Wildland Fire Behavior Case Studies and Analyses: Other Examples, Methods, Reporting Standards, and Some Practical Advice

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Case studies done in one country can be applied to another, if fuel type characteristics are relevant, by interpreting burning conditions through the other country's fire danger rating system.

This special issue of *Fire Management Today* constitutes the second installment of articles involving fire behavior case studies and analyses of wildland fires. All articles in this series appeared in past issues of *Fire Management Today* or its predecessors. The 18 articles in this issue are in chronological order, from 1967 to 2001.

In the lead article to the first installment (*Fire Management Today*, volume 63(3) [Summer 2003]), we overviewed the value, approaches, and practical uses of fire behavior case studies and analyses (Alexander and Thomas 2003). Here we point out examples of case studies published elsewhere (both nationally and internationally) and offer some general thoughts on wildland fire behavior observation and documentation.

Other Examples of Case Studies

Fire Management Today and its predecessors have certainly not been the only source or outlet for case studies. In the last issue of the journal, we cited some examples of other sources (Alexander and Thomas 2003). Others are cited below.

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USDA Forest Service fire researchers, in collaboration with other investigators, have published a number of case studies in the form of journal articles, conference papers, and in-house station publications. Notable examples include studies on the:

- 1965 Hellgate Fire, western Virginia (Taylor and Williams 1968);
- 1966 Gaston Fire, central South Carolina (DeCoste and others 1968);
- 1966 Loop Fire, southern California (Countryman and others 1968);
- 1967 Sundance Fire, northern Idaho (Anderson 1968);
- 1968 Canyon Fire, southern California (Countryman and others 1969);
- 1971 Little Sioux Fire, northeastern Minnesota (Sando and Haines 1972);
- 1971 Air Force Bomb Range Fire, eastern North Carolina (Wade and Ward 1973);
- 1980 Mack Lake Fire, northern Lower Michigan (Simard and others 1983);
- 1990 Dude Fire, northern Arizona (Goens and Andrews 1998); and the
- 1994 South Canyon Fire, west-central Colorado (Butler and others 1998).*

In the 1990s, the National Fire Protection Association (NFPA) produced several case studies, in very glossy formats, on the following wildfires:

- 1989 Black Tiger Fire, central Colorado (NFPA 1990);
- 1990 Stephan Bridge Road Fire, northern Lower Michigan (NFPA 1991);
- 1991 Spokane area fires, northeastern Washington (NFPA 1992a); and
- 1991 Oakland–Berkeley Hills Fire, west-central California (NFPA 1992b).

A few of these U.S. case studies are available on the World Wide Web or in hard copy for a nominal fee through the National Fire Equipment System (NFES 2003).

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* For an overview of this excellent publication, see the very fine summary prepared by Butler and others (2001) on page 77 in this issue of *Fire Management Today*.

The challenge of writing a case study report is to distill the mass of information into a coherent summary.

Canadian Forest Service fire researchers have also formally prepared several case studies over the years on the following wildfires:

- 1964 Gwatkin Lake Fire, eastern Ontario (Van Wagner 1965);
- 1968 Lesser Slave Fire, central Alberta (Kiil and Grigel 1969);
- 1971 Thackeray and Whistle Lake Fires, northeastern Ontario (Walker and Stocks 1972);
- 1980 DND-4-80 Fire, east-central Alberta (Alexander and others 1983);
- 1986 Terrace Bay 7/86 Fire, north-central Ontario (Stocks 1988); and
- 2001 Duffield Fire, central Alberta (Mottus 2002).

Australasian fire researchers have also made numerous contributions, including studies on the following wildfires:

- 1955 Balmoral Fire, South Island of New Zealand (Prior 1958);
- 1958 Wandilo Fire, South Australia (McArthur and others 1966);
- 1977 Western District fires, Victoria (McArthur and others 1982);
- 1979 Caroline Fire, South Australia (Geddes and Pfeiffer 1981);
- 1983 Ash Wednesday fires, South Australia (Keeves and Douglas 1983);
- 1991 Tikokino Fire, North Island of New Zealand (Rassmusen and Fogarty 1997);
- 1994 Karori fires, North Island of New Zealand (Fogarty 1996);
- 1995 Berringa Fire, west-central Victoria (Tolhurst and Chatto 1998);
- 2002 Atawhai Fire, South Island of New Zealand (Peace and Anderson 2002); and
- 2003 Miners Road Fire, South Island of New Zealand (Anderson 2003).

The Australians have also published several case studies analyzing the effectiveness of fuel reduction burning on subsequent fire behavior and on fire suppression of high-intensity wildfires (e.g., Buckley 1992; Underwood and others 1985).

Case studies have been undertaken by fire researchers in other countries as well (Cruz and Viegas 1997; Dentoni and others 2001). It is worth noting that one can extend the usefulness of wildland fire case studies done in one country to another, provided that the fuel type characteristics are relevant, simply by interpreting the burning conditions through the use of the other country's fire danger rating system (e.g., Alexander 1991, 1992, 2000; Alexander and Pearce 1992a, 1993).

Field Observations and Records

Whereas no recipe or step-by-step procedural manual on wildland fire observations presently exists, a good number of general references are available (Alexander and Pearce 1992b; Burrows 1984; Cheney and Sullivan 1997; Chester and Adams 1963; Rothermel and Rinehart 1983; Turner and others 1961). Moreover, the various case studies already published offer guidance themselves.

Wildland fire observation and documentation can be broken into four distinct stages or phases:

1. Detection,
2. Initial attack,
3. Later stages of suppression, and
4. After containment.

Some of the information on the early phases of a wildland fire is normally recorded as part of the operational procedures related to completing the individual fire report, although additional data might be requested (e.g., Haines and others 1985). However, if we are to acquire high-quality data (Donoghue 1982), then we need to emphasize the importance of fire behavior observation/documentation for our initial-attack firefighters so that we get their "buy-in."

Although myriad things might be recorded between the time of initial attack and the time when a fire is finally deemed "out," the most important thing to record is the position of the head fire at various times—the more observations, the better. From these observations, the rates of fire spread and intensity can be calculated. At times, these observations are difficult to make, for a variety of reasons, such as limited visibility and logistical issues (see the sidebar on page 6). When they can be made, they must be coupled with observations or measurements of wind velocity.

Although advances in photography, remote sensing and weather monitoring technology over the years have greatly facilitated matters (Anderson 2001; Dibble 1960; Lawson 1975; Ogilvie and others 1995; Schaefer 1959, 1961; Warren and Vance 1981), good representative or site-specific wind readings, for example, are still difficult to obtain. In this regard, one should not discount the relative value of

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field observers using the Beaufort Wind Scale (Jemison 1934; List 1951) as a simple means of acquiring estimates of windspeed.

Several forms exist for eventually developing a wildland fire case study (e.g., Rothermel and Rinehart 1983; Rothermel and Hartford 1992). However, forms can sometimes deter data gathering; an observer might cringe at the thought of completing yet another form. Remember, the most important information to gather is the time/location of the head fire and the corresponding windspeed.

The old adage is true: A picture is worth a thousand words. In case studies, however, it is worth more to record the time and location. One should consider obtaining vertical aerial photography of the fire area relatively soon after the fire's occurrence, especially in forested areas. This is often a very useful tool in carrying out a case study investigation.

Report Preparation and Documentation

Case study reports on wildland fire behavior vary tremendously in length and complexity. They range from short, very simple descriptions (e.g., USDA Forest Service 1960) to very large and extremely detailed, comprehensive accounts (e.g., Graham 2003a, 2003b). One should not be intimidated by the sheer size and level of detail in some case study reports; their bulk should not discourage you from preparing some type of report, no matter how short.

The size of a report is often driven by fire size and duration. A brief account might suffice for a specific issue (e.g., Countryman 1969) or for a particular situation or event during an incident (e.g., Pirkso and others 1965; Sutton 1984). For a long incident, a more voluminous publication might be more appropriate, with numerous appendixes to document the fire (e.g., Bushey 1991). Regardless of size, all reports have some things in common, such as descriptions of the components of the fire environment, although the level of detail might vary.

Distractions From Making Fire Behavior Observations

Brown and Davis (1973) identify some of the distractions on a fire that can keep one from preparing good wildland fire behavior case studies.

A common deficiency of most analyses of large fires is that the detail and sequence of what men did in their efforts to bring the fire under control overshadow what the fire did. This is a natural outcome. Usually all participants are so fully engaged in other emergency duties that no one is available to make objective and continuing firsthand observations of the fire itself. So the fire's overall behavior, and particularly the time and sequence of significant changes in its behavior, are uncertain and are likely to be poorly reconstructed from circumstantial evidence. This seriously limits the validity of conclusions drawn as to the adequacy or inadequacy of the efforts made to control it.

The case study can usually correct this difficulty. Ideally, it is planned in advance and carried out by a trained research team who moves in as soon as it is apparent that a blowup fire is in progress. By means of observation and measurements, such a team develops a detailed time history of the fire. Usually this is the form a detailed log of events and a carefully drawn map showing the spread of the fire at various time intervals. In addition to such information, detailed weather measurements are sought …

As better understanding and prediction of large-fire behavior develops, analysis of action on large fires and the more comprehensive case studies as well will become more meaningful and consequently more valuable in training men and in planning fire suppression strategy.

If one isn't careful, the plethora of information can stymie even the most dedicated case study author.

After compiling all the information required to produce a case study report, one must write it up. The challenge is to distill the mass of information into a coherent summary. To assist in this process, we suggest a certain format (see the sidebar below). The case study by Pearce and others (1994) is a good example of a very concise report based on this format.

Other sections could be added to the format, such as fire effects on people (both firefighters and the public), homes, and ecosystems. The suppression strategy and tactics could also be addressed, including any associated human factors.

However, as Thomas (1994) points out, not all of us are writers. Some might wish to follow a one- or two-page format (e.g., McAlpine and others 1990 [figure 2]). Ideally, it should include a photograph or two and additional weather products (surface and upper air charts and profiles of temperature/moisture and winds aloft).

Some General Advice and Lessons Learned

We offer the following practical advice in preparing wildland fire behavior case studies. Our thoughts and comments are based on actual lessons learned from preparing case studies (e.g., Carpenter and others 2002; Pearce and others 1994).

Suggested Outline for Preparing a Wildland Fire Behavior Case Study Report

These guidelines are based in part on those originally prepared by M.E. Alexander for use in three advanced fire behavior courses sponsored by the National Rural Fire Authority in New Zealand in 1992–93. The guidelines were subsequently used in six wildland fire behavior specialist courses sponsored by the Canadian Interagency Forest Fire Centre in Hinton, Alberta, in 1996–2001.

1. **Introduction:** Significance of the fire, including regional map with fire location.
2. **Fire Chronology and Development:** Cause; time of origin and/or detection; initial attack action; forward spread and perimeter growth; fire characteristics, such as spotting distances and crowning activity; suppression strategy and tactics employed; mopup difficulty; fire progress map showing point of origin; final area burned and perimeter; ground and aerial photos, where possible.
3. **Details of the Fire Environment:**
   - **Topography**—Review major features; include topographic map and photos, if pertinent.
   - **Fuels**—Describe the principal fuel type(s); include a vegetation cover type map and any photos, if possible.*
   - **Fire Weather**—Describe prefire weather as appropriate; summarize synoptic weather features and include surface map; present daily fire weather observations; present fire danger ratings, including drought indexes, and append monthly fire weather record form; present hourly weather observations, if relevant; denote location of weather station(s) on regional map or fire progress map and comment on the relevance of the readings to the fire area, including notes about the station's instrumentation.**
4. **Analysis of Fire Behavior:** For example, discuss the fire's behavior in relation to the characteristics of the fire environment and the success/failure of the suppression operations.
5. **Concluding Remarks:** For example, what did you learn about predicting fire behavior and fire behavior documentation from this assignment?

*Detailed work on fuel characteristics (e.g., amounts by fuel complex strata, moisture content of live fuels) will depend on the situation and the specific need. Generalizations are often satisfactory for most purposes.

**It is a good idea to cultivate a long-term relationship with your local fire weather meteorologist/forecaster and seek their assistance as a cooperator.

Form your own view of what happened only after interviewing many firefighters and getting multiple perspectives.

Motivation. It is often very difficult to find the motivation to write a case study. On all wildland fires, other demands and the rapidity of events can be discouraging. Moreover, no policy or regulation requires a case study. It must come from your own motivation and sense of professionalism. ***Lesson Learned:*** As a practitioner, make it a habit to always prepare at least a one- to two-page case study. You will be richly rewarded, for it will force you to reflect on why a fire behaved the way it, honing your skills as a predictor of fire behavior (see the sidebar).

Your Standard Is Too High. There is a human tendency to establish goals that are nearly impossible to reach. ***Lesson Learned:*** Limit the length and depth of the report to the time available. Don't think you have to write a research report that meets the quality standards of a fire laboratory publication. A simple, short case study, told from your individual perspective, is better than no case study at all.

Organization. Just as we must practice our fire behavior prediction skills before going on a wildfire, so it is also important to mentally prepare ourselves for writing a case study. ***Lesson Learned:*** Get organized before the fire season begins. Prethink how you are going to prepare your case studies. Ask yourself what generic fire behavior information you are going to need (such as fire danger ratings, remote automatic weather station data, or fuel moisture readings), and prepare yourself to quickly access the information. Useful Webpages include the Western Regional Climate Center (http://www.wrcc.dri.edu) and the U.S. Drought Monitor (http://www.drought.unl.edu). Become familiar with such sources before the fire occurs. Finally, be systematic in your collection of data. An indexed, three-ring notebook constructed around the themes of observed fire behavior, such as fuels, topography, and weather, will help you organize pertinent information for easy retrieval.

Information Overload. The amount of information available about the fire environment can be overwhelming. If one isn't careful, the plethora of information can stymie even the most dedicated case study author. ***Lesson Learned:*** Don't try to use or validate every fire danger, fire weather, or fire behavior model available. Decide which model you want to use for your case study and stick to it. For example, ask yourself whether the BEHAVE fire behavior prediction system would meet your need as opposed to FARSITE. Think about the amount of time you have available to run various models. Pick the

Why Write a Case Study?

Luke and McArthur (1978) give a good rationale for writing wildland fire behavior case studies, even on small incidents:

Inquiries should be made into all fires as soon as possible after they have been controlled. Even short descriptions of very small fires have a value.* Recording the details of large fires is vital because success in the future depends largely on knowledge gained in the past.

A map showing the perimeter of a fire at progressive time intervals provides the best basis for a case history analysis. This should be accompanied by descriptions of fire behavior related to weather, fuel and topography, and details of the manning arrangements, strategy and tactics employed during each suppression phase. Particular attention should be given to initial attack action.…

At the conclusion of the analysis it should be possible to prepare a précis of the reasons for success or failure, not for the purpose of taking people to task for errors of judgment, but solely to ensure that the lessons that have been learnt contribute to the success of future suppression operations.

*It is true that we do naturally tend to focus solely on just the conflagration type wildland fires.

If every fire manager and fire researcher made it a personal goal to produce one case study per year, just think how many case studies could be produced in a 20- to 35-year career!

model that meets the time available.

Sources of Information. Secondary sources of fire behavior information are often as important as primary sources. In a way, the preparation of a fire behavior case study is like detective work: You are always on the hunt for clues explaining why your fire behaved the way it did. ***Lesson Learned:*** Don't depend solely on the standard sources of fire behavior information, such as models, Websites, and fire weather forecasts. For example, photographs or video taken by newspaper or television* and amateur photographers can be rich sources of fire behavior data. Even articles in general magazines can offer different perspectives on your case study.

Interviewing. Interviews with firefighters are a common source of fire behavior information. But be careful, for recollections are prone to hindsight bias. Recollections of fire events are often flawed, and they always reflect only a single point of view. ***Lesson Learned:*** When interviewing firefighters, be aware of hindsight bias. Always compare one person's memory of the fire with another's. Be skeptical. Seek information that disproves strongly held cause–effect relationships. Form your own view of what happened only after interviewing many firefighters and getting multiple perspectives.

Fire Behavior Model Versus Reality. It is understandable when fire behavior specialists or analysts lament the fact that a fire behavior model did not predict what actually happened. But such discrepancies are simply part of making fire behavior predictions, and they will never fully disappear. One of the most interesting purposes of a fire behavior case study is to compare the projection against reality. ***Lesson Learned:*** In every case study, compare the fire behavior projection or prediction to what actually happened. Then discuss why the fire did or did not behave as predicted. In so doing, you will be honing your fire behavior prediction skills.

Peer Review. A case study, in the end, is the official fire behavior record. Your reputation is on the line. ***Lesson Learned:*** Time permitting, get peer review. Simply ask your colleagues what they think of your case study. It will ease your anxiety and improve your final product. But be prepared for contrary opinions, and don't be intimidated when others think differently. Always remember that fire behavior is complex and not easily captured in a report. You are doing the best you can.

Case Study Publication. You've prepared a case study. Now how are you going to distribute your report so that it will be useful to the fire community? ***Lesson Learned:*** A logical location for case studies are the Websites of local or national fire management agencies, such as the National Interagency Fire Center or the geographic coordination centers. Another possible location is the Lesson's Learned Center at the National Advanced Research Technology Center in Marana, AZ ((http://www.wildfirelessons.net/). But be careful about including color digital photographs with your report. Although photographs are truly worth a thousand words, they can bog down e-mail systems and limit the distribution of your report, although some of these obstacles can be overcome (Christenson 2003).

Just Do It. If fire behavior case studies are to become routine—our hope for more than a decade—then you must make a personal commitment to prepare them. ***Lesson Learned:***

A fire behavior model cannot make a commitment; only an individual can. We hope that nothing will hold you back. When it comes to fire behavior case studies, we hope that you will, as the saying goes, "Just do it!"

More Case Studies Needed!

In 1976, Craig Chandler, then Director of the Forest Service's Division of Forest Fire and Atmospheric Sciences Research, pointed out that many wildland fire behavior case studies were produced by fire researchers and fire weather meteorologists during the 1950s and 1960s, but that he had not seen many lately, presumably due to "higher priorities elsewhere" (Chandler 1976). He suggested that "we reexamine our priorities." Alexander (2002) has proposed establishing permanent, full-time national operational fire behavior research units. But there is also the opportunity to help oneself directly.

* Inquire as soon as possible (within at least 24 hours) about the availability of videotape footage, because the complete record is typically not archived.

Chandler's comment is still valid for everyone involved in wildland fire, not just scientists and forecasters.

We should be observing/documenting wildland fires and preparing case studies not for fear of litigation (Underwood 1993), but rather to improve our understanding of fire behavior for the safe and effective management of wildland fires (Countryman 1972). If every fire manager and fire researcher made it a personal goal to produce one case study per year, regardless of size, just think how many case studies could be produced in a 20- to 35-year career! As it stands now, less than one-tenth of 1 percent of all wildland fires are properly analyzed and documented. We must do better.

Acknowledgments

The authors offer their sincerest heartfelt appreciation to Hutch Brown, Madelyn Dillon, and Carol LoSapio, editors of *Fire Management Today*, for their significant contributions to this special issue, and to April Baily, the journal's general manager, for supporting the concept of these special issues on wildland fire behavior. Their dedication and outstanding editorial abilities have brought "life" to many of the articles contained in this issue that have long been forgotten.

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Fire Management today

Volume 63 • No. 4 • Fall 2003

Wildland Fire Behavior Case Studies and Analyses: Part 2

United States Department of Agriculture
Forest Service

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On the Cover:

Smoke is drawn into the center of a 3,200-acre (1,300-ha) prescribed burn unit on the Lower Klamath National Wildlife Refuge in California. The growing need for fire use nationwide makes it more important than ever for land managers to fully understand fire behavior. The photo was a winner in Fire Management Today's photo contest for 2003 (see page 85 for more on the contest). Photo: Troy Portnoff, U.S. Fish and Wildlife Service, Tulelake, CA, 2002.

The FIRE 21 symbol (shown below and on the cover) stands for the safe and effective use of wildland fire, now and throughout the 21st century. Its shape represents the fire triangle (oxygen, heat, and fuel). The three outer red triangles represent the basic functions of wildland fire organizations (planning, operations, and aviation management), and the three critical aspects of wildland fire management (prevention, suppression, and prescription). The black interior represents land affected by fire; the emerging green points symbolize the growth, restoration, and sustainability associated with fire-adapted ecosystems. The flame represents fire itself as an ever-present force in nature. For more information on FIRE 21 and the science, research, and innovative thinking behind it, contact Mike Apicello, National Interagency Fire Center, 208-387-5460.

FIRE 21

Firefighter and public safety is our first priority.

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