The 1988 Fires of Yellowstone and Beyond as a Wildland Fire Behavior Case Study

by Martin E. Alexander

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High-intensity crown fire behavior on the Clover-Mist Fire in Yellowstone National Park during the 1988 fire season. Photo: Jim Peaco, National Park Service, courtesy of Yellowstone Digital Slide File, 1988.

This report is based in part on a presentation featured at The '88 Fires: Yellowstone and Beyond Conference *held September 22-27, 2008 in Jackson Hole, Wyoming (Alexander 2009).*

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The report was initially drafted while he was on a leave of absence from his position as a senior fire behavior research officer with the Canadian Forest Service at the Northern Forestry Centre, Edmonton, Alberta, Canada.

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I Foreword

A "Learning Organization" is an organization that creates, acquires, interprets, transfers, and retains knowledge, and purposefully modifies its behavior to reflect new knowledge and insights (Garvin 2000).

Dr. Marty Alexander's report *The 1988 Fires of Yellowstone and Beyond as a Wildland Fire Behavior Case Stud*y now provides the international wildland fire community an important resource for ensuring that such vital organizational learning occurs.

Through this insightful case study compilation, Dr. Alexander captures the essence of the 2008 *'88 Fires: Yellowstone and Beyond Conference's* key theme: "Fire behavior, weather and fuels, including crown fire modeling, long-range fire behavior, weather forecasting, fuels, and fuels management."

As Dr. Alexander points out, prior to this work, one single, comprehensive case study or history that focuses on lessons learned from the 1988 Yellowstone fires did not exist. Now, however, thanks to the efforts of this dedicated wildland fire science professor and fire behavior researcher, we have a thoughtfully prepared summary of significant wildland fire behavior insights that surround this historic wildland fire event.

These lessons learned include everything from fire behavior forecasting and procedures for making long-range duration fire growth projections, to advances in fire dynamics and crown fire behavior predictions.

Dr. Alexander also references philosopher George Santayana's observation:
"Those who cannot remember the past are condemned to repeat it."

Certainly, this succinct and comprehensive lessons learned case study summary—brimming with a mother lode of important wildland fire articles and publication references—will now help move the wildland fire community into a more informed future.

A future where—thanks to Dr. Alexander—we can all more effectively learn from the myriad lessons that the 1988 fires in Yellowstone and beyond have provided us.

Paula Nasiatka
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"We all thought this was one of those once-in-a-lifetime career experiences. Little did we suspect then that 1988 would be the first of ever-intensifying fire seasons."

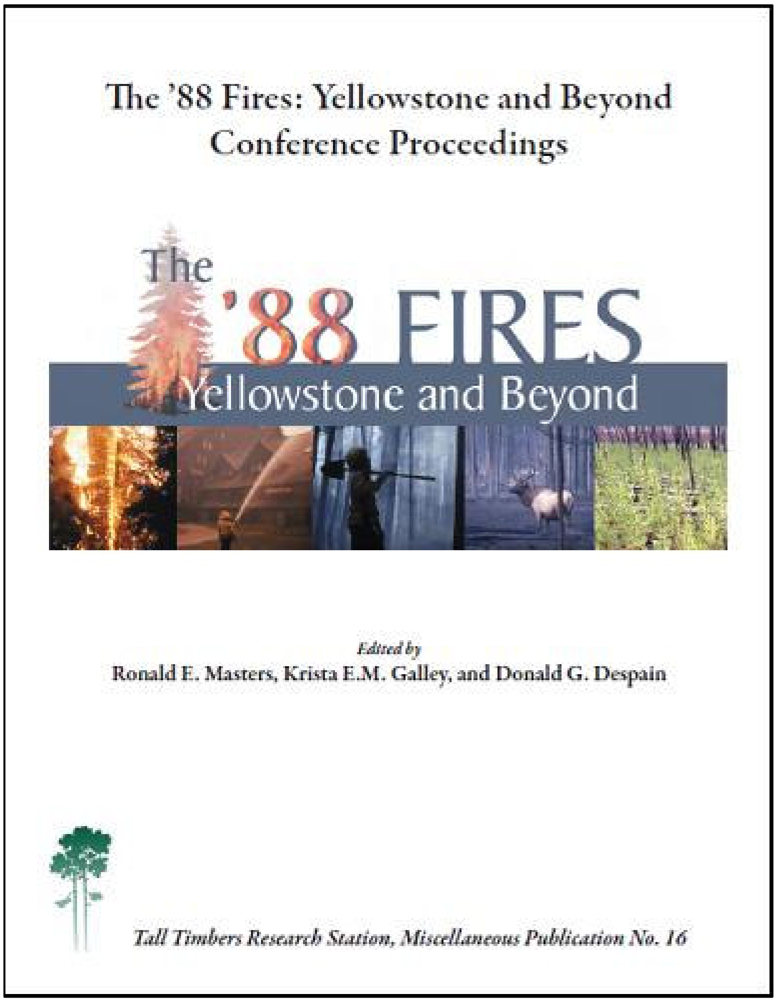
Bushey (2008)

II Introduction

The '88 Fires: Yellowstone and Beyond Conference held in 2008 in Jackson Hole, Wyoming, commemorated the 20th anniversary of 1988 fires in Yellowstone National Park and adjoining U.S. Rocky Mountain areas.

This extraordinary event was organized by the International Association of Wildland Fire (IAWF) in cooperation with the National Park Service 9th Biennial Science Conference on the Greater Yellowstone Ecosystem, with the support of numerous sponsors and partners.

The conference presented a unique opportunity to reflect on past and present fire management practices and scientific research which will serve as a foundation for managing wildland fires in the future.



The proceedings of The '88 Fires: Yellowstone and Beyond Conference*, published by the Tall Timbers Research Station, includes the extended abstracts of the 18 oral presentations featured during the session on fire behavior, weather and fuels, as well as some 90 or so other oral presentations and 85 poster presentations.*

The conference proceedings (Masters and others 2009) thus constitute a valuable resource for fire managers and fire researchers. To order a copy go to: http://www.talltimbers.org/info-publications.html.

The conference focused on five major themes:

- Fire behavior, weather and fuels, including crown fire modeling, long-range fire behavior, weather forecasting, fuels, and fuels management.
- Fire ecology, including wildlife, water, aquatic systems, landscape ecology and fire history.
- Fire management and policy, including fire suppression, operations, safety, and planning.
- Global trends: carbon, invasive species, climate change.
- Cultural and social perceptions of fire and the human interaction.

Fire Behavior, Weather and Fuels Session

The session on "fire behavior, weather and fuels" featured 18 oral presentations (see box on next page), including talks on crown fire modeling, long-range fire behavior, weather forecasting, and fuels management.

This session was specifically organized along the lines of a fire behavior case study by the author and Chuck Bushey, current IAWF president. Bushey and the author served as co-moderators for the session.

The session's first presentation constituted an overview of all of its featured topics (Alexander 2009) as they pertain to the 1988 fires in Yellowstone and beyond, while also referencing the presentations that followed.

This report represents a summary of this opening presentation to the conference's "fire behavior, weather and fuels" session.

International Association of Wildland Fire

Facilitating *communication* and providing *leadership* for the wildland fire community.

http://www.iawfonline.org/

Presentations Featured During the Fire Behavior, Weather and Fuels Session at the '88 Fires: Yellowstone and Beyond Conference

- Opening remarks: The 1988 Yellowstone fires as a fire behavior case history – Marty Alexander
- The 1988 Fire Season in the U.S. Northern Rocky Mountains – Chuck Bushey
- What Fuel Types Burned During the 1988 Yellowstone Fires? – Don Despain
- The Chronology of the 1988 Yellowstone Fires – Bob Mutch
- Synoptic Weather Patterns and Conditions During the 1988 Fire Season in the Greater Yellowstone Area – Rick Ochoa
- Trends in Fire Weather and Fire Danger in the Greater Yellowstone Area – Chuck McHugh
- The Old Faithful Inn Fire Run in Retrospect – Dave Thomas
- Observations and Reflections on Predicting Fire Behavior During the 1988 Yellowstone Fires – Dick Rothermel
- Burn Mapping Comparisons on Yellowstone 1988 Fires – Donald Ohlen and Don Despain
- Wildland Fire Legacies: Temporal and Spatial Constraints of Historic Fires to Current Fire Behavior – Roy Renkin, Don Despain, and Carrie Guiles
- The 1988 Yellowstone Fires and Crown Fire Modeling in BehavePlus – Tobin Kelly and Patricia Andrews
- Recent Advances in Modeling Crown Fire Initiation and Rate of Spread – Marty Alexander and Miguel Cruz
- Assessing Discontinuous Fire Behavior and Uncertainty Associated with the Onset of Crowning – Miguel Cruz and Marty Alexander
- Spatial and Temporal Evolution of Atmospheric Boundary-Layer Turbulence During the 1988 Yellowstone Fires – Warren Heilman and Bian Xindi
- Yellowstone and Beyond: Pyrocumulonimbus storms sent smoke to the stratosphere and around the globe – Michael Fromm, Rene Servranchx, Dan Lindsey, Brian Stocks, and Dennis Quintilio
- Predicting Yellowstone: Decision-Support of the Past, Present, and Future – Tim Brown and Tom Wordell
- Could Fuels Management Have Altered the Outcome of the 1988 Yellowstone Fires? – Ron Wakimoto
- Closing Remarks: What Did We Learn and What Must We Do To Avoid Relearning It? – Bob Mutch

"We are continuing to learn, and relearn, from these case studies. They will only seem to become dated if we don't use them."

Thomas (1994)

III The Role of Fire Behavior Case Studies

Case studies (also known as case histories) provide a systematic method for looking at events, collecting data, analyzing information, and reporting the results (Alexander and Thomas 2003a, 2003b, 2004b, 2006; Alexander and Taylor 2010).

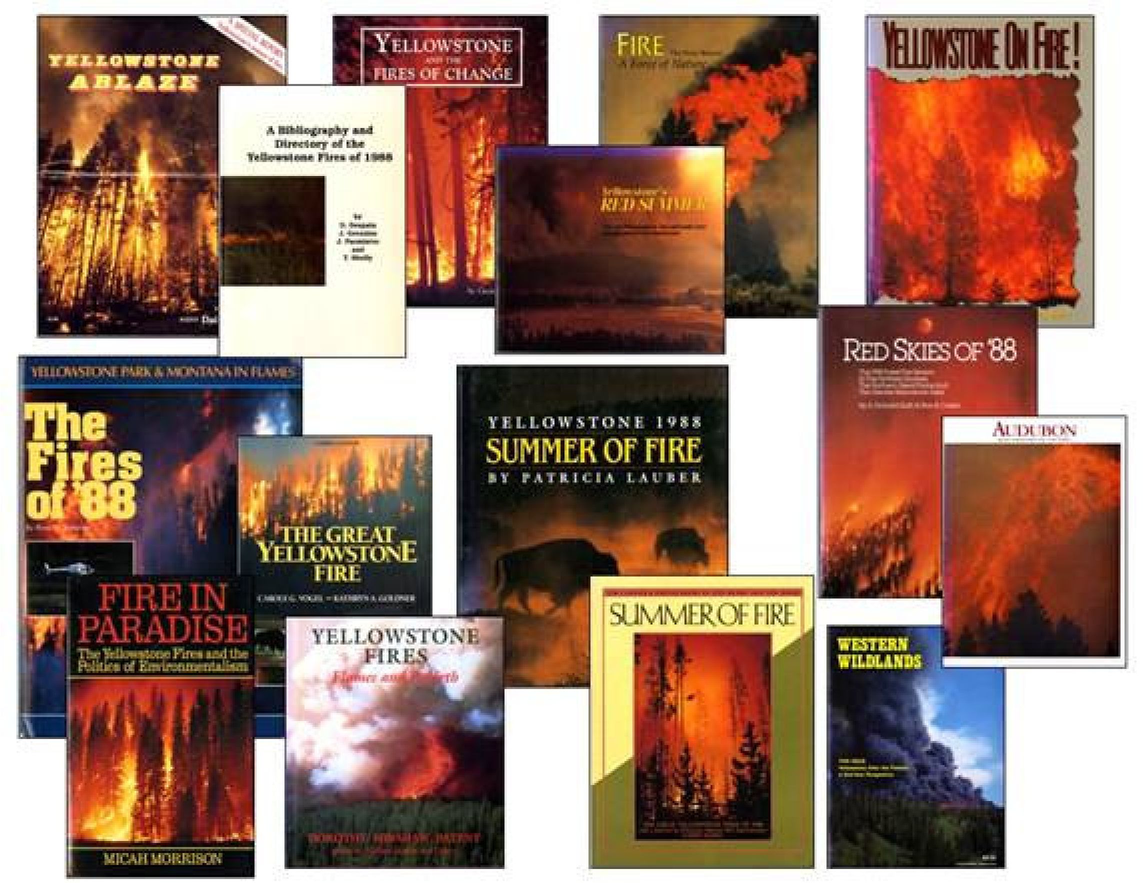
The value of documented case studies of wildland fires has been repeatedly emphasized by both fire managers and fire researchers. Over the years, they have proven valuable as training material and as sources of research data. These case studies also provide a mechanism for formalizing the basis for experienced judgment in predicting fire behavior (Gisborne 1948; Alexander 2003, 2007; Alexander and Thomas 2004a).

In recent years, several issues of *Fire Management Today* have focused on wildland fire behavior case studies. For example, a standard approach to case history or study report preparation was suggested by Alexander and Thomas (2003b) in this publication's fall 2003 issue. This standard format has since been recommended for use by the Wildland Fire Lessons Learned Center in Tucson, Ariz.

A case history or study report should consist of five main parts:

1. Introduction, highlighting the significance of the fire;
2. Fire chronology and development;
3. Details of the "fire environment"—i.e., fuels, weather and topography (Countryman 1972);
4. Analysis of fire behavior; and
5. Conclusions or concluding remarks, including recommendations, lessons learned, etc.

The following chapters provide a review of the existing literature (books, journal articles, agency publications, and conference papers) related to these five topics as they pertain to the 1988 fires in Yellowstone National Park and the surrounding areas in the U.S. Northern Rocky Mountains.



The fires in the Greater Yellowstone Area and the Northern Rocky Mountain region of the U.S. during the 1988 fire season spawned a host of books, special journal issues, and other publications.

IV Significance of the 1988 Fires in Yellowstone and Beyond

The 1988 fire season in the U.S. Northern Rocky Mountains was unprecedented in modern times regarding the prevailing fire weather and fire danger conditions, the ensuing fire behavior, and the area burned.

For example, in many ways the 1988 fires exceeded the severity of previous fire seasons (Barrows 1951a, 1951b), including the1967 fire season (USDA Forest Service 1968; Fischer 1969) and the associated Sundance Fire (Anderson 1968, 1969; Rothermel 1968; Finklin 1973; Aronovitch 1989).

However, the 1988 fire season was much less severe than the historic 1910 fires in which three-million acres (1.2 million hectares) were burned. Much of this burning activity occurred over a two-day period, August 20-21 (Spencer 1956; Cohen and Miller 1978; Pyne 2008).

As Bushey (2008) points out in reflecting on the 1988 fires and fire season, “We all thought this was one of those once-in-a-lifetime career experiences. Little did we suspect then that 1988 would be the first of ever-intensifying fire seasons.”

In the Greater Yellowstone Area (GYA) alone, seven major fires accounted for 95 percent of the 1.2 million acres (0.49 million hectares) burned in 1988. Approximately two-thirds of the total area burned occurred within the boundaries of Yellowstone National Park—affecting approximately one-third of the total park area. “Extreme fire behavior became nearly the order of the day, as fires ran as much as 10 miles [16 kilometres] in a day, sending embers as much as a mile and a half [2.4 kilometres] ahead of the main fire” (Schullery 1989).

The fires in Yellowstone and beyond in 1988 are widely regarded as one of those benchmark or landmark fire seasons (Alexander 2005) with far reaching consequences (Barker 2005, 2008; Omi 2005).

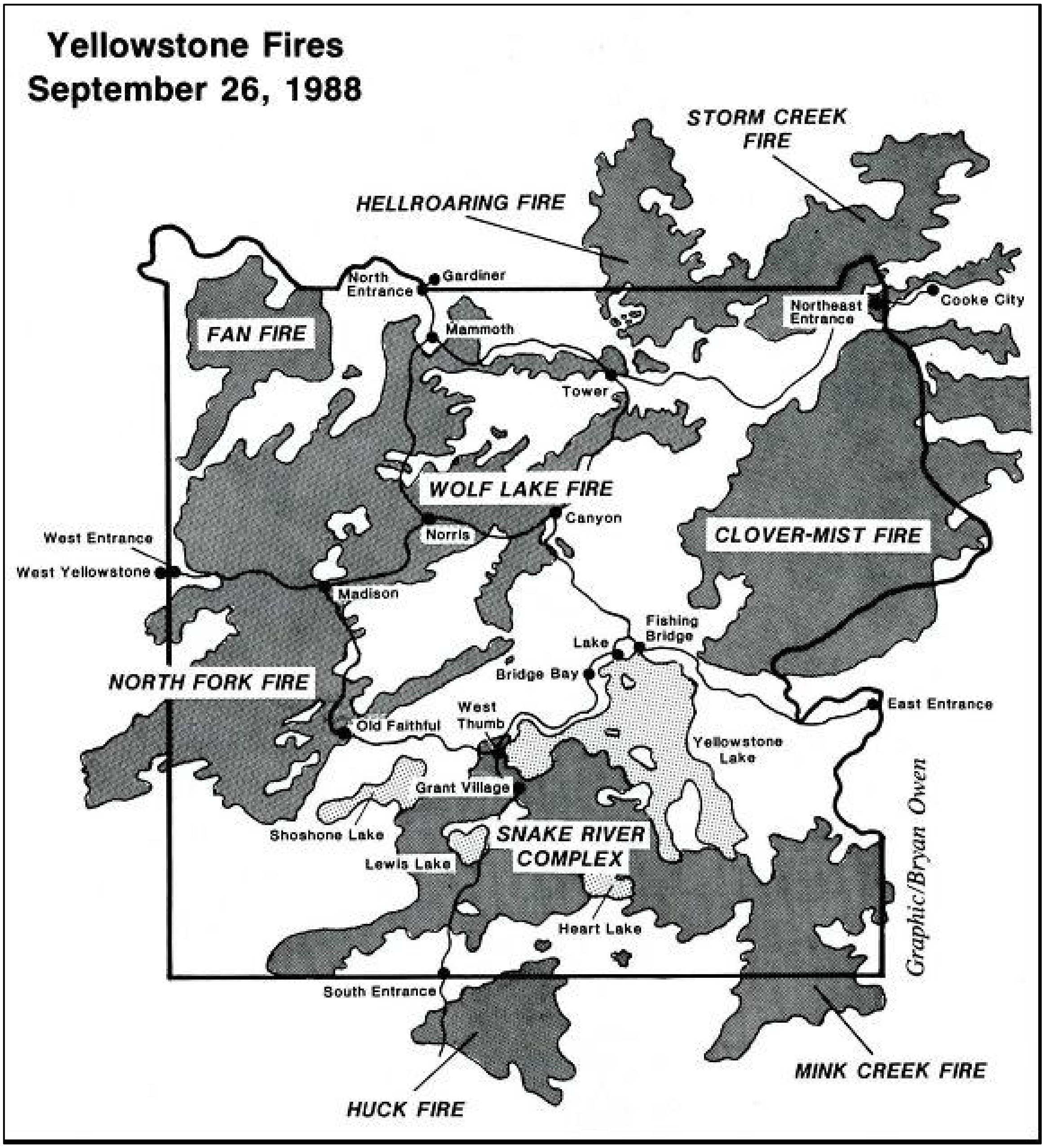
Several popular-style or non-technical books exist and numerous journal articles have been published (Despain and others 1994; IAWF 1995). Unfortunately, one single, comprehensive case study or history document that focuses on lessons learned from this landmark event and its associated experiences does not currently exist.

V Chronicling the 1988 Fires and Fire Season in Yellowstone and Beyond

Bushey (1989) has compiled a comprehensive summary of the 1988 Yellowstone National Park area fire events, including weather, fire occurrence, and fire behavior growth. This compilation includes a daily log from May 27 to September 30. A concise timeline of the events as they unfolded in Yellowstone National Park is given in USDI National Park Service (2008).

In turn, Davis and Mutch (1989) have provided a chronological overview that focuses on these 1988 fires. Their synthesis is based on the reports prepared by the joint Interagency Task Force (1988) comprised of U.S. Forest Service and National Park Service personnel.

Additionally, Rothermel and others (1994) have documented the daily growth of the 1988 fires in the GYA—available in both printed map and electronic forms. Rothermel (1991c) has also provided an account of the experiences of the team that was assembled to provide long-range projections of fire growth (Rothermel 1998) in the GYA in 1988, in relation to the actual fire chronology.



Final gross area associated with the major fires in the Greater Yellowstone Area toward the end of the 1988 fire season (from Davis and Mutch 1989).

VI Describing the Fire Environment

Prior to the 1988 Greater Yellowstone Fires, Despain (1990) had studied in detail the fuel characteristics and related fire behavior potential for the major cover types found in Yellowstone National Park. Despain focused on the various successional stages associated with the stand development of lodgepole pine, the major tree species found in the park.

In addition, Hartford and Rothermel (1991) documented the dead and live fuel moistures, during a 48-hour period on the North Fork Fire in late August, 1988.

Bushey (1989) included considerable detail on the weather conditions in his report on the 1988 fire season. Goens (1990) complimented this work with his detailed case study of the weather conditions associated with the Canyon Creek Fire that burned some 188,071 acres (76,120 hectares) of the Lolo National Forest in western Montana, with special emphasis on the factors contributing to the major fire run on September 6 and 7, 1988.

North Fork Fire, Yellowstone National Park, Wyoming
Old Faithful Inn Fire Run
1540 h MDT - September 7, 1988

Fire Weather Observations

Dry-bulb Temperature - 67 °F (19.6 °C) — **Relative Humidity - 24%**
33-ft (10-m) Open Wind Speed - 15 mph (24 km/h) — **Days Since Rain - 25**

Canadian Forest Fire Weather Index (FWI) System Components

Fine Fuel Moisture Code (FFMC) - 93.9 — **Initial Spread Index (ISI) - 25**
Duff Moisture Code (DMC) - 183 — **Buildup Index (BUI) - 232**
Drought Code (DC) - 787 — **Fire Weather Index FWI) – 70**

Canadian Forest Fire Behavior Prediction (FBP) System Outputs*

Head Fire Rate of Spread - 114 ch/hr (39 m/min)
Head Fire Intensity - 19,450 Btu/sec-ft (69,275 kW/m)
Flank Fire Intensity - 2,950 Btu/sec-ft (10,197 kW/m)

Predicted Type of Fire & Crown Fraction Burn (CFB):
Continuous Crowning at Head & CFB - 1.0
Intermittent Crowning along Flanks & CFB - 0.5

*Based on FBP System Fuel Type C-3 (Mature Jack or Lodgepole Pine, 0% Slope, and 120% Foliar Moisture Content.

Burning conditions and fire potential associated with the 1988 Old Faithful Fire run expressed in terms of the two major subsystems of the Canadian Forest Fire Danger Rating System or CFFDRS (adapted from Pearce and Alexander 1994 and Alexander 1995). This information is frequently used by the author in national wildland fire behavior training in Canada. By way of comparison, the maximum or peak head fire intensity during the major run of the 1967 Sundance Fire in northern Idaho was estimated to have reached 22,500 Btu/sec-ft (77,830 kW/m) (Anderson 1968). For more information on the CFFDRS, refer to Taylor and Alexander (2006).

Smoke and convection column or plume associated with the major, wind-driven crown fire run of the Canyon Creek Fire that occurred on the Lolo National Forest in western Montana on September 6-7, 1988. Photo: Jim Dolan, U.S Forest Service, Northern Region, Missoula, Mont., 1988.

VII Analyzing the Fire Behavior

Fire behavior analysts Beighley and Bishop (1990) and Campbell (1998) have described the difficulties and their solutions to predicting fire behavior on the 38,507-acre Fayette Fire that occurred in the high country of the Bridger-Teton National Forest which adjoins Yellowstone National Park.

Detailed documentation reports were prepared by Bushey (1990, 1991) on the 32,400-acre (13,115 hectares) Red Bench Fire that burned portions of the Flathead National Forest and Glacier National Park in northwestern Montana and on the Canyon Creek Fire. Stiger (1989) provided a detailed chronology of the Gates Park prescribed fire that covered 51,840 acres (20,980 hectares) inside the Bob Marshall Wilderness area in the Lewis and Clark National Forest in western Montana.

Thomas (1991) completed a case study of the crown fire run by the North Fork Fire that threatened the Old Faithful geyser complex in Yellowstone National Park on the afternoon of September 7, 1988. On this day, the North Fork Fire—which eventually grew to 504,000 acres (203,990 hectares)—burned more than

56,000 acres (22,665 hectares). Largely due to the “safety zone” created by the large, open spaces in and around the Old Faithful Inn and geyser area, this event was able to receive much media publicity and television coverage (Barker 2008).

Despain and others (1996) undertook a novel study of fire behavior on the fires that occurred in Yellowstone National Park in 1988. From their analysis of the extensive video footage taken of the crown fire activity, they found that the duration of flaming combustion in lodgepole pine tree crowns averaged 25 ± 10 seconds and varied from 5 to 48 seconds.

Other analyses undertaken include the role of historic mountain pine beetle activity on the spatial growth of fires in Yellowstone National Park in 1988 (Lynch and others 2006) and the role of fuel moisture and fuel type on the ignition and behavior of lightning-ignited fires (Renkin and Despain 1992) during the first 17 years (1972-1988) the park had operated a prescribed natural fire program (Despain and Sellers 1977).

A number of studies focusing on fuels management in relation to fire behavior and fire impacts also emerged (e.g., Brown 1989; Schullery and Despain 1989; Omi and Kalabokidis 1991; Omi 1996).

Crowning forest fire in mature lodgepole pine approaches the Old Faithful complex in Yellowstone National Park on September 7, 1988. Photo: National Park Service, courtesy of Yellowstone Digital Slide File, 1988.

Fire behavior analysts Dick Rothermel (r) and Jim Saveland in the fire behavior service center at the Greater Yellowstone Area Command during the 1988 fire season. Photo: Robert W. Mutch, U.S. Forest Service, Washington, DC, 1988.

The fires of 1988 in Yellowstone and beyond highlighted a long-standing need for a guide to predicting crown fire behavior in the western U.S. (USDA Forest Service 1980; Steen 2007; Wells 2008).

In this regard, Rothermel (1991a), relying on the current state-of-knowledge and available data, developed methods for predicting "first-order approximations of crown fire behavior"—namely, the rate of spread, intensity, and flame length of crown fires as well as the shape and size of the corresponding burned area.

Rothermel also devised a means of differentiating wind-driven crown fires from plume-dominated or convection-driven crown fires, which he considered less predictable from the standpoint of spread rate and direction of spread. (Rothermel 1991b, 1995).

VIII New Knowledge Gained and Lessons Learned

Operationally, many advances were made in fire behavior forecasting as a result of the experiences gained during the 1988 fires in Yellowstone and beyond. These advances include the value of fire behavior service centers (Bushey and Mutch 1991) and procedures for making long-range duration fire growth projections (Rothermel 1998, 2000).

Scientifically, the 1988 fires and fire season inspired new fire behavior research and development activity in such areas as fire dynamics and fuel moisture (e.g., Williams and Rothermel 1992; Latham and Rothermel 1993; Rothermel 1994; Parkhurst and others 1995).

The North Fork Fire threatens the Old Faithful complex at Yellowstone National Park on September 7, 1988. Photo: Jeff Henry, National Park Service, courtesy of Yellowstone Digital Slide File, 1988.

IX Concluding Thoughts

There is little doubt that we are continuing to learn—and relearn—from case histories or studies (Thomas 1994; Alexander and Thomas 2003a). The 1988 fires of Yellowstone and beyond are certainly no exception.

However, as the philosopher George Santayana has stated, “Those who cannot remember the past are condemned to repeat it.” Furthermore, as Weick and Sutcliffe (2001) have pointed out, "If timely, candid information generated by knowledgeable people is available and disseminated, an informed culture becomes a learning culture.”

To this end, in what will likely become a seminal publication in the field of fire behavior prediction, Dick Rothermel’s (2000) article “The Great Western Wildfires: Predicting the Future by Looking at the Past” is reproduced here (see X Epilogue chapter) as a fitting conclusion to this report.

Wildland Fire Behavior and an Organizational Learning Opportunity

We missed and continue to miss a wonderful learning opportunity with the 1988 fires in Yellowstone and beyond.

Think about it, a fire that came close to burning down the “Sistine Chapel” of the National Park Service—the Old Faithful Inn—was never reviewed in detail to see whether we just lucked out—or made good decisions based on good fire behavior forecasts. Doesn’t this display an alarming characteristic? Is that characteristic still in place now?

I’m continually surprised that 20 years later, we’re still speculating from a fire behavior standpoint on what happened that day on September 7, 1988. This says much about our propensity for organizational learning. Are we truly only willing to learn the hard way, from trial and error? Isn’t there a better way—such as case studies?

Dave Thomas
Private Consultant, Renoveling
Ogden, Utah
2009

(Dave Thomas served as the fire behavior analyst on the incident management team assigned to the North Fork Fire when the Old Faithful Inn was threatened on September 7, 1988.)

East Fork of the Bitterroot River near the town of Sula in western Montana on August 6, 2000. On this day, several fires burned together to form the 100,000-acre (40,475-hectare) Sula Complex. Photo: John C. McColgan, Bureau of Land Management, Alaska Fire Service, Fairbanks, Alaska, 2000.

X Epilogue

The Great Western Wildfires: Predicting the Future by Looking at the Past*

by Richard C. Rothermel

In the middle of August (2000), several large forest fires were burning out of control in Western Montana. This situation resulted from a light winter snow pack, a lack of spring rains, an early hot dry summer, and highly efficient, dry lightning storms.

Strong, gusty winds spread the fires and hampered fire control efforts. The problems were aggravated by a shortage of firefighting personnel and equipment, largely due to a high incidence of fires in other areas. Furthermore,

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*After Rothermel (2000)—this article was originally based on a briefing paper prepared in mid-August 2000 for incident command teams deployed in the Northern Rocky Mountain region. The author came out of retirement to undertake this task after a request was made by the Northern Rockies Coordination Center in Missoula, Mont. The subsequent article by Rothermel (2000) was published in *National Woodlands* magazine in the fall of 2000.

the presence of a large number of homes in the urban wildland interface where the fires were burning required special efforts to protect homes by diverting resources that might otherwise have been used to contain the fires.

As of this writing, severe burning conditions can be expected to continue through the middle of September and possibly beyond. What can these fires be expected to do?

It should be clear to everyone concerned that weather conditions and the availability of fuel largely control the behavior of fires. Because projections of actual fire growth depend on weather forecasts, and the weather beyond three to five days is highly uncertain, an examination of previous years' weather and the resulting fire behavior provides the best insight as to what might be expected for the balance of this season, and into the future.

Possible Fire Situations

The high-pressure dome situated over the western states—responsible for the hot, dry conditions—often breaks down over this region by the third or fourth week of August. For example, the fire seasons in 1962, 1968, and 1985 began with very severe conditions in early August.

This change is caused by the onset of a series of passing cold fronts. These fronts upset the hot, dry conditions and bring more unsettled weather conditions to the region. The fronts can be accompanied by rain, wind, and lightning in various combinations. Depending on the mix of these factors, the later part of the season is highly unpredictable.

This process has already begun this year (2000) with the cold front that passed through the region on August 10. This is not an indication of the end of the season. Many new fires were started and the high pressure with hot dry weather may return.

The situation in other years has been quite different. Rather than ending the fire season, the fronts brought winds that caused extremely large fire growth. In 1988, the weather fronts, which were producing strong winds through July and August, became more frequent in late August and early September.

These later fronts were responsible for extremely strong winds and very large fire growth. For example on September 6 and 7, the Canyon Creek fire, burning in west central Montana, grew by 117,000 acres (47,355 hectares) and had a final spread distance of 33 miles (53 kilometres). During these two days, it crossed the Continental Divide and burned to ranchland on the east side.

In Yellowstone Park, very large fire runs were also experienced on September 5 and 7 in 1988. The strongest winds were forecast for September 9 and 10.

Indeed, these winds came, but, fortunately, brought both rain and snow which effectively ended the fire season for that year.

The year 1910 produced the largest fires ever recorded in the U.S. Northern Rocky Mountain area. These huge fires—extending 30 to 50 miles (48 to 80 kilometres)—began in Northern Idaho. Driven by gale force winds, they swept to the east across the mountain ranges that separate Idaho and Montana. These winds—resulting from unprecedented low atmospheric pressure over the region—drove the fire for two days, August 20 and 21.

Another significant fire run occurred in northern Idaho on September 1, 1967 on the Sundance Fire, which ran for 16 miles (26 kilometres) across the panhandle from north of Sandpoint toward Bonners Ferry. It eventually grew to more than 50,000 acres (20,235 hectares). This fire was also driven by strong westerly winds.

Dick Rothermel standing near the remains of the Pack River Bridge, destroyed during the major run of the Sundance Fire in northern Idaho (from Anderson 1968). On one day, September 1, 1967, 90 percent of approximately 56,000 acres (22,665 hectares) burned. Photo: William H. Frandsen, U.S. Forest Service, Intermountain Forest and Range Experiment Station, Northern Forest Fire Laboratory, Missoula, Mont. 1967.

Aside from the strength and southerly wind direction on these fires, a commonality appears to be the large lengths of uncontrolled fire line when the winds hit. This was the case in all three of the aforementioned fires. Because the spread of large crown fires requires extensive areas of available fuel and initial fuel conditions to support the onset of crowning, this situation is not unexpected. In other words, the more area on fire with open fire line, the higher the chance that the fire will encounter fuel conditions favoring crown fire spread. This acknowledgement is important. It identifies initial conditions other than weather that appear to be conducive to large fire spread.

Another commonality—associated with weather—is that the strong winds driving these large fires consistently came from the west or southwest. This is a critical factor in projecting the possible growth of large fires at this time of year.

Characteristics of Large Fires

If a weather situation develops that is forecast to produce very strong and sustained winds, assuming a continuous range of continuous fuel, the resulting fires would have the following characteristics:

- Existing fires with uncontrolled lines would become very active and nearby fires would begin to merge. Widely-spaced fires could burn independently and each would produce a rapidly spreading front. The fires would be classed as wind-driven rather than plume-dominated. The direction of spread would be consistent with the wind direction, although some channeling by topography might occur.
- Long-range spotting would be expected to bridge the fire across barriers such as mountain ridges, roads, rivers, and irrigated farmland. The rate of spread would vary according to fuels, wind gusts, and topography—but can average as much as four mph (6.4 km/h). Fire intensity would be extreme and very large firewhirls could be expected to form on either side of the running fire. While these firewhirls could be hidden by dense smoke, the turbulence they produce sounds like a fast-moving railroad train. Firewhirls can carry large firebrands in their core. They are driven by the wind at the fire's edge faster than the fire front. As they move ahead of the active fire, they lose energy and fire-brands in the core drop to the surface, initiating spot fires.
- Firefighters can be fooled by spot fires ahead of the front and think that the front has passed, only to be hit minutes later by the full force of the fire. Every effort should be made to remove personnel stationed in areas in front of such a fire.
- When the winds subside, miles of active burning will exist. If the frontal winds are not accompanied by rain or snow, a very dangerous situation will be created. A new weather situation may develop with the wind blowing at a 90-degree angle to the previous wind, turning the flank into a new front. (This was forecast to occur on the Sundance fire, but never

materialized.) A more likely situation would be for locations along the line that have favorable fuel and topography to burn actively. Without strong winds, a number of plume-dominated fires would form, producing short but very intense fire runs.

Estimating Large Fire Growth

Fire behavior analysts familiar with specific fire and fuel situations may find the following information helpful in estimating the possible extent of large fire growth.

Without a specific forecast, accurate predictions cannot be made, but scenarios that examine "*what if*" situations can be developed to better prepare for such an eventuality. As this is done, it must be kept in mind that in the weeks that follow, the fire situation may change dramatically. Existing fires may be controlled or no longer pose a threat due to poor burning conditions. On the other hand, new fire starts can be expected and some may become large and thus pose a serious threat in completely new areas.

The following considerations and fire situations should be considered in estimating large fire growth:

1. Strong sustained winds of the time, scale, and magnitude of 1910, 1967, and 1988 may occur. If a specific forecast of wind speed direction and duration is not available, spread distances experienced in previous years may be used as a guide:

    - *Sundance Fire*: Total spread length 16 miles (26 kilometers). Spread during 12-hour period, approximately 11 miles (18 kilometers).

    - *Canyon Creek Fire*: Total spread length 33 miles (53 kilometers). Spread during 5.5 hour period, 21 miles (34 kilometers).

    - *1910 Fires*: Total spread length 30 to 50 miles (48 to 80 kilometers). Spread during two days of a fire run not known, but probably about the same.

2. The wind direction during the fire growth will vary but probably be westerly to south westerly.

3. Assume burning conditions preceding and during the run are favorable to active burning.

4. Existing fires not under control and large lengths of open fireline are highly favorable to large fire growth.

5. The fires may be assumed to have elliptical shape and initially large fires with broad fronts may be expected to spread farther than smaller fires.

6. Consider the existence of favorable fuel conditions ahead of the fire for initiating crowning and the extent of conifer forests ahead of the fire.

7. Topography will play a role in estimating the channeling of winds and the possible extent of fuels. High elevations may be barren of fuels. The usual expectation of weather conditions on northern exposures will not exist due to the drought, unless additional precipitation, in the form of snow or rain, is obtained.

XI Acknowledgments

Appreciation is extended to Mikel Robinson of the University of Montana for her always cheerful assistance and role in the planning and organization of *The '88 Fires: Yellowstone and Beyond Conference*.

I would also like to thank all of the people who participated in the fire behavior, weather, and fuels session of *The '88 Fires: Yellowstone and Beyond Conference*.

In particular, I wish to express my deepest appreciation to Dick Rothermel. At age 79, Dick's involvement in the conference was very much appreciated—evident by the standing ovation he received at the conclusion of his presentation. I'd also like to thank Dick for his permission to reproduce (X Epilogue chapter) his article published in the *National Woodlands* magazine in the fall of 2000.

The extraordinary editorial expertise of Paul Keller is hereby duly acknowledged.

Finally, I appreciate the time taken by Chuck Bushey, Don Despain, Bob Mutch, Dick Rothermel, and Dave Thomas to review a draft version of this report.

Martin E. Alexander
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XII References

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Crown fire approaching the parking lot at the Old Faithful complex in Yellowstone National Park on September 7, 1988. Photo: Jeff Henry, National Park Service, courtesy of Yellowstone Digital Slide File, 1988.