps are created using existing vegetation maps overlaid with basal area loss results. LANDFIRE EVT data (Rollins and Frame 2006) are grouped and used for the GIS overlay analysis. The seven-class basal area loss layer contains the following classes:

Class 0: outside fire perimeter
Class 1: 0% basal area (BA) loss
Class 2: 0% – < 10% BA loss
Class 3: 10% – < 25% BA loss
Class 4: 25% – < 50% BA loss
Class 5: 50% – < 75% BA loss
Class 6: 75% – < 90% BA loss
Class 7: 90% or greater BA loss

This layer is then recoded into the following four basal area loss classes for further GIS analysis:

Class 0: outside fire perimeter
Class 1: 0% – < 25% BA loss
Class 2: 25% – < 50% BA loss
Class 3: 50% – < 75% BA loss
Class 4: 75% – 100% BA loss

The LANDFIRE EVT data are grouped into the following eight vegetation type classes for the GIS overlay analysis:

Class 1: Grassland/Shrubland/Non Vegetated
Class 2: Pinyon–Juniper Woodland
Class 3: Deciduous Open Tree Canopy
Class 4: Evergreen Closed Tree Canopy
Class 5: Evergreen Open Tree Canopy
Class 6: Mixed Evergreen–Deciduous Open Tree Canopy
Class 7: Deciduous Closed Tree Canopy
Class 8: Mixed Evergreen–Deciduous Closed Tree Canopy

RAVG-Related Web Sites

- National RAVG Web site – Post-Fire Vegetation Conditions on the National Forests: <http://www.fs.fed.us/postfirevegcondition/>
- RAVG FTP site: <ftp://fsweb.rsac.fs.fed.us/RAVG/>
- The Threat of Deforested Conditions in California's National Forests: <http://www.fs.fed.us/r5/rsl/projects/postfirecondition/>
- LANDFIRE Web site: <http://www.landfire.gov/>

How Do I Get RAVG Data?

The product suite for all fires in the RAVG data record can be downloaded from the RAVG Web site. Forest Service users can access RAVG data via FTP. The RAVG Web site offers extensive information about the RAVG program, including links to related Web sites, references, and peer-reviewed articles. In addition, a Web-enabled application (fig. 3) allows users to query the RAVG data

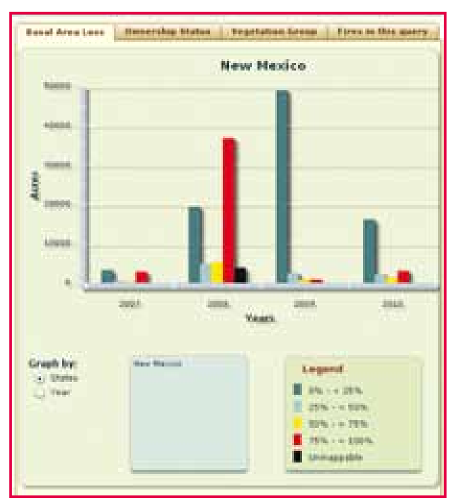

Figure 3—*RAVG Web resources include a Web-enabled tool for data access and summaries.*

record by several user-specified criteria. This provides a powerful tool for exploring trends and summarizing vegetation severity data across the entire RAVG data record.

Scope of Effort

RAVG analysis is performed by both the NFS Pacific Southwest Region and the Forest Service's Remote Sensing Applications Center (RSAC). The Pacific Southwest Region initially developed the RAVG analysis process and serves national forests in California. In 2007, RSAC adapted the Pacific Southwest Region methodology for nationwide implementation. RSAC provided RAVG analysis for national forests in the Western United States during the 2007 fire season and received funding to continue RAVG support for national forests across the United States. RAVG mapped 184 fires and a total of 5,055,881 acres (2,046,014 ha) between 2007 and 2009. The table provides annual summary statistics for all wildfires processed for RAVG from 2007 to 2009, and figure 4 shows the spatial distribution of all 2007–2009 RAVG fires. RAVG has successfully supported strategic and budgetary planning activities for reforestation and restoration needs at the national and regional levels within the Forest Service. Additionally, reforestation and restoration specialists have successfully used RAVG data to directly support project-level work on numerous fires from 2007 to present at the forest and district levels in the Northern, Rocky Mountain, Southwestern, Intermountain, Pacific Southwest, and Pacific Northwest Regions.

Summary statistics for 2007–2009 RAVG fires.

Year	Fires Processed	Acres (ha) Mapped
2007	66	2,840,598 (1,149,533)
2008	65	1,598,046 (646,697)
2009	53	617,237 (249,783)

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Key, C.H.; Benson, N.C. 2006. Landscape assessment: sampling and analysis methods. Gen. Tech. Rep. RMRS-164-CD. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station.

Miller, J.D.; Thode, A.E. 2007. Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR). Remote Sensing of Environment. 109: 66–80.

Rollins, M.G.; Frame, C.K., tech. eds. 2006. The LANDFIRE Prototype Project: nationally consistent and locally relevant geospatial data for wildland fire management. Gen. Tech. Rep. RMRS-175. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 416 p.

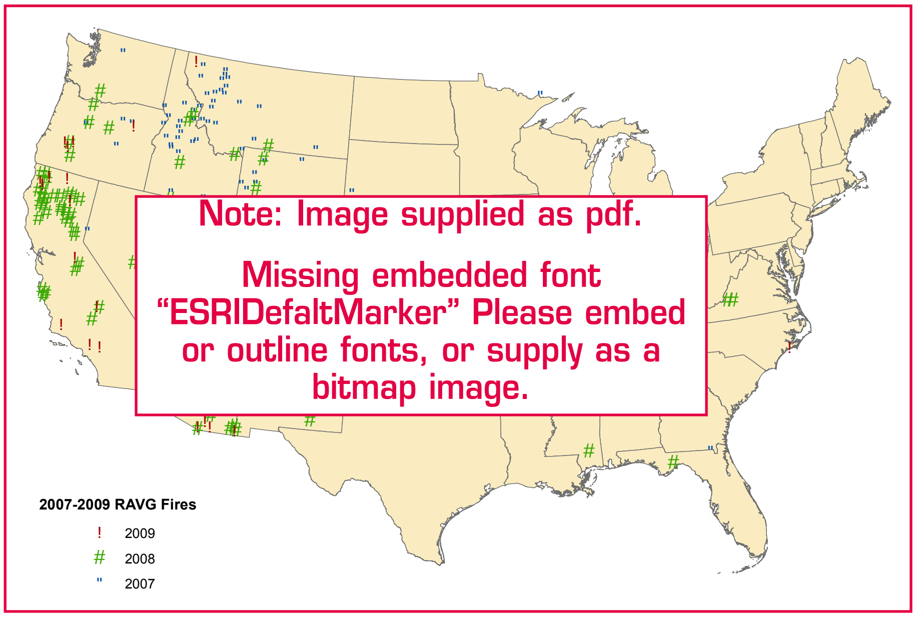

Figure 4—*Spatial distribution of 2007–2009 RAVG fires.*

Accelerated Remeasurement and Evaluation of Burned Areas

Kevin Megown, Mark Finco, Ken Brewer, and Brian Schwind

> A timelier revisit for plots that are within a fire perimeter speeds up the assessment of sudden changes in the resource due to fire.

The Wildland Fire Leadership Council, which implements and coordinates National Fire Plan and Federal wildland fire management policies, has adopted a strategy to monitor the effectiveness and effects of the National Fire Plan and the Healthy Forests Restoration Act. One component of this strategy is to assess the environmental impacts of large wildland fires and identify the trends of burn severity on all lands across the Unites States using Monitoring Trends in Burn Severity (MTBS) data (USDA 2009). One objective of the MTBS project was to quantitatively describe first- and second-order fire effects depicted in MTBS burn severity maps. The postfire plot remeasurement performed for the Accelerated Remeasurement and Evaluation of Burned Areas (AREBA) project accomplishes this task using national Forest Inventory and Analysis (FIA) and Northern Region inventory intensification plots. These permanent plots designed to monitor forest change were established before the study areas burned. There are three primary benefits in using these plots. First, because the plots were measured before the fire, AREBA can analyze change after the fire. Second, the plot locations are taken from a designed sample, allowing unbiased estimates of burn severity to be made for the burned areas. Third, the Northern Region plots augment the nationwide FIA sample, thus increasing the number of plots available on Forest Service lands and increasing the precision of estimates (fig.1).

The AREBA project accelerated postfire remeasurement on these plots and made possible the assessment of sudden changes in the resource due to fire. In the Western United States, the FIA program remeasures plots every 10 years, so the effects of a fire may take up to 10 years to be seen in inventory assessments. Northern Region inventory plots are not on a remeasurement cycle and are only

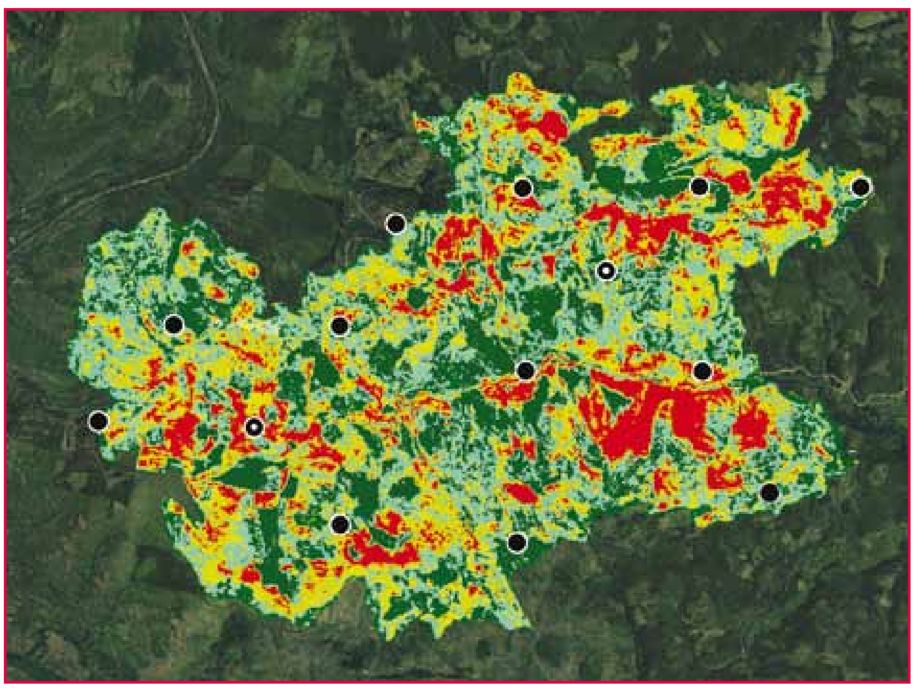

Figure 1—*An MTBS severity map showing examples of FIA and regional intensification plot locations for the 2007 Brush Creek Fire on the Kootenai and Flathead National Forests, Montana. Approximate FIA plot locations are shown as black circles with white dots; Northern Region intensification plot locations are shown as black circles without white dots. The regional intensification plot program added many plots to existing FIA plots, improving the potential to quantify the effects of forest fires at regional scales. Image: Kevin Megown, Forest Service.*

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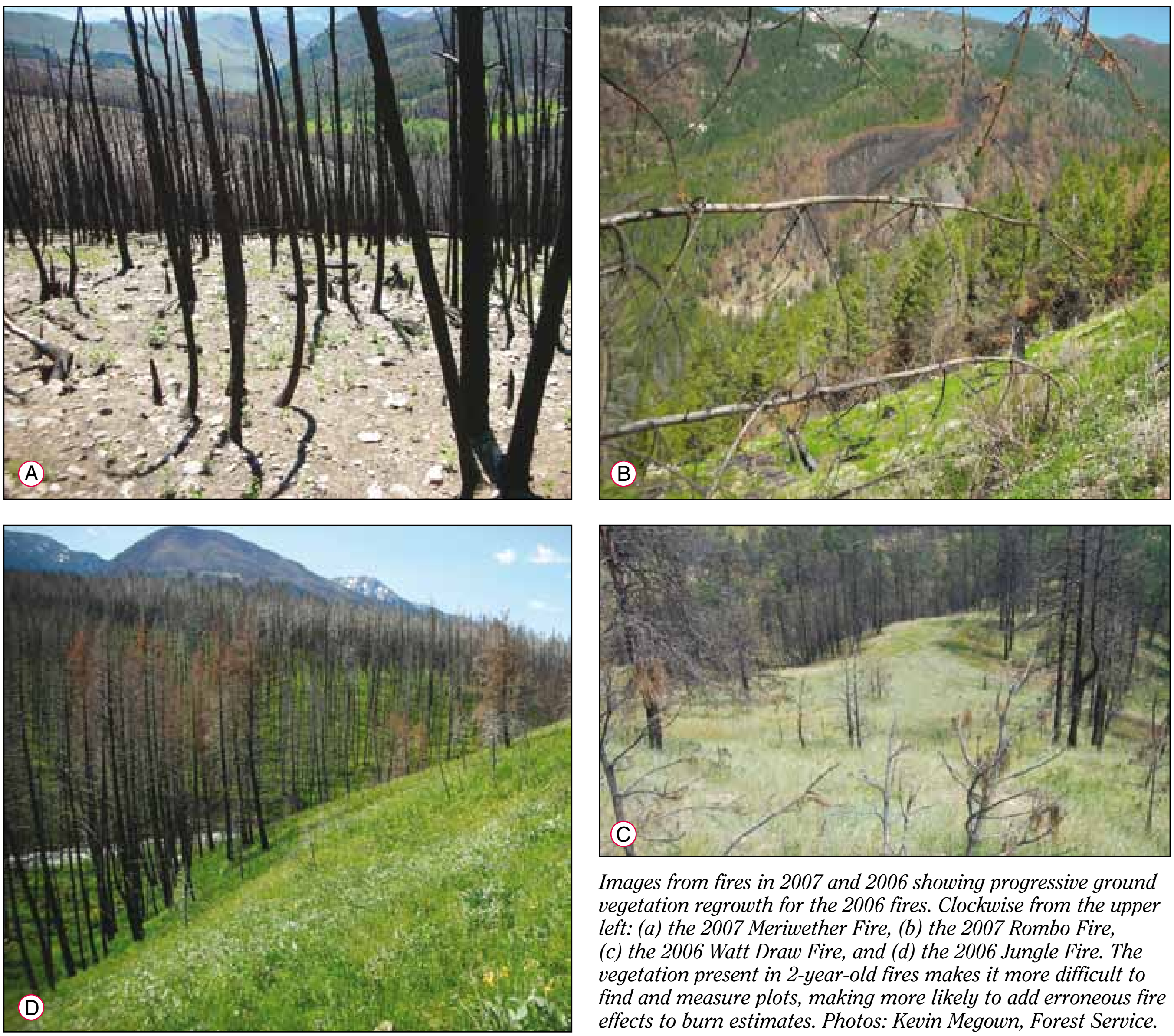
remeasured as needed. Collecting data for the AREBA project taught us the importance of remeasuring plots within 1 year of a fire event, as vegetation regrowth that occurs within 2 years can make fire effect characterizations more difficult.

Information gathered on the AREBA plots identified all previously measured trees and evaluated the effect of the fire on each tree. This included information such as tree condition (alive or dead, due only to fire); scorch height; and percentage of crown that is black, brown, or unburned. All other tree re-measurements were assumed to be unchanged from the time of prefire measurement. For each plot, researchers took ground pictures in the cardinal directions, re-established fuel transects, assigned a composite burn index value to the plot to define fire severity (Key and Benson 2006), and re-measured

Andy Kies of the Northern Region enters data for an AREBA plot on the 2007 Black Cat Fire, Montana. Photo: Kevin Megown, Forest Service.



Images from fires in 2007 and 2006 showing progressive ground vegetation regrowth for the 2006 fires. Clockwise from the upper left: (a) the 2007 Meriwether Fire, (b) the 2007 Rombo Fire, (c) the 2006 Watt Draw Fire, and (d) the 2006 Jungle Fire. The vegetation present in 2-year-old fires makes it more difficult to find and measure plots, making more likely to add erroneous fire effects to burn estimates. Photos: Kevin Megown, Forest Service.

a line intercept point sample for characterization of ground cover.

Data collected from AREBA are being used to characterize various conditions, from identifying changes to vegetation cover and tree mortality to analyzing regional changes in carbon stocks. In addition, the remeasured plots are used to quantitatively describe assigned MTBS burn severity classes. For example, initial AREBA analyses have established that tree mortality reflects assigned MTBS burn severity class (fig. 2). While not surprising, this improves our understanding of the MTBS burn severity classes and expands our knowledge of how fires change forests.

Data collected from AREBA are being used to characterize various conditions, from identifying changes to vegetation cover and tree mortality to analyzing regional changes in carbon stocks.

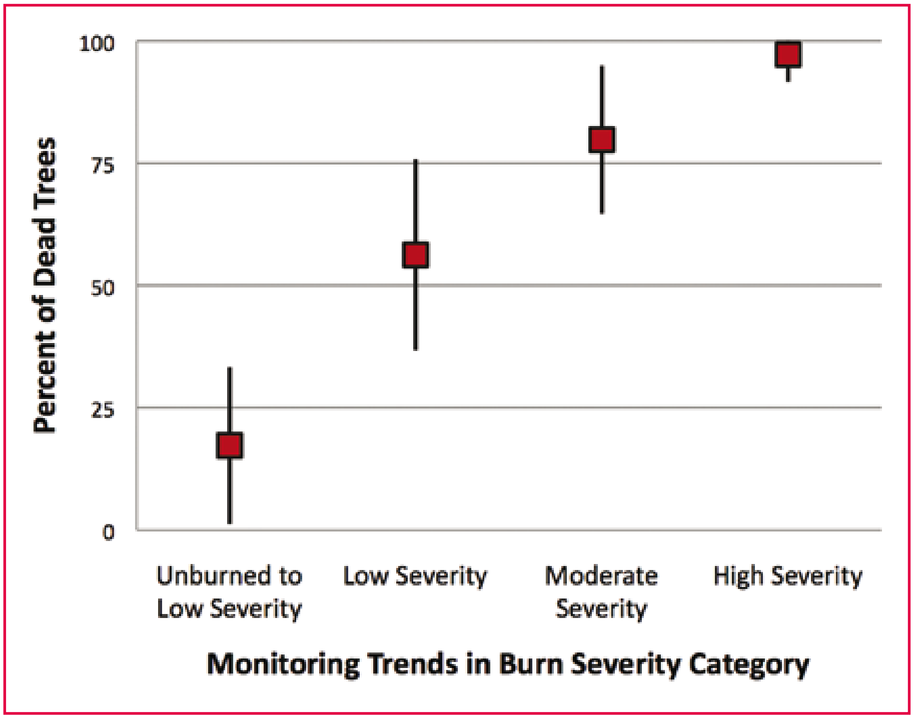


Figure 2—*Mean and 95 percent confidence interval for percentage of trees killed by fire for each MTBS burn severity category (n=51 plots). An analysis of AREBA data for tree mortality by MTBS burn severity shows a significant increase in tree mortality with increasing MTBS burn severity. This is but one of the numerous analyses that AREBA data support at regional scales.*

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Use of Waste Oil as an Alternative Fuel in Drip Torches

John R. Weir and Ryan F. Limb

The recent rise in the cost of gasoline and diesel fuel has increased the materials cost of conducting prescribed burns. This increase is not critical, but can have impacts on the number and size of prescribed burns conducted each year. Finding an alternative for one of these fuels might help avoid last-minute changes in mission planning.

Simultaneously, many private land managers, nongovernmental organizations, and agency personnel use motorized vehicles. Periodic maintenance of those vehicles yields used motor oil that has to be stored and disposed of properly. If waste motor oil could be used in drip torches to ignite prescribed fires, fire managers may have a new way to dispose of oil, reduce stockpiles of waste petroleum products, and offset some of the fuel costs associated with conducting prescribed burns.

We wondered whether the use of waste motor oil was a viable alternative to diesel fuel in drip torch mixtures and at what ratios it would work best. The recommended gasoline-diesel fuel ratios for drip torch use range from 50:50 to 30:70, depending upon fuels, season, weather conditions, and personal preference (Weir 2009). We set up a study to determine whether waste oil could be used as a substitute for diesel fuel in a drip torch fuel mixture and whether these mixtures would burn at similar temperatures and durations as typical drip torch fuel mixtures.

John R. Weir is a research associate and Ryan F. Limb, Sr., is a senior research specialist with the Department of Natural Resource Ecology and Management, Oklahoma State University, Stillwater, OK.

Waste oil could be a viable alternative to using diesel fuel in drip torch fuel mixtures. The waste oil burns at the same temperatures and for the same length of time as traditional gasoline-diesel fuel mixtures, and ignition personnel did not experience problems in 12 field tests.

If waste motor oil could be used in drip torches, fire managers may have a new way to dispose of oil, reduce stockpiles of waste petroleum products, and offset some of the fuel costs associated with conducting prescribed burns.

Fuel Mixture Lab Tests

We burned mixtures of unleaded gasoline, diesel fuel, and used motor oil at various ratios in a laboratory setting to determine burn time and maximum burn temperature. One at a time, we measured 0.135 ounces (4 ml) samples of fuel mixtures and placed them in a foil tray. We then placed the tray under a laboratory fume hood with the vent turned on, ignited the fuel mixture, measured the flame time (time from ignition to flame extinction) using a digital stopwatch, and recorded the maximum burn temperature using a thermometer datalogger positioned 4 inches (10 cm) above the center of the tray.

We tested typical drip torch fuel mixtures of gasoline and diesel at ratios of 50:50 and 40:60 to establish comparison information on burn time and maximum burn temperature. Then, we tested five different mixtures to determine which gasoline to waste oil ratios might be similar to the standard torch fuel mixtures: 75:25, 60:40, 50:50, 40:60, and 25:75. We tested five samples of each mixture, then averaged the resulting burn time and maximum temperature for each mixture.

What Did the Tests Show?

Burn Time

There was little difference in burn times between fuel mixtures containing gasoline and diesel fuel or gasoline and waste oil in 50:50 and 60:40 ratios (table 1 and fig. 1). Gasoline-waste oil mixtures at ratios of 75:25 and 25:75 had the shortest burn times; these two samples only burned until the gasoline was consumed, leaving most of the waste oil unburned in the tray. In all other combinations, the waste oil burned off.

We found that the 50:50 gasoline-waste oil combination had a higher maximum burn temperature, on average, than the 50:50 gasoline-diesel fuel mixture (fig. 2). It was interesting that there was a difference between the 40:60 mixtures as well, but these results were reversed: the gasoline-diesel fuel mixture burned hotter than the gasoline-waste oil mixture. There were no great differences in temperature results among other ratios of gasoline to waste oil except for the 25:75 mixtures, in which the mixture burned at a significantly lower temperature. The higher maximum burn temperature from some of the gasoline-waste oil combinations could promote increased ignition of fuels in field use.

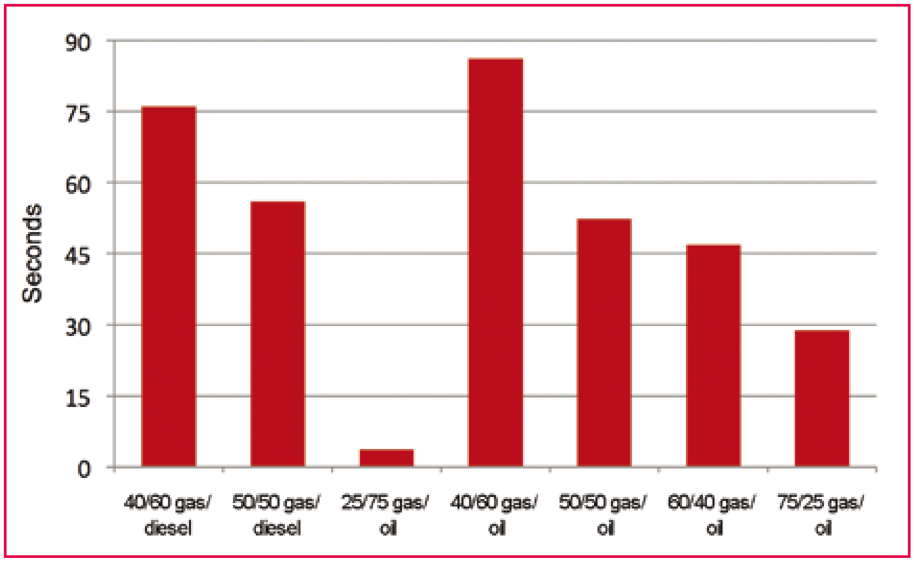

Figure 1—*Average burn time (time from ignition to extinction of flame) of fuel mixtures tested in the laboratory. Baseline results for the gasoline-diesel fuel mixtures are on the left, and results for the various gasoline-waste oil mixtures are on the right.*

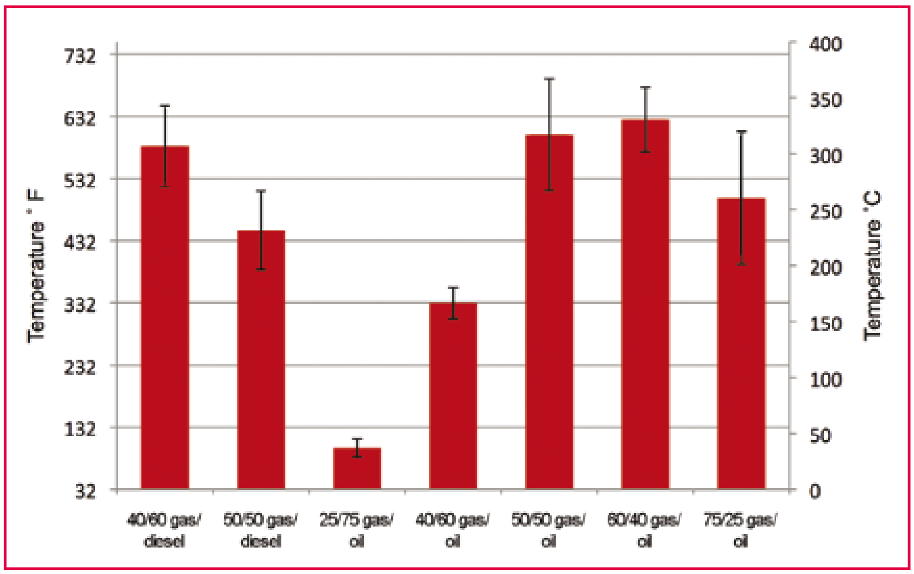

Figure 2—*Average maximum burn temperature of fuel mixtures tested in the laboratory. Baseline results for the gasoline-diesel fuel mixtures are on the left, and results for the various gasoline-waste oil mixtures are on the right. Error bars indicate standard error.*

Testing Waste Oil in the Field

To apply our laboratory work to real-world use, we took our findings to the field for testing. During the summer of 2009 and spring of 2010, field crews used the gasoline-waste oil mixture in drip torches on 12 separate prescribed burns, and we interviewed the crews afterward to gauge results.

During the summer burns, half of the torches were filled with the normal 40:60 gasoline-diesel fuel mixture and the other half were filled with a 40:60 gasoline-waste oil mixture. In the spring, half of the torches were filled with a 50:50 gasoline-diesel fuel mixture and the other half with a 50:50 gasoline-waste oil mixture. The torches were used by experienced operators, who were not informed of the mixture in their drip torches.

Two types of information were of interest to us: how easily the gasoline-waste oil mixed (and stayed mixed) and how well the gasoline-waste oil mixture burned in comparison to the typical gasoline-diesel fuel mixtures. Results were anecdotal (that is, not quantifiable), but were taken to indicate acceptance of the new formulation in the field.

To prevent ignition personnel from knowing which mixture they were using, we filled the drip torches prior to assignment at the work site. There were no problems mixing the gasoline and waste oil, and the oil stayed in solution very well. We are not sure how long the fuels will stay mixed before they separate, but if adopted, it may be advisable to mix only enough fuel for each burn and not store the mixture for long periods of time. Even if the fuels do separate over time, they should readily blend together again by simply agitating the mixture.

> Ignition personnel commented that the mixture worked just as well as the traditional gasoline-diesel fuel drip torch mixture and that they encountered no problems with its use.

From the 12 field tests, there were no negative comments regarding the gasoline-waste oil mixture. Ignition personnel commented that the mixture worked just as well as the traditional gasoline-diesel fuel drip torch mixture and that they encountered no problems with its use.

Conclusion

Waste motor oil appears to be a viable alternative to diesel fuel for use in drip torch fuel mixtures at all typical ratios except the ratio of 25:75, which could leave unconsumed waste oil on the ground. In general, the waste oil burns as long as and, at certain ratios, hotter than diesel fuel, which could help with ignition of some hard-to-light fuels. The use of waste oil would allow for reuse of a product that is difficult to dispose of, meanwhile reducing ignition fuel costs for prescribed fire programs.

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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:

USDA Forest Service
Attn: Monique Nelson, Managing Editor
2150 Centre Avenue
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Fort Collins, CO 80526
Tel. 970-295-5707
Fax 970-295-5885
email: <firemanagementtoday@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 970-295-5707.

Remote Sensing and Geospatial Support to Burned Area Emergency Response Teams

Jess Clark and Randy McKinley

A major concern of land managers in the United States is the response of watersheds to weather after a wildfire. With an ever-expanding wildland-urban interface (WUI), land managers must be cognizant of potential damage to private property and other values at risk. In the United States, land-management agencies from the U.S. Department of Agriculture (USDA) and the U.S. Department of the Interior (DOI) deploy Burned Area Emergency Response (BAER) teams to address these concerns and to "prescribe and implement emergency treatments to minimize threats to life or property or to stabilize and prevent unacceptable degradation to natural and cultural resources resulting from the effects of a fire" (USDA Forest Service 2004, p. 17). BAER teams' objective is emergency stabilization of burned areas, rather than long-term restoration of the landscape after a fire.

The Forest Service must assess all fires larger than 300 acres (121 ha) to determine the need to deploy a BAER team. Once deployed, BAER teams assess conditions and prescribe treatments in an effort to protect life and property and prevent additional damage to resources. Treatments can include seeding desired herbaceous plant species, mulching to provide ground cover, contour felling, building log erosion barriers, and protecting transportation corridors by enlarging culverts or installing debris fences to capture increased runoff.

Jess Clark is a remote sensing analyst contracted to the Forest Service, Remote Sensing Applications Center, in Salt Lake City, UT. Randy McKinley is a senior scientist with the U.S. Department of the Interior, U.S. Geological Survey Earth Resource Observation and Science Center, in Sioux Falls, SD.

One of the BAER team's first tasks is to develop a soil burn severity map that highlights the areas of low, moderate, and high burn severity within a wildfire perimeter.

The work of BAER teams is important because of the hazards that burned areas represent for the years following a fire. In areas of high burn severity, land may be susceptible to mud and debris slides during and after heavy rain. BAER teams locate areas of high burn severity and assess the potential downstream damage that can result from such slides. Team members must consider such factors as personal property, threatened and endangered species, archeological sites, water supplies, and threats to soil productivity.

Mapping the Burn

One of a BAER team's first tasks is to develop a soil burn severity map that highlights the areas of low, moderate, and high burn severity

Burned Area Emergency Response team members make field visits to burn areas to identify potential erosion areas and outline stabilization measures. Photo: Jess Clark.

within a wildfire perimeter. This map then serves as a key input to subsequent erosion modeling.

Traditionally, the BAER soil burn severity map was created by sketching burn perimeters on a topographic map—or even a forest-visitor map—from a helicopter or road-accessible overlook. This method often made locational accuracy and complete wall-to-wall coverage of the burned area difficult to achieve.

In 2001, the Forest Service, Remote Sensing Applications Center (RSAC), and the DOI U.S. Geological Survey (USGS), Earth Resource Observation and Science Center (EROS), pioneered use of satellite imagery and remote sensing techniques for soil burn severity mapping. Working cooperatively, the two centers succeeded in establishing an operational program to serve all BAER teams requesting assistance. BAER teams now base the maps on satellite imagery acquired at or near the time of the fire's containment.

Using prefire imagery in the mapping process helps account for vegetation characteristics and changes not directly related to the fire, such as the current effects of historic fires, drought, and management activities.

Beyond Pictures

RSAC and EROS applied two mapping techniques, the normalized burn ratio (NBR) and differenced normalized burn ratio (dNBR), to map burn areas during the 2003 fire season and continue to use this approach today (Clark and Bobbe 2006; Key and Benson 2006). The NBR is a remote sensing image derivative that exploits the characteristics of the near-infrared and short-wave infrared portions of the electromagnetic spectrum, which are good discriminators of burn scars and the mosaic of burn severities within a burn perimeter. The dNBR compares NBR imagery acquired before the fire with imagery of the same area acquired immediately after the fire to identify the location of changes in vegetation.

Comparing a prefire image to a postfire image captures the fire-related changes that interest BAER teams. For example, sites that were heavily forested before a fire and then experience complete tree or shrub canopy loss are more likely to exhibit drastic increases in runoff during rainfall. In contrast, sites with little prefire biomass that experience complete canopy loss are less likely to exhibit drastic increases in runoff. Using prefire imagery in the mapping process also helps account for vegetation characteristics and changes that are not directly related to the fire, such as the effects of historic fires, drought, and management activities.

Remote Sensing Products

Despite the frequent media portrayals of complete devastation, the typical wildland fire burns at varying levels of intensity depending on weather and fuel conditions. As a result, the postfire area is a mosaic of unburned islands, sections with a lightly burned understory, and patches with highly and moderately severe damage. It is the job of the BAER team to identify these areas and produce a full-coverage, four-class soil burn severity map. RSAC and EROS assist in this process by providing BAER teams in the field with a number of remote-sensing products.

Burned Area Reflectance Classification

BAER teams rely most on maps based on burned area reflectance classification (BARC), a generalization of the dNBR created for team members with varying geospatial skills. The BARC has two formats: BARC4 and BARC256. BARC4 is a four-class (unburned and low, moderate, and highly burned) thematic map layer created by analysts at RSAC or EROS with predefined, discrete severity classifications. BARC256 is a continuous-value map layer with a 0–255 data-value range generated by simplifying dNBR values.

If BAER teams analyze the BARC4 map and determine that certain elements are inappropriately classified, users can assign colors to the cells in the BARC256 to show the mosaic of severity based on their ground data and/or observations by local experts.

Imagery

In addition to the BARC layers, the remote sensing centers provide BAER teams with georeferenced satellite imagery in digital format. This allows the team to do its own digital image interpretation. It also provides a synoptic view of the entire fire area for team meetings and public presentations. Finally, such imagery functions as a basis for traditional sketchmapping if the BAER team is uncertain of the accuracy of portions of the BARC map. For example, some images of fire areas may include smoke, clouds, and their shadows over a portion of the burn scar (fig. 1), obscuring ground conditions. In those cases, the BARC map may show incorrect or "no data" values; BAER teams must either ignore this information or make field visits to hand-map those areas more accurately. Postfire imagery helps BAER teams quickly identify areas that need review, while prefire imagery shows the prefire vegetation condition for comparison.

The majority of the prefire and postfire imagery used to map wildfires in the United States comes from the Landsat series of Earth-observing satellites. The USGS provides this imagery at no cost to BAER teams. On the occasions when Landsat satellite imagery is not available, other domestic and international sources of imagery are tapped.

Three-Dimensional Visualizations

Viewing geospatial data in two dimensions is useful, and most geographic information system (GIS) users visually analyze data in this form. However, in some circumstances, adding a "third dimension" enhances the ability of users to visualize complex relationships linking terrain and burn severity. When appropriate, RSAC and EROS create three-dimensional visualizations by draping the BARC layer over terrain photographs and imagery taken from Google Earth (fig. 2). This allows both GIS and non-GIS users to view geospatial data in a "natural" and dynamic form. In fact, these visualizations may be the best way to prioritize field work for time-limited BAER teams. For example, highly burned patches on steep slopes directly above canyon roads are easily visible in three-dimensional visualizations and may then be targeted for further discussion and immediate inspection by various BAER team specialists.

Outreach

Except for a designated specialist, BAER team members are generally not GIS experts. BAER teams are typically staffed by hydrologists, soil scientists, archeologists, and wildlife biologists. BARC and other geospatial map layers require

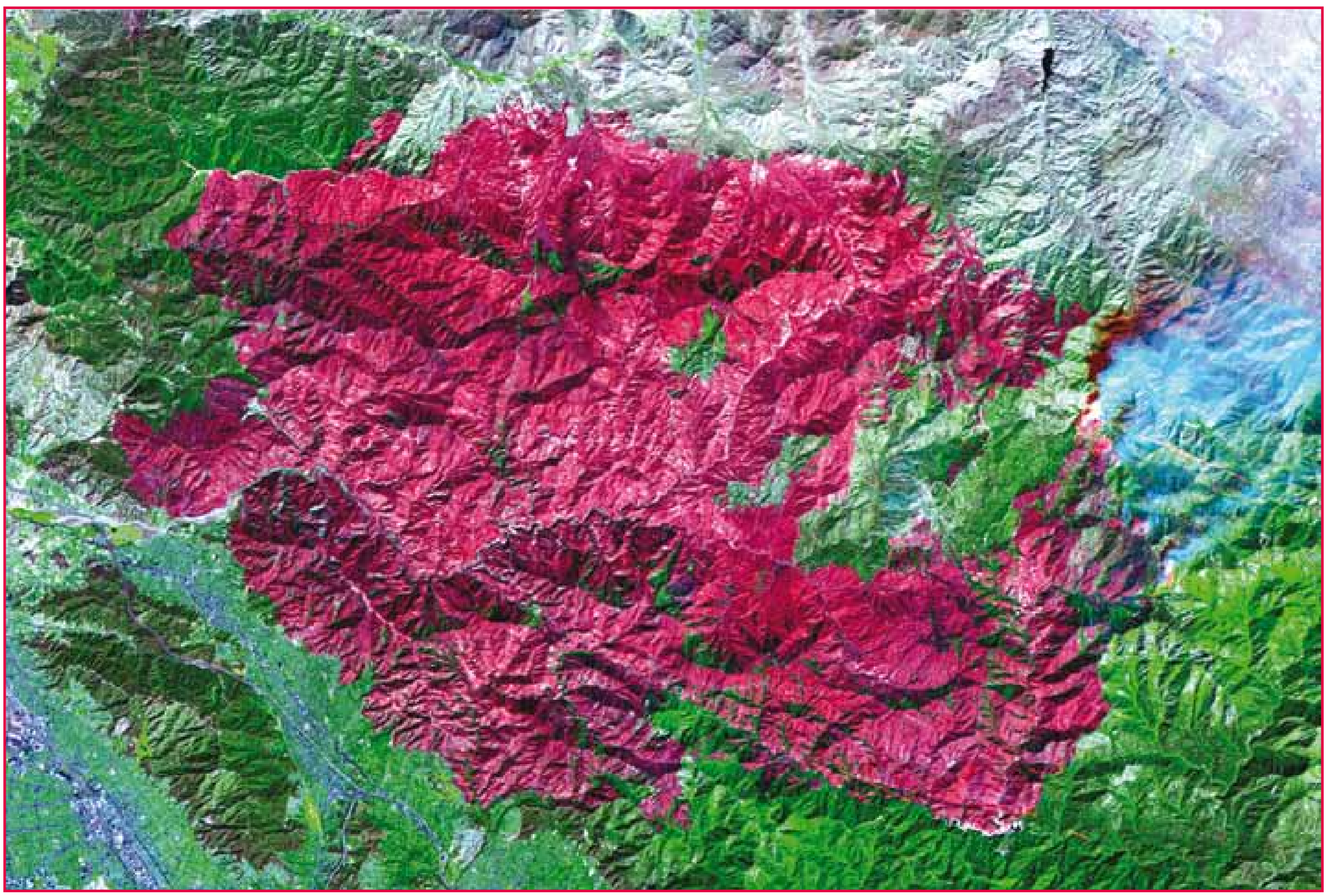

Figure 1—*Infrared satellite images can show the extent and severity of wildfires, though these images have a limited ability to display the ground through smoke and cloud cover. This image shows the September 2009 Station Fire on the Angeles National Forest, California.*

some ability to view and manipulate data in common GIS software. Therefore, the remote sensing centers offer training annually in basic remote sensing theory, BARC editing, and methods for appropriate use of BARC data in erosion-risk and other models. These training sessions are open to all interagency professionals.

More information about the remote sensing support offered to BAER teams is available at <http://www.fs.fed.us/eng/rsac/baer/>.

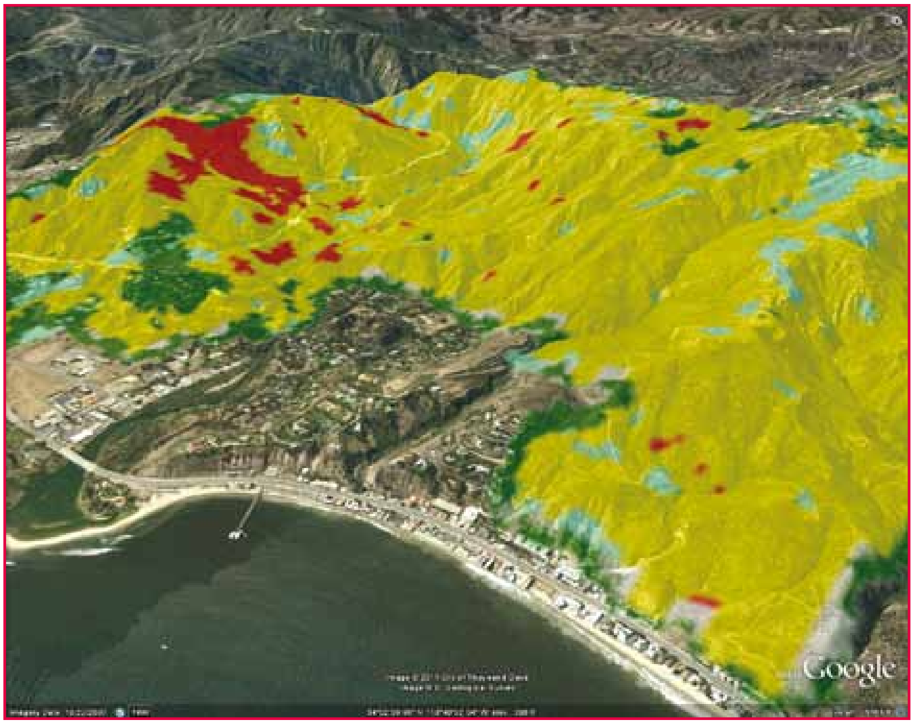

Figure 2—*GIS layers representing fire extent and severity can be projected onto photographs and elevation models for easy three-dimensional visualization of the burn area. This image shows the October 2007 Malibu Canyon Fire burn area in Malibu, CA.*

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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 and Fish Dynamics in a Changing Climate

Lisa Holsinger and Robert Keane

Wildland fire is a natural disturbance that affects the distribution and abundance of native fishes in the Rocky Mountain West (Rieman and others 2003). Fire can remove riparian vegetation, increasing direct solar radiation to the stream surface and leading to warmer summer water temperatures (fig. 1). Fire can also consume vegetation and organic biomass on the forest floor, changing hydrologic flows, stream quality, and fish habitat suitability.

Many native fish species, such as bull trout (*Salvelinus confluentus)* and cutthroat trout (*Oncorhynchus clarkii*), have evolved with fire, and their populations are resilient to fire's effects given adequate connectivity to robust population segments elsewhere in a basin. This resiliency, however, has been reduced in many watersheds through stream habitat loss and degradation and the invasion of nonnative fishes (e.g., brook trout, *Salvelinus fontinalis,* and brown trout, *Salmo trutta*) that better tolerate warmer water temperatures and threaten native fish persistence through displacement and hybridization.

Forecasting the long-term effects of climate change and fire on water temperatures and native fish populations requires an understanding of fire dynamics—the size, distribution, frequency, and severity of

Male bull trout in East Fork Bitterroot River basin. Photo: Aubree Benson, Forest Service.

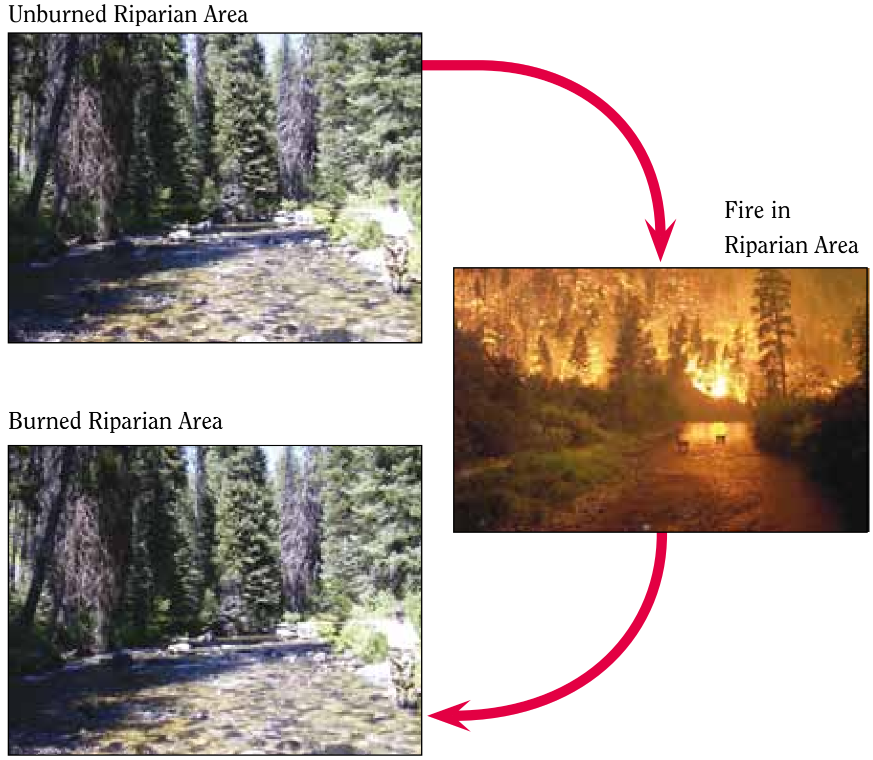

Figure 1—*Fire disturbance can affect stream temperatures by removing canopy shading.*

Lisa Holsinger and Robert Keane are research ecologists with the Forest Service, Rocky Mountain Research Station Fire Sciences Lab, in Missoula, MT.

fires across a landscape—as well as the extent and location of changes in riparian forest structure and the time necessary for riparian stands to recover. It will also depend on the distributions of native and non-native fishes and their responses to changes in water temperature.

To evaluate such fire and fish population dynamics, we are using a landscape fire succession simulation model called Fire-BGCv2, linked to a stream temperature model, to predict bull trout persistence and changes in fish communities. Analyses of model simulation outputs allow us to examine how temporal and spatial changes in water temperature and fish distributions are influenced by fire and landscape characteristics. This information will provide the ability to predict potential thresholds in fire risk and the scales at which to expect recovery in stream temperatures and fish communities, in both time and space, under various fire and climate regimes across the landscape. Given that climate change appears to be affecting both fire patterns (Westerling and others 2006) and air temperature (a good predictor of water temperature), tools that assist managers in predicting changes in the distribution of fire and the influence of fire management on native fishes are a critical need.

Study Site

We chose to apply our simulation modeling to the East Fork Bitterroot River basin in west-central Montana due to the extensive data available for the area on fire and fish (fig. 2). The upper portion of this basin is a core conservation area for bull trout (MFWP 1998), and a rich spatial dataset describing burn severity and extent was developed following the 2000 and 2007 wildfires in the basin. Also, Montana Fish, Wildlife, and Parks and the Forest Service have collected long-term data on the effects of those fires on stream temperatures and fish communities.

Many native fish species, such as bull trout and cutthroat trout, have evolved with fire, and their populations are resilient to fire's effects.

Modeling Approach

Forest-Fire Succession

We are using a spatially explicit fire ecosystem model called Fire-BGCv2 to simulate fire and forest succession (Keane and others 1996, 1997, 1999) (fig. 3). FireBGCv2 integrates vegetation succession, fire behavior and effects, and climate conditions. More specifically, the model simulates the flow of carbon, nitrogen, and water across various ecosystem components to calculate individual tree growth in the basin. The driving variables for these processes are taken from daily weather. Fire behavior and its effects are incorporated by linking a spatial fire simulation model to Fire-BGCv2 and simulating fire ignition, spread, and effects across landscapes using inputs such as topography, vegetation, weather, and fuelbed characteristics.

In 2009, we collected upland and riparian habitat data describing forest structure and composition to calibrate the Fire-BGCv2 model to the East Fork Bitterroot River basin. We also acquired records from a nearby weather station with data from 1955 to present, as well as 98-foot (30-m) spatial data describing soil composition and distribution, topography, stream networks, and fire history.

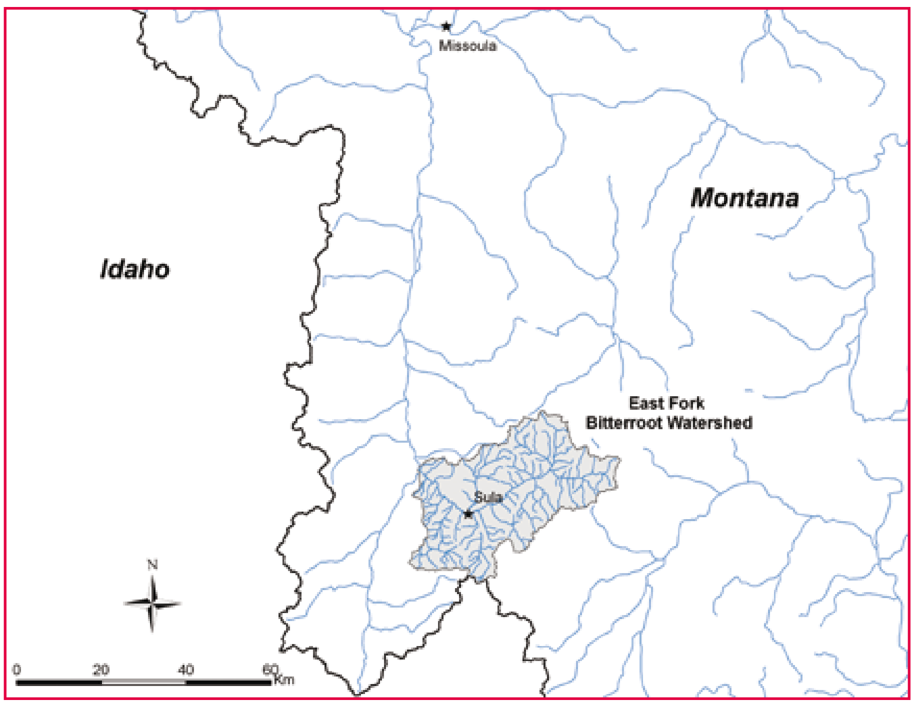

Figure 2—*East Fork Bitterroot River basin.*

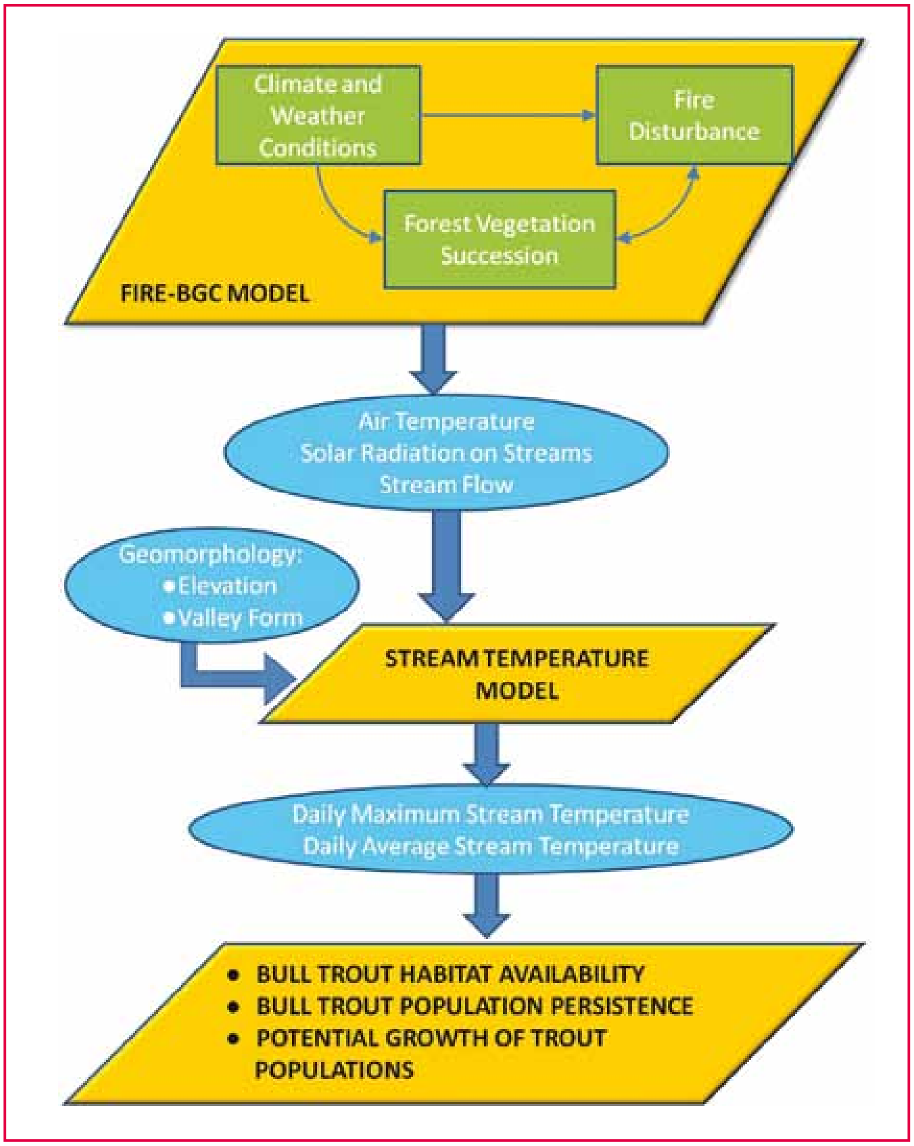

Figure 3—*Overview of the Fire-BGCv2 simulation model, modified to predict stream temperature and fish population dynamics.*

We hope to identify what fire and landscape characteristics pose higher risks to bull trout populations to help aid in their conservation and management under current and possible future climates.

Stream Temperature

We developed a quantitative model that predicts water temperature for the East Fork Bitterroot River basin based on methods used for the Boise River (Isaak and others 2010). After calibrating Fire-BGCv2 to the East Fork Bitterroot, we ran model simulations for the basin to develop a suite of potential predictor variables of stream temperature. We compared these variables to stream temperature data collected for 19 locations across the basin and found that the best predictors for stream temperature were air temperature, stream flow, elevation, solar radiation reaching the stream, stream channel slope, and the area within the drainage basin that contributes water to streamflow. Using these variables, we created a stream temperature prediction equation and embedded it into Fire-BGCv2 to predict water temperatures across the entire watershed with a relatively high accuracy (R^2 = 0.78 for average daily stream temperatures; R^2 = 0.71 for maximum daily stream temperatures).

Planned Model Simulations and Anticipated Results

We will run model simulations to explore the long-term effects of climate change and fire management on stream temperatures and aquatic species in the East Fork Bitterroot River basin. We will model historical climate, two climate conditions commonly predicted under climate change (warmer-wetter, hotter-drier), and two fire management scenarios (fire exclusion and prescribed burning), as follows:

1. **Historical climate** to describe conditions that streams historically experienced—**with historical fire regime and with fire exclusion** to simulate the effects of active wildfire suppression.
2. **Future warm/wet climate—with fire exclusion, and with fuels management** where fuels are treated to reduce fire ignition and spread potential.
3. **Future hot/dry climate—with fire exclusion and with fuels management.**

Each scenario will produce a time series on stream temperature and fire disturbance related to specific areas of the watershed, which we can relate to aspects of fish population dynamics in terms of bull trout persistence and native versus nonnative trout community composition. For bull trout, their distribution has been correlated to maximum summer water temperature and stream habitat patch size (Dunham and others 2003). Using predictions from our stream temperature model, we will estimate the total habitat patch size and number of available habitat patches available for bull trout under each climate scenario. Assuming large patches greater than 24,700 acres (10,000 ha) will support local populations with a high probability of persistence and small patches less than 12,350 acres (5,000 ha) will not (Rieman and others 2007), we can estimate how each climate scenario may change bull trout survival in the East Fork Bitterroot River basin.

To evaluate the balance of native versus nonnative trout populations, we will evaluate shifts in stream temperature distribution across the East Fork Bitterroot basin with each simulation scenario and determine whether these shifts affect fish community composition. More specifically, we will use energetic models that predict potential growth for westslope cutthroat trout, rainbow trout, brook trout, brown trout, and bull trout based on average daily stream temperature. Using these potential growth rate equations, we can measure habitat quality for each of the native and nonnative trout species and forecast shifts in the extent and location of high-quality habitat for these species across the basin.

By exploring a variety of fire regimes for each climate simulation scenario, we anticipate a suite of results, presented in bullets below, which should prove useful in understanding the impacts of fire on native and nonnative fish populations under current and a changing climate.

- We expect the probability of bull trout persistence to vary in each of our climate and fire management scenarios as a function of increasing fire frequency, magnitude, and severity (fig. 4). If this is true, our key next questions will be to evaluate: (1) where we should focus conservation efforts (e.g., higher elevation areas where stream temperatures may be cooler?) and (2) whether fuel treatment alters the outcomes.
- We also anticipate identifying thresholds at which the frequency of area burned becomes detrimental to bull trout populations based on the minimum habitat area needed for population persistence (fig. 5). Based on these

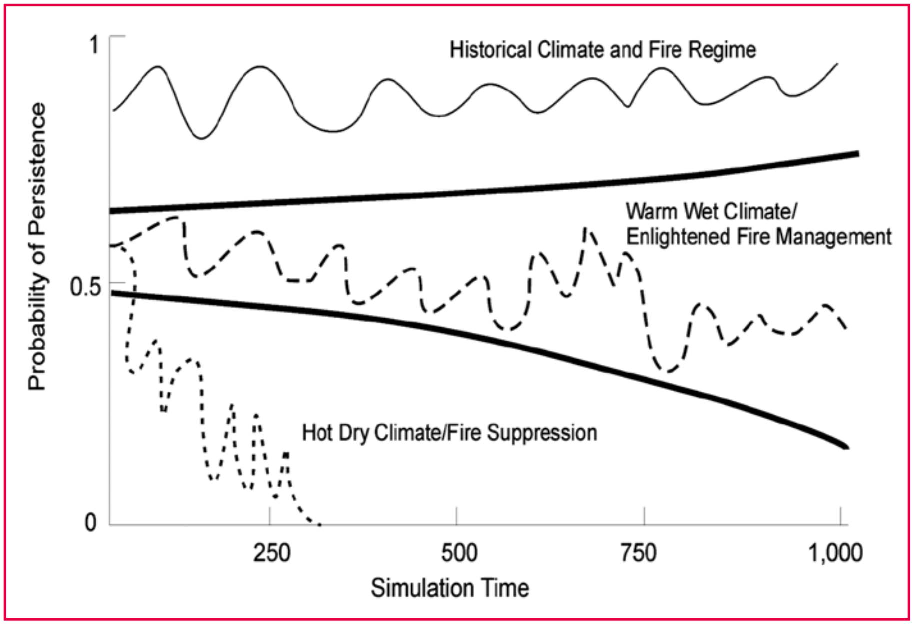

Figure 4—*Potential outcomes from simulations where bull trout persistence probability is evaluated (where 1 represents 100 percent survival and 0 is extinction) under various climate and fire scenarios.*

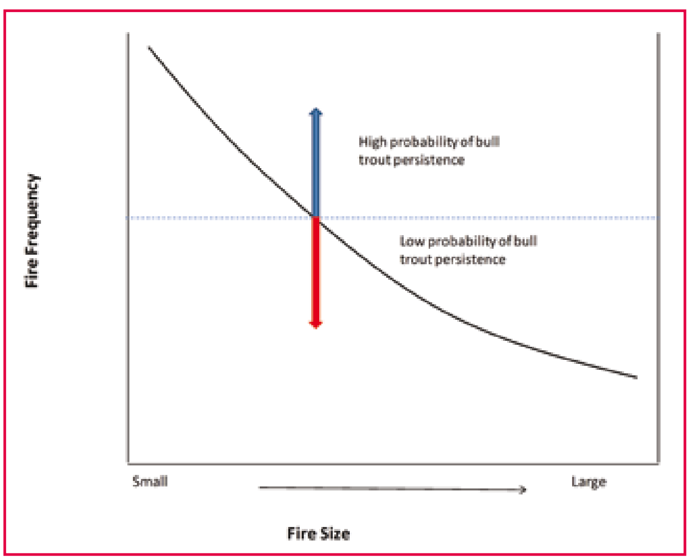

Figure 5—*Potential relationship of fire size and frequency where the dotted line across the curve represents the critical point where either persistence in bull trout is likely or extinction is predicted.*

thresholds, we will evaluate which factors, such as fire severity, fire size, vegetation, or fuels, result in large-scale, long-term changes in fish communities to better understand under what circumstances one might consider fire or fuel management.
- Similarly, we expect burn severity and fire size to affect fish populations. We expect large, high severity fires to have strong impacts on stream temperature and fish populations, depending on the amount of riparian area burned, and we expect little change with low severity burns (fig. 6). The magnitude and scale of response in mixed severity fires will likely be variable, depending on fire and landscape characteristics (fire behavior, topography, vegetation).
- Finally, we will evaluate the relationship of fire size and severity to the stream distance from burns at which temperatures become suitable for bull trout (fig. 7). We anticipate that stream distance appropriate for bull trout will increase with increasing fire size and severity.

At this stage, we are poised to begin our simulations and expect to be reviewing simulation results by summer 2011. Our goal is to develop information that offers a comprehensive approach for understanding how the occurrence and persistence of bull trout may vary with changing climate regimes. In particular, we hope to identify what fire and landscape characteristics pose higher risks to bull trout populations to help aid in their conservation and management under current and possible future climates.

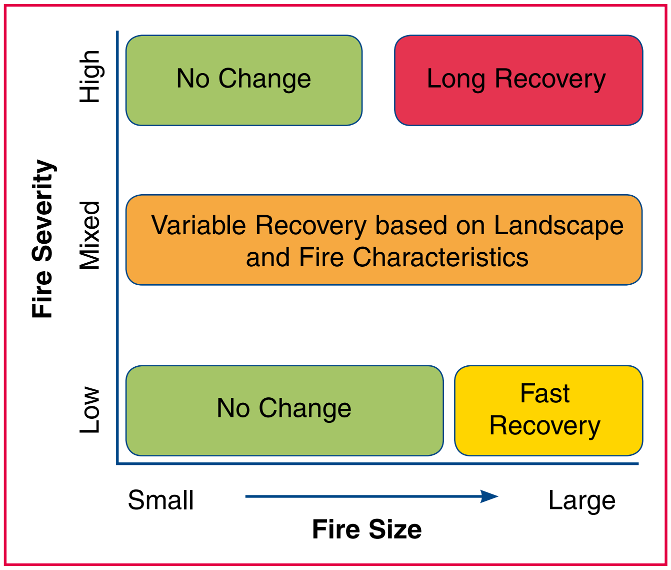

Figure 6—*Range of fire sizes and severity and the expected effects on native bull trout and cutthroat trout populations.*

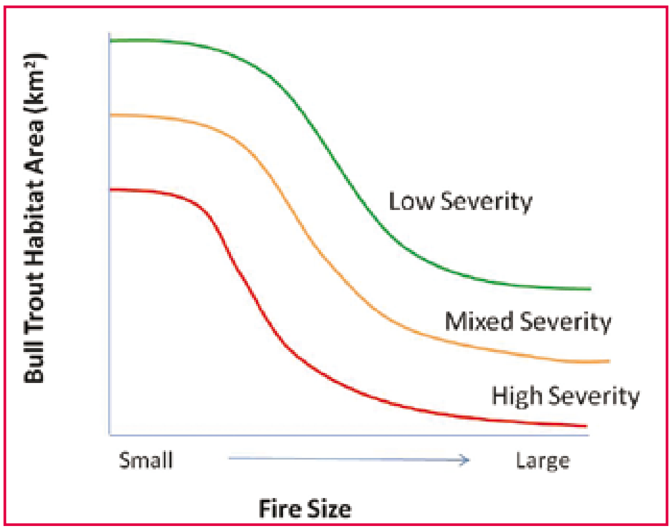

Figure 7—*Possible relationship of fire size to the stream distance from those fires where stream temperatures become suitable for bull trout.*

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Fire Management *today*

Announcing the 2011 Photo Contest!

The Fire and Aviation Management branch of the USDA Forest Service began conducting photo contests in 2000 for its quarterly publication, *Fire Management Today* (*FMT*). Over the years, we have had hundreds of photos submitted, giving us an inside look at your wildland fire experiences.

This year, we look forward to seeing your best fire-related images in our 2011 Photo Contest. Photos in the following categories will be considered: Wildland Fire, Prescribed Fire, Aerial Resources, Ground Resources, Wildland-Urban Interface Fire, and Miscellaneous (fire effects, fire weather, fire dependent communities, etc.). The contest is open to everyone, and you may submit an unlimited number of entries taken between 2009 and 2011.

Guidelines for contributors and the mandatory release form can be found on the *FMT* website: <www.fs.fed.us/fire/fmt/>. Entries must be received by 6 p.m. eastern time on Friday, December 2, 2011.

Winning images will appear in *FMT* and may be publicly displayed at the Forest Service national office in Washington, DC. As appropriate, we may use a photo contest image in an *FMT* article or as a cover photo. If your photo is used in *FMT*, we will supply you with a free copy of the issue so that you can see your contribution to the publication.

Winners in each category will receive the following awards:

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

Mapping the Potential for High Severity Wildfire in the Western United States

Greg Dillon, Penny Morgan, and Zack Holden

Each year, large areas are burned in wildfires across the Western United States. Assessing the ecological effects of these fires is crucial to effective postfire management. This requires accurate, efficient, and economical methods to assess the severity of fires at broad landscape scales (Brennan and Hardwick 1999; Parsons and others 2010). While postfire assessment tools exist (such as the burned area reflectance classification (BARC) maps produced in the burned area emergency response (BAER) process), land managers need new tools that easily and quickly *forecast* the potential severity of future fires. We are currently working on one such tool aimed at helping managers to make decisions about whether and where future wildfire events may restore fire-adapted ecosystems or degrade the landscape. This tool is a 98-foot (30-m) resolution, wall-to-wall map of the potential for high severity fire in the Western United States, excluding Alaska and Hawaii.

Understanding Where Fires Are Likely To Burn Severely

Measures of burn severity are a reflection of fire intensity and aim to capture the effects of fire on vegetation and soils. In the field, burn severity can be thought of most simply as the loss of biomass as a result of fire (Keeley 2009). When assessing burn severity across large geographic areas from satellite imagery, the definition of burn severity can be thought of more broadly as the degree of change from a prefire image to a postfire image (Lentile and others 2006). Such broad-scale assessments of burn severity have proven useful to managers in evaluating the potential for erosion, extent of tree mortality, and pathways for vegetation recovery after a fire. These assessments are valuable largely because they provide a framework for scientists and managers alike to consider the ecological effects of fire spatially. Moving beyond the application of such information to postfire rehabilitation, we believe that analyzing burn severity in a spatial context and over a long period of time can provide insight to aid management decisions at multiple planning stages, including prefire fuels treatments and strategic management of active fire incidents.

While postfire assessment tools exist, land managers need new tools that easily and quickly *forecast* the potential severity of future fires.

In our research, we are analyzing where and when fires burned severely between 1984 and 2007. While we understand much about how climate, fuels, and topography influence fire extent, their effects on burn severity are little understood. We are, therefore, capitalizing on the vast database of satellite-derived burn severity data recently made available by the national Monitoring Trends in Burn Severity (MTBS) project (<http://www.mtbs.gov>) to ask the following basic questions: (1) Are there underlying properties of a landscape that drive where fires burn hotter and, therefore, result in higher severity fires? and (2) Do the influences of the physical landscape change under different climate and weather scenarios? To answer these questions, we combine burn severity observations from more than 7,000 past fires with spatial data on topography, climate, and vegetation to build predictive statistical models.

As scientists, one of our primary goals in doing this research is to further our collective understanding of where, why, and when fires burn severely. Just as important, however, is transferring this increased understanding into a set of applied products that will truly be useful to managers. By taking our statistical models built on observed relationships from past fires, we can extrapolate out across

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entire landscapes to predict the potential for high severity fires in the future.

How We Map Probability of High Severity Fire

Our approach for mapping the probability of high severity fire builds on preliminary work by Holden and others (2009). Using data from the Gila National Forest, they developed methods to map the probability of severe fire occurrence based on topography and vegetation. We are now expanding on their general approach to produce a west-wide map of the landscape potential for severe fire. As an improvement on their methods, we are including weather and climate information into our predictions, even adding the capability to include current season climate and fire weather data, resulting in dynamic predictive maps of the potential for severe fire. Over the next year, we will produce maps and 98-foot (30-m) raster spatial data covering all lands across the Western United States. Both the maps and the data will be available for download online by March 2012.

Our predictive modeling and mapping work will be based on more than 7,000 fires that have been mapped by MTBS within our study area (fig. 1). Most of these are more than 1,000 acres (405 ha) in size, and all vary greatly as they encompass unburned islands and areas with low, moderate, and high severity (fig. 2). As observations of burn severity, we will use an index known as the relative differenced normalized burn ratio (RdNBR) that is produced by comparing prefire and postfire Landsat satellite images. Because our objective is to

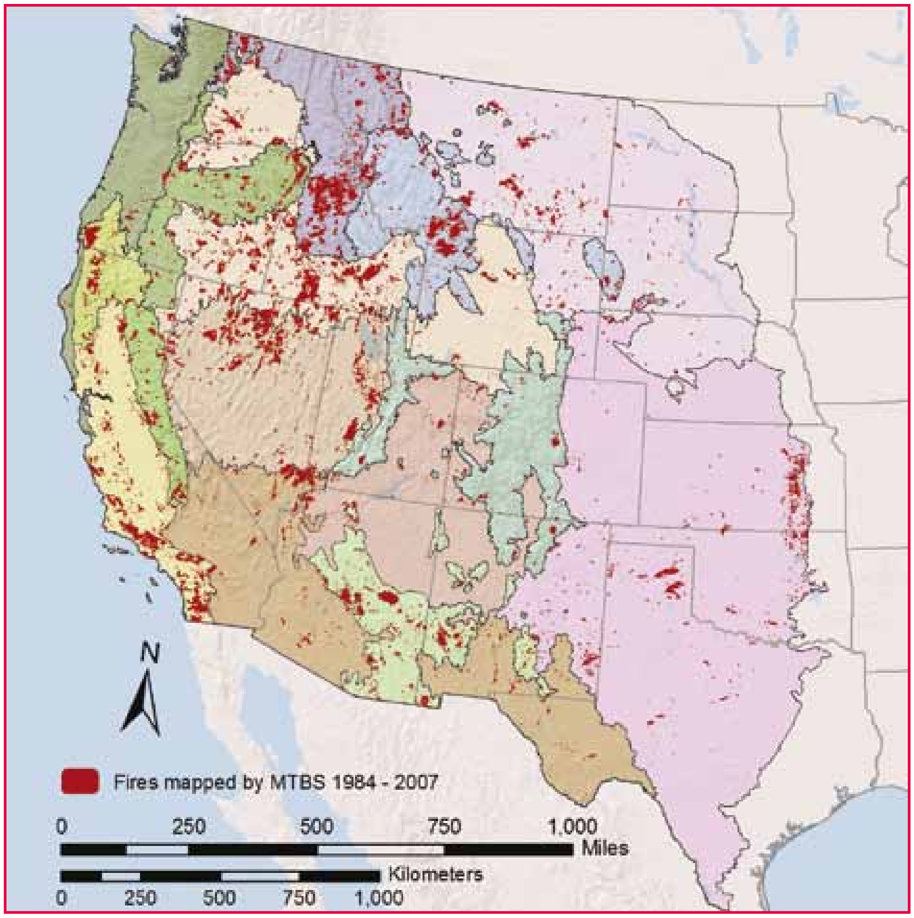

Figure 1—*The geographic extent of our west-wide effort to map the potential for high severity fire. The colored areas are the 15 mapping regions we plan to use in building predictive models and producing maps.*

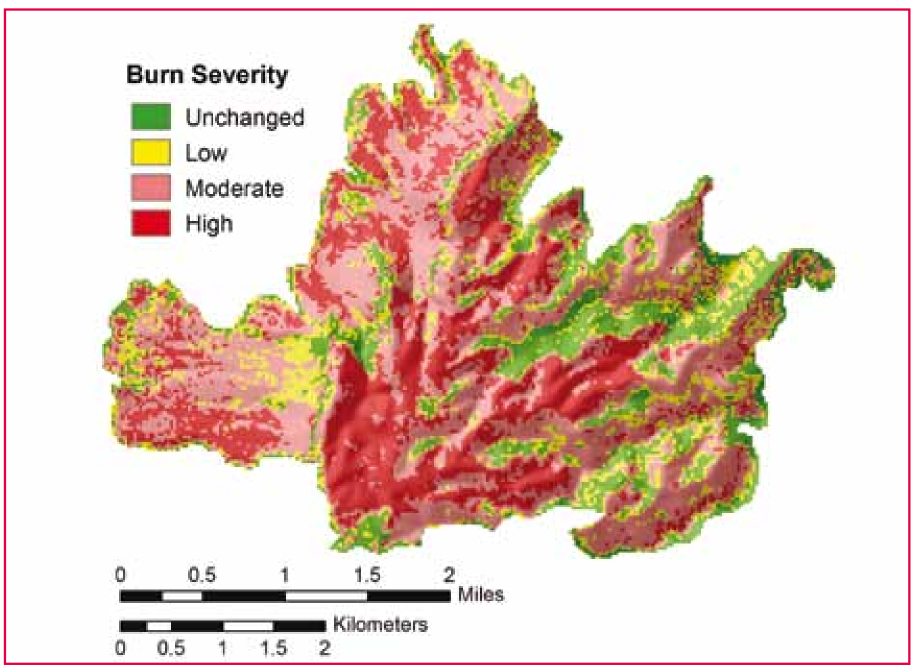

Figure 2—*Example of the spatial variability in burn severity within a single fire. This map shows the relative differenced normalized burn ratio (RdNBR), classified into four categories of burn severity. We focus specifically on areas of high severity fire, where a high proportion of overstory trees are killed (in forests) or aboveground biomass has been removed (nonforest). These areas also usually experience a high degree of surface fuel consumption and exposure of bare mineral soil.*

predict high severity fire, we reclassify the RdNBR into simple categories of high severity versus not high severity, using thresholds that we calibrate from field data that we and others have collected across the study area.

In each of 15 broad mapping regions based upon Omernik Ecoregions (fig. 1), we will construct separate predictive models for forested and nonforested areas. As predictors of severity, we have multiple spatial layers of topographic variables, such as elevation and incoming solar radiation, at 98-foot (30-meter) spatial resolution. Weather and climate are represented at coarser spatial scales, but at fine enough temporal scale to get values specific to the time of each fire event.

Given the size of our study area and the huge number of 98- by 98-foot (30- by 30-m) pixels in it, we begin our modeling process by selecting a very large random sample of pixels from within the MTBS burned areas. For each sampled pixel, we extract values for all predictors and use a computationally intensive algorithm called Random Forest (Breiman 2001; Prasad and others 2006; Cutler and others 2007) to develop predictive models. We then apply these models across the entire landscape to produce maps showing the potential for high severity fire for all locations.

Lastly, we will perform accuracy assessments on our map products. Already, we have collected fire severity information from 204 plots on 16 fires that burned in 2008 and 2009, and we will sample plots on fires that burned in 2010 during the summer of 2011. Our goal is to have at least 500 plots from a variety of geographic regions and vegetation types; we can use these data to tell managers where the maps are more, or less, accurate. Going back to the work of Holden and others (2009), they achieved over 70 percent classification accuracy for forested areas in the Gila National Forest (fig. 3), which we think lends promise to our application of this process to other areas across the West.

> As an "off-the-Web" resource, our maps will be immediately available when new fires start, and managers expect to use them in evaluating the potential risks and effects associated with new fire events.

What Are the Expected Benefits?

Weather and climate affect fire behavior, and fires burn differently at different elevations and

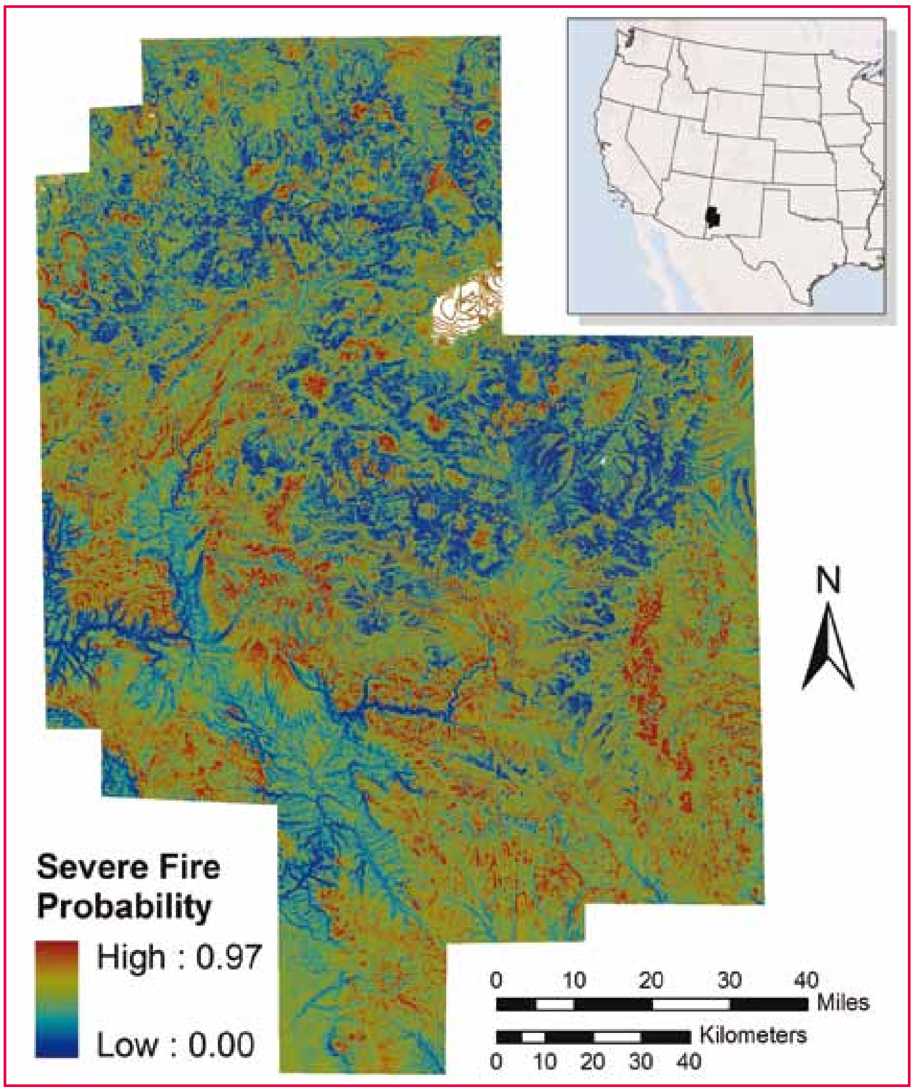

Figure 3—*Map of the potential for high severity fire for part of the Gila National Forest, produced by Holden and others (2009). We will build on their methods to produce similar maps for the Western United States.*

topographic settings. Yet, we don't fully understand why fires burn more severely in some places than in others. We think of climate and weather as "top-down" influences on wildland fire (e.g., through fuel moisture, temperature, or wind) that affect where and how fires burn at a broad scale. In contrast, topography and fuels are "bottom-up" controls that interact with climate and weather to alter fire behavior and effects locally. Topography is often a strong driver of general vegetation distribution, which in turn influences the distribution of fuels and patterns of severity. Based upon our preliminary analyses, we think that, while area burned is greatly affected by climate (Littell and others 2009), local topography and fuels are relatively more important to the ecological effects of those fires, though this varies across vegetation types and ecoregions. We also expect that topography and fuels may be less important when it is especially hot, dry, and windy, and so we will have multiple maps reflecting this.

Managers tell us that they will find many uses for our maps depicting the potential for severe fire. As an "off-the-Web" resource, our maps will be immediately available when new fires start, and managers expect to use them in evaluating the potential risks and effects associated with new fire events. They are also eager to see these map layers and related tools incorporated into existing decision support frameworks, such as the Wildland Fire Decision Support System (WFDSS) and the Rapid Assessment of Values at Risk (RAVAR).

Our work is part of a much larger research project, FIRESEV (<http://www.firelab.org/research-projects/fire-ecology/128-firesev>), funded by the Joint Fire Science Program, designed to create a Fire Severity Mapping System (FSMS) for the Western United States. With this system, managers can access fire severity map products when and where they need them. By integrating LANDFIRE data layers, fire effects models, and new techniques for analyzing satellite-derived burn severity data into one comprehensive computer modeling package, we hope to make it easier for managers to acquire fire hazard and fire severity maps at real-time or short-term timeframes and over a wide range of spatial scales. This FSMS will be composed of a suite of digital maps, simulation models, and analysis tools that can be used to create fire severity maps for: (1) real-time forecasts and assessments in wildfire situations, (2) wildfire rehabilitation efforts, and (3) long-term planning. This FSMS will NOT replace the suite of fire severity products currently used by fire management (e.g., BARC severity maps); rather, it would complement them to provide a more comprehensive suite of fire severity mapping products. The blend of many fire severity mapping approaches that are incorporated into this system should help meet fire management demands for rapid but accurate assessment of spatial fire severity given their time, funding, and resource constraints.

We hope to make it easier for managers to acquire fire hazard and fire severity maps at real-time or short-term timeframes and over a wide range of spatial scales.

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Environmental Impact Statement for Aerial Fire Retardant Application on National Forests and Grasslands

Background

In July 2010, the U.S. Federal District Court in Montana ruled that the Forest Service was in violation of the National Environmental Policy Act and the Endangered Species Act regarding its use of fire retardant applied from aircraft. In response to the court ruling, the Forest Service has reinitiated consultation with the Fish and Wildlife Service and the National Marine Fisheries Service. The agency has also initiated scoping for a national Environmental Impact Statement (EIS) that will analyze the impacts of aerial application of fire retardant on the environment. The EIS will inform a Forest Service decision whether to continue aerial application of fire retardant and, if so, under what conditions. Scoping for the EIS ended October 12, 2010. A draft EIS was released for public review and comment in May 2011 and a final decision will be released no later than December 31, 2011. In the meantime, the Forest Service will continue to follow April 2000 “Guidelines for Aerial Delivery of Retardant or Foam Near Waterways” and use aerial application of fire retardant when appropriate for firefighting activities.

A Douglas DC-7 drops a load of retardant on the Glassford Hill Fire near Prescott Valley, AZ, 2005, to prevent a human-caused fire from spreading toward homes. Photo: Sean Hagan, Dewey, AZ.

More Information

The DEIS was released in May, 2011 and more information on public and stakeholder involvement is available at the project website: http://www.fs.fed.us/fire/retardant/. Questions, contact Kenton Call, public affairs for the national interdisciplinary team at ckcall@fs.fed.us or (435) 865-3730.

Exploring the Mega-Fire Reality 2011

A Forest Ecology and Management Conference

14–17 November 2011, Florida State University Conference Center, Tallahassee, Florida, USA

In many parts of the world, both the area and the intensity of wildland fires have been growing alarmingly. However, it is not only the number of fires that are changing, but also the nature of these fires. Global warming, over-accumulation of fuels in fire-prone forests, and growth at the wildland-urban interface all suggest that the fire protection strategies we have used in the past may no longer serve us so well in the future.

Exploring the Mega-Fire Reality 2011 is bringing together experts from around the world to address the following major topics:

- Mega-fires: why is their frequency increasing?
- Why mega-fires require special understanding and approaches
- Perspectives and lessons learned from around the world
- Choices and options before and after mega-fires
- For more information please visit: www.megafirereality.com

The Fourmile Canyon Fire: Collaboration, Preparation, and Outcomes

John Bustos

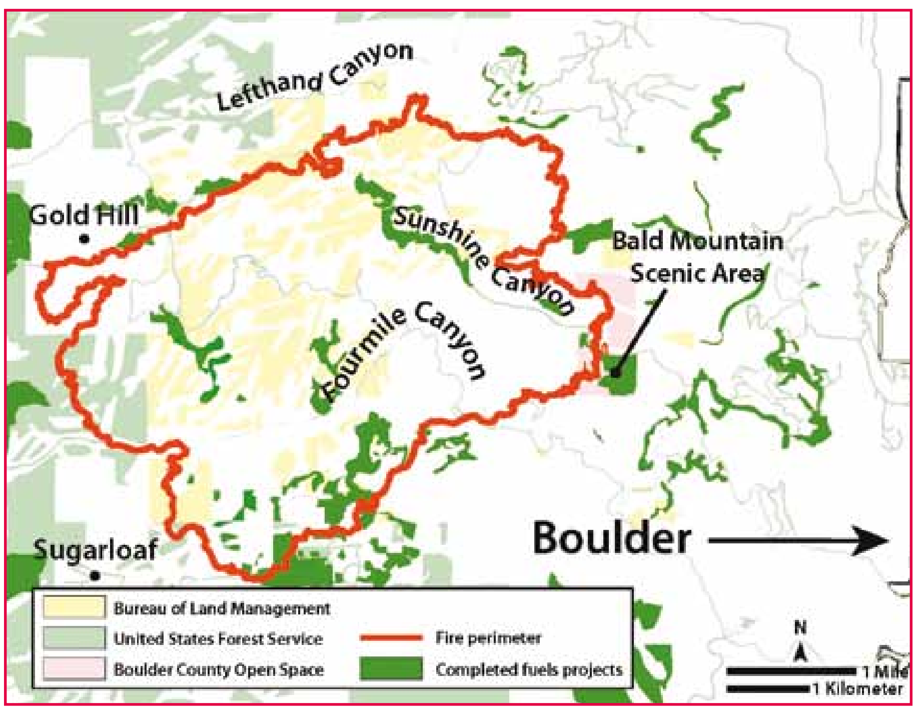
On September 6, 2010, the Fourmile Canyon Fire started near Boulder, CO. It was a very fast-moving fire. Varying winds and low humidity mixed with dry trees, grasses, and shrubs caused the fire to change directions numerous times. The setting, in conjunction with a very targeted, costly, and aggressive firefighting response to save houses and communities, resulted in a mosaic of burned and intact patches in the wildland–urban interface (WUI) landscape. In terms of personal property damage, it was the most destructive fire in Colorado history, with an estimated $217 million in losses as it burned through steep, heavily forested canyons within a few city blocks of the Boulder city limits. The fire destroyed 169 homes.

Yet, the story of that fire did not begin and end in the days following its ignition. Both the worst of the damage and the best of prevention measures had their roots in the landscape; the fire conditions; and the efforts of Federal, State, county, and local efforts to recognize and address the fire danger beforehand.

Foresight and Mitigation

One part of the story of the Fourmile Canyon Fire began in 2002. That year, a group of Front Range government agencies came together under the umbrella of the National Fire Plan in an alliance of Federal, State, and local governments called the Front Range Fuels Treatment Partnership (FRFTP). At the time, their intent was to reduce wildland fire risks through sustained fuels treatments. In 2004, the FRFTP expanded and formed a roundtable comprising environmental conservation organizations, academic and scientific communities, and industry and user groups. The first product of this new partnership was the publication *Living with Fire: Protecting Communities and Restoring Forests*. This publication documented the 1.5 million acres (600,000 ha) along the Front Range of Colorado that required treatment to reduce the risks of severe wildfire to Front Range communities and measures to restore forests to historic fire-adapted conditions. It also recommended 10 initiatives. One, "the need to promote the development of community wildfire protection plans (CWPP) for Front Range communities at risk," is key to this story.

Boulder, CO, is like many areas in the WUI, both a dreamscape and nightmare: a dreamscape because the mountains envelop a well-educated, wealthy, and progressive city noted for its extraordinary social activity, and a nightmare because



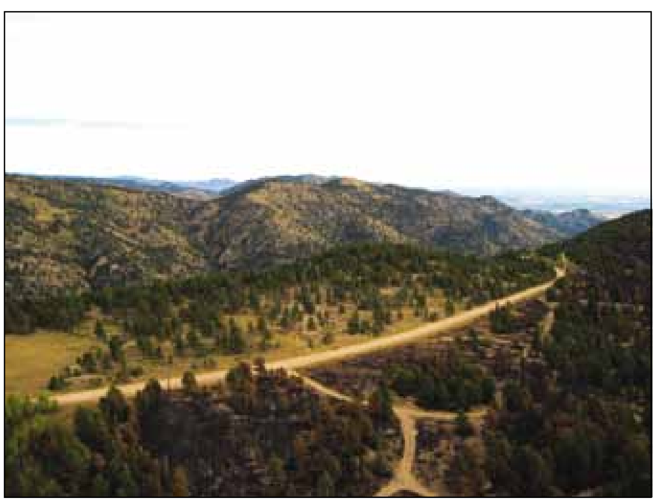
The Fourmile Canyon Fire burned across several land ownerships: State, County, Forest Service, BLM, and private land. Fuels treatment projects had been implemented in many areas both within and outside of the fire perimeter. Map: Carrie Adair, Coalition for the Upper South Platte.

John Bustos is a public affairs officer for the Arapaho-Roosevelt National Forests and Pawnee National Grassland in Fort Collins, CO.

the setting poses a severe wildfire threat to property and infrastructure. Recognizing the fire threat and common elements for treating that threat, the Forest Service, Colorado State Forest Service, Boulder County, and many private landowners have implemented fuels treatment projects in these nearby mountains. In 2002, the FRFTP began its efforts in Boulder County, work that continues today. Through 2010, more than 8,500 acres (3,400 ha) of projects were completed with the intent of reducing hazardous fuels in WUI communities such as Allenspark, Ward, Jamestown, and Nederland.

In May 2010, Boulder County was awarded just over $100,000 in American Recovery and Reinvestment Act funds to develop a countywide CWPP. County officials pursued the grant because they believed that implementing a CWPP would increase forests' resistance to wildfire and insect infestations such as mountain pine beetle, and that actions outlined in the CWPP would help protect homes, infrastructure, water quality, and recreation areas. They hoped the development of the CWPP could be used to identify areas of highest risk, prioritize treatments, increase the visibility of forest health needs in Boulder County, and "ignite" fire-risk mitigation actions, such as thinning and pruning trees and clearing brush near homes. Several fire protection districts and communities in Boulder County have developed and are successfully implementing CWPPs.






Treatments on Forest Service, Boulder County, and private lands completed prior to the Fourmile Canyon Fire in cooperation with the Colorado State Forest Service. Clockwise from upper left: Aerial view of Bald Mountain Scenic Area ponderosa pine surface fire and thinning restoration treatments, completed in 2008. Photo: Chad Julian, Boulder County. Ground view of Bald Mountain Scenic Area restoration treatments. The Fourmile Canyon Fire moved through the treatment area in 2010 as a low-severity burn. Photo: Mark Martin, Forest Service. Patch cut forestry treatments on Federal lands around Gold Hill in Boulder County, completed in 2007 and 2008. These treatments helped to hold the fireline along the road during the Fourmile Canyon Fire. Photo: Chad Julian, Boulder County. A combination of patch cuts and defensible space work helped to control the Fourmile Canyon Fire as it entered Gold Hill along the Sunshine Canyon Road. Photo: Chad Julian, Boulder County.

Because of the longstanding potential for a high-severity fire in Colorado, many Federal and State agencies and the City and County of Boulder were already preparing for a large-scale crisis. Efforts included the construction and outfitting of an emergency operations center and strengthening the Office of Emergency Management. In 2009 and 2010, simulations to provide incident training and practice were carried out by Federal, State, and local agencies. Additionally, contracts and memoranda of understanding were put in place to make incident management equipment and personnel available. Before the fire, proactive training and preparations provided resources and a common understanding of their use. Finally, per roundtable recommendations, CWPPs for Gold Hill, Sugar Loaf, Fourmile, and Sunshine Fire Prevention Districts were produced and implemented.

Assessing the Outcomes

It is hard to say exactly how preparation affected every outcome of the Fourmile Canyon Fire, and harder still to say if the preparations were done at the right time and in the right places. But most fire professionals involved before and after the fire would say that, without past mitigation activities, the outcome could have been worse, response would have been less effective, and more homes could have been lost.

About 500 homes in the burn and around the fire perimeter were untouched, but after the fire, many properties are still vulnerable to flooding and debris flow. There are also threats to burned areas from noxious weed invasion and fire-associated threats to downstream ecosystems, community water supplies, and roads.

Moving Forward

On October 10, 2010, the Fourmile Canyon Emergency Burned Area Report was completed. It identifies the single most complicating factor in the emergency stabilization of the Fourmile Canyon Fire area as land ownership within the perimeter. This assessment stems from the fire burning through a historic mining district with a mixture of land ownerships and very small parcels. Locating property lines and identifying land ownership in such areas is time-consuming and expensive. Yet, in order for stabilization techniques to be effective, there is a need for close coordination among private landowners and county, State, and Federal land managers.

The emergency stabilization plan treatments include mulching the moderately and severely burned slopes between 20 and 60 percent gradient, seeding to prevent noxious weed invasion, culvert upsizing, channel clearing, warning sign installation, and flood warning systems. The stabilization plan focuses on threats to:

- Human health, life, and safety from increased flooding and debris flows, abandoned mine lands, and hazard trees killed by fire;
- Private property;
- Irrigation water supply ditches and roads;
- Natural resources from noxious weed establishment and spread;
- Water used for domestic and municipal supply for communities like Pine Brook Hill;
- Water quality from mine tailings within the perimeter of the fire; and
- Cultural and heritage resources.

To promote coordination, response actions are planned on a watershed basis rather than on individual land ownerships. The USDA Natural Resources Conservation Service (NRCS) is now working with private landowners to implement the stabilization plan on private and county-owned lands, while the Bureau of Land Management (BLM) and Forest Service are working with NRCS to implement projects across their part of the landscape. The plan proposes that a single contract be used to treat Federal, county, and private lands. Thus, beyond the FRFTP and FRFTP roundtable members, collaboration is a valuable tool both before and after severe wildfire.

This collaboration demonstrates that the model for preparing for and treating catastrophic wildland fire involves more than establishing fire management plans and obtaining firefighting resources. It involves collaborative efforts toward public education; the continued timely and costly commitment to prevention, protection, and planning; and a common vision of roles and responsibilities in future actions. Individuals no longer have the luxury of passing off responsibility for preparing for fire, and money alone cannot treat the landscape after a fire.

The response to the Fourmile Canyon Fire began 8 years before ignition, and treatment did not end with putting it out. It will not be the last severe fire along the Front Range, nor does it represent the end of the need for meaningful action. The lessons of wildland fire continue, and we still need to perfect how to help fight wildfires before they have begun. We can expect and must be prepared for many more lessons. ■

Fourmile Canyon: Living with Wildfire

Hannah Brenkert-Smith and Patricia A. Champ

The most devastating wildfire in Colorado's history in terms of property loss began on Labor Day, September 6, 2010. The Fourmile Canyon Fire was located just 5 miles west of downtown Boulder, CO, in a wildland–urban interface (WUI) zone with homes located on steep slopes and in dense ponderosa pine and Douglas-fir forest. The fire, fueled by high winds, burned 6,181 acres (2,501 ha), mostly on private land, and destroyed 169 homes. The Fourmile Canyon Fire will likely garner much attention as landowners and land managers turn their efforts to trying to understand how such devastation can be avoided or minimized in the future.

A survey of homeowners was conducted to understand the behaviors and attitudes of residents who live in high fire-risk areas concerning wildfire.

The location of the fire within the WUI prompted much predictable response from the public. References to irresponsible homeowners who chose to live in a tinderbox and then expected the government to rescue them when a fire broke out were common. But is that really an accurate characterization of the individuals who

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Aerial view of the Fourmile Canyon area. Steep slopes, dense ponderosa pine and Douglas-fir forest, and mixed land ownership characterize this wildland-urban interface zone near Boulder, CO. Photo: Joe Amon, The Denver Post.

live in the area evacuated during the Fourmile Canyon Fire? In this article, we summarize the results of a prior survey of homeowners in the area to gauge their awareness of, and response to, fire risk in their neighborhoods.

Living Among the Trees

We conducted a survey of homeowners in Boulder County in 2007, 3 years before the Fourmile Canyon Fire, as part of a larger effort to understand the behaviors and attitudes of residents who live in high fire-risk areas. Among the 127 survey respondents who live in the Fourmile Canyon Fire evacuation zone, 9 lost their homes and 2 others suffered significant property damage. The survey summarized here describes a population that had an awareness of wildfire risk and their need to take responsibility for reducing that risk on their property.

The Costs of Fire

The Fourmile Canyon Fire outside Boulder has been characterized as the most destructive fire in Colorado's history. The majority of the property damage and loss from the fast-moving and dramatic fire occurred in the first hours of the week-long fire (Miller 2010; personal correspondence with Eric Philips, Boulder County Wildfire Mitigation Coordinator), and losses are largely associated with the destruction of 169 homes (Bounds and Snider 2010). Insurance claims for losses topped $217 million. Fire suppression costs totaled approximately $10.1 million, though U.S. Department of Homeland Security, Federal Emergency Management Agency assistance grants will likely defray the total cost of local fire-suppression efforts (Udall 2010). The full cost associated with clean-up and recovery and the extent to which grants will defray costs to the county have yet to be determined.

Mountain Communities and Fire

Dramatic wildfires and the losses suffered by those living in high fire-risk areas often capture the headlines during the wildfire season, and those living in the WUI become the subjects of study after major wildfire events. However, it is less common for studies to collect data on property owners' attitudes, beliefs, and mitigation activities before a major wildfire event, as this one did in Boulder County, CO.*

> Most of the survey respondents knew about the risk when they made the decision to purchase a home in a high fire-risk area.

With the largest number of developed square miles of land in the WUI in Colorado (57.1 square miles or 147,889 km^2), Boulder County is one of the top Colorado counties at risk of wildfire. Boulder County also has a large amount of undeveloped land that has the potential to dramatically increase future wildfire losses as more individuals choose to live in these high fire-risk areas.

However, Boulder County has an active wildfire mitigation program to inform property owners of existing risk and to encourage fuel reduction through mitigation cost-sharing programs. In 2010, Boulder County received more than $100,000 in American Recovery and Reinvestment Act funds to develop a county-level Community Wildfire Protection Plan (CWPP). In addition to the county-wide CWPP being developed, five of the communities in the area affected by the Fourmile Canyon Fire— Fourmile Canyon, Lefthand Canyon, Gold Hill, Sugarloaf, and Sunshine Canyon—had completed their own CWPPs. While the establishment of CWPPs does not imply any specific level of completed mitigation, it does reflect an organized community-level effort to evaluate conditions and develop plans among property owners, local government, local fire authorities, and the Colorado State Forest Service to reduce fuels and prepare for a wildfire event.

*The survey area included Larimer County, the county to the north of Boulder County, but this article focuses only on respondents in Boulder County in the area evacuated during the Fourmile Canyon Fire.

Did Homeowners Understand Wildfire Risks?

Survey Methods

We collected data from mail-in and on-line surveys. We used geo-coded data from the Boulder County Assessor's Office, geographic information system (GIS) software, and county fire hazard maps to develop a sample frame of privately owned residential properties containing a structure in Boulder County's WUI to identify survey recipients. In June 2007, we mailed letters of invitation to a total of 1,750 Boulder County addresses. Of these, 602 were not deliverable; 1,148 letters were successfully delivered. As an alternative to the traditional paper survey, participants had the option of completing a Web-based version of the survey. Three-hundred sixteen individuals completed the online survey, and 105 completed the paper survey. The overall response rate was approximately 37 percent.

To identify the respondents within the Fourmile Canyon Fire evacuation zone, we used GIS to map the boundaries of the evacuation zone onto a county map populated with location data points for the respondent addresses. We then used GIS to pull the unique survey identifier number of each respondent to the Boulder County survey within the evacuation zone. Among the 421 respondents to the Boulder County survey, 127 live in the Fourmile Canyon Fire evacuation zone. We discuss the results related to these respondents (hereafter "Fourmile respondents") below and clearly note any results from the broader population of Boulder County residents.

Demographics

The average Fourmile respondent was 57 years old, and respondents were equally divided among men and women. Almost all of the respondents (96 percent) identified "white" as their racial group, and more than 75 percent were married. The Fourmile respondents were well educated: 86 percent had at least a college degree. Median income among Fourmile respondents was $87,500. The average household size was 2 people, and only 19 of the 127 households (15 percent) had any children under age 18 living in the household. Most of respondents (64 percent) reported that they had household pets or nonincome generating livestock on their property.

Place of Residence

While some WUI areas in the United States have many seasonal residents, respondents in the Fourmile Canyon Fire evacuation zone were primarily full-time residents (94 percent) and owners (98 percent) living in single family homes (99 percent). Approximately 25 percent of the respondents expected to move within the next 5 years, though plans to move were primarily related to the challenges of mountain living (travel and health concerns) rather than wildfire risk. Land parcel sizes ranged from less than ¼ acre (0.1 ha) to 37 acres (15 ha). Only a small portion of survey respondents (9 percent) live on land parcels that are less than ¼ acre (0.l ha), while over half (52 percent) live on parcels between ¼ and 2 acres (0.1 and 0.8 ha), and nearly 40 percent live on parcels larger than 2 acres (0.8 ha) (mean= 7.89 acres or 3.52 ha).

Experience With Wildfire

At the time of the survey, over a quarter of the Fourmile respondents (26 percent) had evacuated their current residence at one time or another due to a nearby wildfire. Although 61 percent had experienced a wildfire within 10 miles (16 km) of their property, only a few respondents had first-hand experience with a wildfire on their property (9 percent), suffered fire- or smoke- related damages or losses (6 percent) or had prepared to evacuate without actually doing so (17 percent). Most of the Fourmile respondents (83 percent) said that they were somewhat or very aware of wildfire risk when they bought their current residence. Similarly, most respondents (83 percent) knew someone who was evacuated due to wildfire, and over a third of respondents (38 percent) knew someone whose residence was lost or damaged due to a wildfire.

Attitudes and Beliefs About Wildfire

We asked a series of questions to ascertain how concerned survey respondents were about a wildfire damaging their home, their health, their ability to earn income, their pets, their property, local water sources, and public lands near their home (table 1). We measured concern on a five-point scale (1 = "not at all concerned" and 5 = "extremely concerned"). Repondents expressed the highest level of concern for wildfire damaging their home (average rating = 3.47) and property/landscape (average rating = 3.42). Fourmile respondents also expressed a high level of concern that a wildfire would affect surrounding public lands (average rating = 3.27). The respondents were least concerned about a wildfire affecting their ability to earn income. This response is not unexpected as many respondents likely commute to the City of Boulder for work.

We included a series of 17 statements about wildfire in the surveys and asked respondents to rate how strongly they agreed or disagreed with each statement (table 2). In general, respondents disagreed with statements about not needing to take mitigation measures because they have insurance, firefighters would protect their home, or the risk of damage was not great. Respondents also seemed to understand that their properties were at risk to wildfire and that they needed to be responsible for reducing the risk. Although 89 percent of the respondents agreed or strongly agreed that wildfires are a natural part of the balance of a healthy forest ecosystem, they felt that wildfires should be suppressed in certain situations. Specifically, the majority of Fourmile respondents agreed or strongly agreed that wildfires that threaten human life or property (91 percent and 82 percent, respectively) should be put out. Likewise, 73 percent of the respondents agreed or strongly agreed that saving homes during a wildfire should be a priority. We also asked respondents about some of the obstacles to taking action to reduce wildfire risk on their property. Few of the Fourmile respondents agreed or strongly agreed that time (5 percent) or money (13 percent) were obstacles to implementing mitigation measures.

The Known Risk of Property Damage

We asked respondents about factors they believed contributed to the chances of a wildfire damaging their property within 5 years (from 2007 to 2012). Respondents believed that fire ignitions in the form of weather-related natural starts (51 percent) and human activity (39 percent) were major contributors to the chances of a wildfire damaging their property within the following 5 years. Respondents also believed the condition of surrounding properties, including vegetation on nearby national forest or national park land (28 percent), vegetation on neighbors' properties (23 percent), and vegetation on other nearby public land (19 percent) were major contributors to the likelihood of wildfire directly affecting their property. Interestingly, only 20 percent believed the vegetation on their own property was a major contributor and even fewer (9 percent) believed that the physical characteristics of their house or other buildings (e.g., roofing or siding materials) were major contributors to the chances of wildfire damage to their property within 5 years.

We also asked respondents to assess the likelihood of certain fire scenarios. Interestingly, while 41 percent of respondents acknowledged that it was not likely that they would be able to put a fire out themselves if it were to occur on their property, a full 52 percent felt that it was likely or very likely that the fire department would save their home. Indeed, only 28 percent thought it was likely or very likely that a wildfire would destroy their homes. Despite the fact that so few thought it was likely that fire would destroy their homes, 69 percent thought it was likely or very likely that the landscape around them would burn. On the other hand, many acknowledged that it was likely or very likely that there would be some smoke damage (63 percent) or physical damage (51 percent) to their home if there was a wildfire on their property.

Taking Action

There are many measures that a homeowner can take to mitigate the risk of wildfire, from thinning vegetation to installing a fire-resistant roof. Based on Firewise recommendations and consultation with county wildfire specialists, we included a list of 12 wildfire risk-reducing actions in the survey (table 3). We asked respondents to indicate which mitigation actions they had undertaken on their property. Only 4 percent of the survey respondents reported not taking any of the listed actions. Therefore, it appears that wildfire risk mitigation is a matter of degree rather than an all-or-nothing course of action.

Table 1—*Distribution of response to the question: "How concerned are you about wildfire damaging or affecting the items listed below?" The letter n indicates the number of respondents to each question.*

Affected Items	Responses					Average Rating
	1=Not at all concerned				5=Extremely concerned	
Your house or other buildings on your property (n = 126)	4%	13%	38%	23%	22%	3.47
Your property/landscape (n = 126)	7%	14%	33%	23%	23%	3.42
Public lands near your home (n = 126)	11%	16%	31%	19%	23%	3.27
Your health or your family's health (n = 126)	24%	21%	26%	14%	15%	2.76
Local water sources (n = 125)	24%	22%	33%	11%	10%	2.62
Your pets and/or livestock (n = 125)	44%	18%	12%	12%	14%	2.33
Your ability to earn income (n = 124)	56%	18%	13%	7%	6%	1.89

Table 2—*Distribution of response to wildfire statements. The letter n indicates the number of respondents to each question. Due to rounding, totals may not add to 100 percent.*

Statements	Responses					Average Rating
	1=Strongly Agree	2=Agree	3=Neutral	4=Disagree	5=Strongly Disagree	
You do not need to act to reduce the risk of loss due to wildfire because you have insurance. (n = 121)	2%	2%	6%	35%	56%	4.42
You don't take action to reduce the risk of loss due to wildfire because, if a wildfire reaches your property, firefighters will protect your home. (n = 121)	0%	1%	9%	39%	51%	4.40
You do not need to take action to reduce the risk of loss due to wildfire because the risk is not that great. (n = 123)	2%	5%	8%	29%	55%	4.30
Your property is not at risk of wildfire. (n = 122)	1%	7%	6%	38%	48%	4.27
You live here for the trees and will not remove any of them to reduce fire risk. (n = 123)	1%	3%	8%	49%	39%	4.22
Managing the wildfire danger is a government responsibility, not yours. (n = 122)	1%	0%	15%	46%	38%	4.21
Actions to reduce the risk of loss due to wildfire are not effective. (n = 121)	1%	2%	13%	46%	38%	4.19
You don't take action because adjacent properties are not treated, leaving your actions ineffective (n = 122)	1%	4%	12%	41%	42%	4.19
You do not have the time to implement wildfire risk reduction actions. (n = 123)	1%	4%	17%	44%	34%	4.07
A wildfire is unlikely to happen within the time period you expect to live here. (n = 123)	0%	10%	18%	37%	36%	3.98
You do not have the money for wildfire risk reduction actions. (n = 122)	3%	10%	21%	40%	25%	3.75
With proper technology, we can control most wildfires after they have started. (n = 122)	2%	24%	29%	36%	10%	3.29
Naturally occurring wildfire is not the problem; people who choose to live in fire-prone areas are the problem. (n = 121)	6%	19%	31%	29%	15%	3.28
During a wildfire, saving homes should be a priority over saving forests. (n = 124)	38%	35%	18%	7%	2%	2.01
Wildfires that threaten property should be put out. (n = 124)	39%	43%	14%	2%	2%	1.86
Wildfires are a natural part of the balance of a healthy forest/ecosystem. (n = 122)	44%	45%	10%	1%	0%	1.67
Wildfires that threaten human life should be put out. (n = 124)	59%	32%	5%	2%	2%	1.56

On average, Fourmile respondents implemented more mitigation measures (6.52) relative to the other Boulder County survey respondents (6.02), though the difference is not statistically significant. Within the 30-foot (9-meter) perimeter of the home, 72 percent of the survey respondents had removed dead or overhanging branches, the most frequently reported mitigation activity by Fourmile respondents. Installing fire-resistant siding and screening over roof vents were the two activities with the lowest reported frequencies.

Wildfire Risk Information Source

Outreach and education efforts are often key strategies to increase awareness and implementation of wildfire risk reduction measures. However, when we asked Fourmile respondents to rate how strongly they considered five different factors in decisions to take action to reduce wildfire risk (1 = "not a consideration" to 5 = "strong consideration"), "lack of specific information about how to reduce risk" was the factor with the lowest average rating.

We asked respondents about two dimensions of wildfire risk information: sources of information and confidence in the accuracy of the information source. Interestingly, the local fire department was the most frequently reported source of information about wildfire risk (68 percent), and it was the information source with the highest rating with respect to the confidence in the accuracy of the information. The second-most commonly reported information source was the media (43 percent). However, survey respondents did not express much confidence in the accuracy of information about wildfire risk provided by the media. Thirty-five percent of respondents reported neighborhood groups as an information source and respondents generally considered the groups to provide accurate information. Neighbors, friends, or family members were one of the more frequently reported information sources (39 percent), and respondents expressed a level of confidence in the accuracy of information similar to that provided by neighborhood groups.

Table 3—*Percentage of Fourmile respondents that completed each wildfire risk mitigation action, based on 127 respondents.*

Mitigation Actions	Rate
In the 30-foot (9-m) perimeter of home or other structures:	
Removed dead or overhanging branches	72%
Pruned limbs so the lowest is 6–10 feet (2–3 m) from the ground	44%
Thinned trees and shrubs	63%
In the 30–100-foot (9–30 m) zone:	
Removed dead or overhanging branches	47%
Pruned limbs so that the lowest is 6–10 feet (2–3 m) from the ground	44%
Thinned trees and shrubs	44%
Maintenance fuel reduction actions:	
Mowed grasses	68%
Cleared leaves and pine needs from roof and/or yard	66%
Structural measures:	
Installed fire resistant roof	61%
Installed fire resistant siding	26%
Installed screening over roof vents	29%
Installed clearly visible house number on house	72%

After the local fire department, the Colorado State Forest Service, USDA Forest Service, and Boulder County wildfire specialists received the highest ratings in terms of confidence in the accuracy of information provided; however, many fewer respondents reported having received information from these sources. Thirty-five percent of the Fourmile respondents received information from their county fire specialist about reducing wildfire risk, 32 percent received information from the Colorado State Forest Service, and 20 percent received information from the USDA Forest Service.

Conclusions

The survey results described in this article provide insight into the population within the Fourmile Fire evacuation zone before the events of September 2010. Clearly, word had gotten out among Fourmile respondents about wildfire risk, as most of the survey respondents in this area knew about the risk

Firefighters talk with a homeowner 5 days after the start of the Fourmile Canyon Fire. Their crew spent a good portion of their day talking with homewoners returning after evaucation, while continuing to monitor winds and watch fire movement to make sure homes were not threatened. Photo: Helen Richardson, The Denver Post.

when they made the decision to purchase a home in a high fire-risk area. Likewise, survey respondents expressed a fairly high level of concern that a wildfire would damage their home, landscape, and surrounding public lands. Most survey respondents also seemed to realize that a wildfire was likely within the time period they expect to live at their current residence. However, concern and awareness about wildfire risk do not necessarily translate directly into taking action. While very few respondents had done nothing to mitigate the risk of wildfire on their property, there appears to be plenty of room for improving mitigation rates.

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Success Story: Colorado State Forest Service Wildland Fire Fleet Always Ready

Ryan Lockwood

More than 40 Colorado State Forest Service (CSFS) personnel were directly involved in fighting the Fourmile Canyon and Reservoir Road fires on the northern Front Range of Colorado last fall. Several personnel who repaired equipment on-site, staffed fire engines, and supported aircraft operations were mechanics from the CSFS fire equipment shop.

Matt O'Leary, lead mechanic at the CSFS fire shop, was in charge of mandatory prefire and postfire safety inspections on the hundreds of fire engines and tender trucks from every agency involved. Shop mechanic Nate Taggatz spent weeks on an engine protecting structures and patrolling the fire line. And others from the shop worked tirelessly, mixing fire retardant and loading it onto single-engine air tankers (SEATs) that flew out of the Fort Collins-Loveland Airport.

Of the more than 1,000 firefighters at the Fourmile Canyon Fire, O'Leary was one of only 13 officially recognized by the type I national incident management team, which awarded him for his outstanding efforts.

Despite the importance of their efforts during the fires, the CSFS mechanics know the bulk of wildland fire suppression work actually occurs before fires even start. To

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Colorado State Forest Service fire shop mechanics Matt O'Leary, Nate Taggatz, Jakob Bonser and Paul Rodriguez pose in front of a type-4 engine.

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.

ensure that Colorado's rural fire departments are ready for the next blaze, the CSFS fire equipment shop constantly maintains a fleet of 140 wildland fire engines for fire departments throughout the State.

Making Engines Affordable

When a wildfire is reported in rural Colorado, the first firefighters on the scene usually are from smaller city or county departments. The initial attack role these fire departments play in fighting Colorado wildfires is significant, yet the budgets of these mostly volunteer organizations often are prohibitively low to allow for the provision and maintenance of fully equipped fire engines.

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 the 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 provides ongoing major vehicle maintenance on the fleet, also replacing vehicles as needed. 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.

Sergio Lopes, the CSFS aerial and ground fire equipment supervisor, said the locations of the 140 fleet vehicles are based on recommendations from CSFS districts, local fire department budgets, and fire risk. For example, several State fleet engines that responded to the Fourmile Canyon Fire are based in Boulder County's highly populated wildland-urban interface. On the other side of the State, Moffat County also needs multiple wildland fire engines, due to a high number of lightning strikes and impressive annual burned-acreage figures. Yet the county does not have the budget to maintain such a large fleet. Todd Wheeler, fire management officer for the Moffat County Sheriff's Department, said that he and the 13 other firefighters who work for the county rely on the CSFS to maintain its five fire engines.

The initial attack role of rural fire departments in Colorado is significant, yet their budgets often are prohibitively low to allow for the provision and maintenance of fully equipped fire engines.

"Without these CSFS engines, the sheriff's office could not afford the equipment necessary to help protect the citizens of Moffat County from wildfires," Wheeler said. He said that he currently has an order in with the CSFS to build a smaller type-6 engine to join his fleet of larger type-4 engines.

CSFS Builds Fire Trucks From Start to Finish

Lopes says that unlike many other States, the CSFS program builds fire engines from start to finish. Most other State agencies provide only the vehicles, and the fire agencies are responsible for adding a fire package and performing maintenance.

"We handle everything, from refurbishing the vehicle chassis to sending a fully completed fire engine to its new position with a rural fire department," Lopes said.

It takes about 4 weeks to build a fire truck. CSFS mechanics first perform a full-scale overhaul of a vehicle from its stockpile, replacing hoses, belts, brakes, fluids, filters, and shocks. They then make necessary modifications to meet wildland firefighting needs and attach a State-owned fire package consisting of such components as a water tank, pump, hose reel, and tool boxes. Finally, a Buena Vista prison crew paints the State fleet trucks their characteristic golden yellow color.

"These trucks are all ready to fight fire right out the door," O'Leary said.

Colorado State Forest Service mechanic Nate Taggatz removes a tire during a truck overhaul.

Better Vehicle Designs

The CSFS primarily builds dump truck-sized type-4 engines that can deliver 1,000 gallons (3,785 L) of water to the fire lines; they also can craft smaller type-6 engines on full-size pickup chassis. Lopes says the CSFS type-4 engines, which make up most of the engines in the State fleet, are unique in that they follow a design offering more balance and stability than typical large fire engines.

A Colorado State Forest Service fleet fire engine before and after fire shop efforts.

"We developed a new type-4 engine design after firefighters regularly complained that standard truck designs were too top-heavy," he said. "Our unique design offers a water tank that rests below the bed height, instead of above it, for a much lower center of gravity and greater stability."

Wheeler says firefighters and cooperating agencies in Moffat County, such as the Bureau of Land Management, have come to appreciate this innovative CSFS engine design, which performs well on the rugged terrain of northwest Colorado.

"We have found that CSFS engines outperform other engines because they are able to go places only hand crews are usually able to access," Wheeler said.

The Hotchkiss Fire District also fights fires with one of the 140 fire engines in the CSFS fleet. Hotchkiss Fire Chief Doug Fritz, who currently is collaborating with the CSFS to build his district another truck, also has good things to say about his current CSFS-built engine.

"I think it's the best wildland engine on the Western Slope," Fritz said. "Our engine has even led bulldozers to fires. In the 15 years we've had it, it has saved more homes from wildfire than we can count."

> We have found that CSFS engines outperform other engines because they are able to go places only hand crews are usually able to access

By the end of next year, the CSFS plans to replace all the type-4 engines in the State fleet that still have the previous higher-profile design.

More Than Routine Maintenance

Available to the CSFS fire division mechanics on-site at the State office are a repair garage, welding shop, fabrications area, and machine shop, which allow them to maintain the State fleet and build new fire trucks. Yet the mechanics also regularly perform maintenance around the State at fire departments and on-scene at wildfires. The majority of CSFS mechanics are certified wildland firefighters who see action alongside other CSFS firefighters, providing an opportunity for insight into how the fire equipment they repair functions on the fire lines.

"It lets us see what works and what doesn't," said O'Leary, who often acts as an interagency fire equipment manager on large incidents throughout the West.

According to Butch Smith, the ground support unit leader for the Great Basin National Incident Management Team that managed the Fourmile Canyon and Reservoir Road fires, roughly 350 mandatory vehicle inspections were necessary prior to engaging the fires. Without the fast response provided by O'Leary and the CSFS fire equipment shop, Smith says the incident management team would have been in a bind.

"O'Leary and his crew were instrumental in helping our team serve the firefighters on the line," Smith said. "I was very impressed with the Colorado State Forest Service fire personnel, who fought so hard to minimize damage to land and property." ■

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