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Abstract

You are about to be entrapped or burned over by a wildfire: What are your survival options?

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The danger of being entrapped or burned over and possibly killed or seriously injured by a wildfire is very real threat for people living, working or visiting rural areas subject to wildfires. Sometimes there may be no chance to easily escape an approaching wildfire. Injuries can be minimized or avoided and possible death averted by adhering to certain fundamental principles and procedures. There are, however, four simple concepts that one must try to adhere to at all times:

- Select an area that would not burn – the bigger the better – or failing that, with the least amount of combustible material, and one that offers the best microclimate (e.g., depression in the ground).
- Use every means possible to protect yourself from radiant and convective heat emitted by the flames (e.g., boulders, rock outcrops, large downed logs, trees, snags, etc.).
- Protect your airways from heat at all costs and try to minimize smoke exposure.
- Try to remain as calm as possible.

There are four fundamental or basic survival techniques or options available to an individual who is caught out in the “open” and is likely to be entrapped or burned over by a wildfire and is not able to take refuge in a vehicle or building

(or in the case of wildland firefighters in the U.S., have a protective fire shelter). The four survival options are:

- Retreat from the fire and reach a safe haven.
- Burn out a safety area.
- Hunker in place.
- Pass through the fire edge into the burned-out area.

These four survival options are presented in no particular order of priority. Such factors as the size of the fire, the fire environment, the size and location of safety areas or zones, the prevailing fire behavior, and the location of the person with respect to the head of fire will ultimately dictate which option or options (should the first of one of these options selected become compromised) should be selected. This state-of-the-art review, based on a soon to be published book chapter (Alexander et al., 2007), utilizes case study examples of fatalities and near-miss incidents from around the globe to illustrate the advantages and disadvantages of each of these survival options.

Reference

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1. Introduction

The danger of being entrapped or burned over and possibly killed or seriously injured by a wildfire is very real threat for people living, working or visiting (USDA Forest Service 2002) rural areas subject to wildfires. Sometimes there may be no chance to easily escape an approaching wildfire. Injuries can be minimized or avoided and possible death averted by adhering to certain fundamental principles and procedures. There are, however, three simple concepts that one must try to adhere to at all times (Ashcroft, 1983; Cheney, 1973; Webster, 1989; Putnam 1996). These are:

- Select an area that won't burn – the bigger the better -- or failing that, with the least amount of combustible material, and one that offers the best microclimate (e.g., depression in the ground);
- Use every means possible to protect yourself from radiant and convective heat emitted by the flames (e.g., boulders, rock outcrops, large downed logs, trees, snags, etc.);
- Protect your airways from heat at all costs and try to minimize smoke exposure; and
- Try to remain as calm as possible.

The first requirement will limit the flame dimensions and in turn the potential heat energy from flame radiation (Sullivan *et al.*, 2003). It will also limit the time of exposure, an important factor in thermal injuries. Radiant heat can kill you long before direct flame contact (Webster, 1989; Country Fire Authority, 2005). The more the exposed skin, the greater the likelihood of death.

Obviously, the last requirement – to remain as calm as possible – may seem difficult to establish and maintain. The expectation that people will panic (i.e., a sudden uncontrollable fear or alarm leading to unthinking behavior) during an emergency situation such as wildfire entrapment or burnover is very strong. Admittedly with the benefit of 20:20 hindsight it is easy to point to some decisions that were not optimal and played a negative role in the outcome of the fire (Omodei *et al.*, 2005). Urban fire researchers feel that the majority of people faced with a fire situation react in a rational manner considering the ambiguity of the initial cues about the fire, their limited knowledge about fire development and fire dynamics, and the restricted time to make a decision and to take action (SFPE Task Group on Human Behavior, 2003).

Panic is viewed as being synonymous with a frightened, scared, nervous or anxious response (SFPE Task Group on Human Behavior, 2003). In actual fact, panic in the form of irrational or crazed behavior (e.g., aimlessly trying to flee) is rare during fires. Social

scientists long go rejected this concept to explain human behavior in urban fires (Clark, 2002 ; Proulx, 2002; SFPE Task Group on Human Behavior, 2003) Instead of panic, what is commonly observed is an increased level of stress. Stress is not panic. As Dr. Guylene Proulx (2002), a human factors specialist with the National Research Council Canada's structural fire research program, suggests that:

This stress is not an abnormal reaction or a negative response; on the contrary, stress is regarded as a necessary state to motivate reaction and action ... Decision-making under stress is often characterized by a narrowing of attention and focusing on a reduced number of options. This explains why training is so important since the person is unlikely to develop new solutions under heightened stress; a well-run decision plan learned and practiced beforehand is easier to apply under stress.

There are four fundamental or basic survival techniques or options available to an individual who is caught out in the "open" and is likely to be entrapped or burned over by a wildfire and isn't able to take refuge in a vehicle or building (Foster, 1976; Luke and McArthur, 1978; Webster, 1989) or have a protective fire shelter (Anderson and Petrilli, 2003). The four survival options are (in no particular order):

- Retreat from the fire and reach a safe haven;
- Burn out a safety area;
- Hunker in place; and
- Pass through the fire edge into the burned-out area.

This purpose of this paper, which is largely based on a soon to be published book chapter (Alexander *et al.*, 2007), outlines these four basic survival options in some detail. The genesis for this material came about as a result of the author's involvement in the investigation of the firefighter fatality and injury associated with the DL-#-85 Fire near Wabasca, Alberta, on June 3, 1995, as documented in a case study in the CD-ROM based training course *Wildland Fire – Safety on the Fireline* (Thorburn *et al.*, 2000).

I want to emphasize that the four survival options outlined here are presented in no particular order of priority. Such factors as the size of the fire, the fire environment, the size and location of safety areas or zones, the prevailing fire behavior, and the location of the person with respect to the head of fire will ultimately dictate which option or options (should the first one of these options selected become compromised) should be selected. Each of these options has its own unique advantages and disadvantages.

It is worth emphasizing that wildland firefighters as well as members of the general public have been killed and seriously burned while engaged in using fire as a land management tool (Steiner, 1976; Millman, 1993; Viegas, 2004; Viegas and Viegas, 2005; Alexander and Thomas, 2006). Thus, the survival principles and options discussed above are equally applicable to prescribed fires or controlled burns.

2. Survival Options

2.1 Survival Option 1: Retreat from the Fire and Reach a Safe Haven

When people are under pressure they fall back on habitual, first-learned, and overlearned responses (Weick, 2002). The natural tendency when a person is threatened by a hazard such as a wildfire is to try and move away from the danger as quickly as possible to a place of safe refuge. If the distance between the fire and safe area is short, the fire's advance

slow, the path to the safe area easily traversed, and the person able-bodied, then selection of this a survival option is appropriate. Bear in mind that a safe refuge may be very near by, so one shouldn't avoid the most obvious place even though it may temporarily be uncomfortable to reach due to smoke or low to moderate radiation levels, for example. In some cases, this might mean just taking a few steps into the "black" or recently burned-over ground. The question of whether a previously burned area will serve as a safety zone will depend not only on the size of the area but on the degree of completeness or fuel consumption both, vertically and horizontally (Butler *et al.*, 1998; Pearce *et al.*, 2004). Furthermore, a recently burned-over area may not immediately serve as a safe refuge due to the burn-out time of woody fuels and duff (Sullivan *et al.*, 2002) in contrast to grassland fuels in which a person can enter the recently burned area in a matter of a few seconds (Cheney and Sullivan, 1997).

There are a good many cases where firefighters have escaped injury and death by being able to outpace or out maneuver a spreading fire (Thorburn *et al.*, 2000; Pearce *et al.*, 2004). There have also been many well publicized cases or incidents where attempting to initially out pace and then ultimately outrun an advancing flame front have ended in tragedy such as the 1938 Pepper Hill Fire in Pennsylvania (Schultz, 2001), the 1949 Mann Gulch Fire in Montana (Maclean, 1992; Rothermel, 1993), the 1953 Rattlesnake (Maclean, 2003), 1956 Inaja (USDA Forest Service, 1957; Schroeder and Taylor, 1968), 1966 Loop (Countryman *et al.*, 1968) and 1968 Canyon (Countryman *et al.*, 1969) fires in California, and the 1994 South Canyon Fire in Colorado (Butler *et al.*, 1998; Maclean, 1999). Sadly, there are many other examples (Retsios and Georges, 1999), one of the most recent being the 2003 Cramer fire in central Idaho involving two firefighter fatalities (Close, 2005, 2006). Dr. Ted Putnam (personal communication, 2006.), a retired wildland fire safety specialist with the USDA Forest Service, considers that many of the above noted fatality fires were in fact escapable had better decision making been employed -- e.g., dropped tools and packs earlier on to maximize rate of advance, put the fastest pace setters at the lead, and used fire shelters as shields against radiant and convective heat (Putnam 1995).

Similar incidents involving civilians have also taken place. For example, on November 30, 1957, four members of a group of nine young hikers perished while trying to outrun a bushfire in the Blue Mountains of New South Wales, Australia, as it advanced upslope (Foster, 1976; Luke and McArthur, 1978). Another incident occurred on August 26, 1995, near the community of São Domingos in the district of Sandtarém, Portugal, on August 26, 1995 (Viegas *et al.*, 2002). Three civilians who had been assisting local firefighters in suppression operations eventually ended up being killed while trying to run ahead of the fire when it blew up. A fourth individual received severe burns to his feet which eventually lead to them being amputated and he died some months later.

Simulations carried out by the FERIC Wildland Fire Operations Research Group based on their research on firefighter travel rates (Dakin, 2002) coupled with case study information gleaned from likes the 1949 Mann Gulch and 1994 South Canyon fires (Butler *et al.*, 2000) clearly indicates that a person is not able to sustain a maximum pace for even a relatively short period of time without being overrun by a rapidly advanced flame front, even on a moderately steep slope (Baxter *et al.*, 2004; Alexander *et al.*, 2005). For example, a fire spreading at 60 m/min up a 26% slope would, depending on the fuel type, overrun someone in about 6-7.5 minutes or after about 365-460 metres once the "race" had started. Chandler *et al.* (1983) state that "In most firefighter fatalities ... the unsuccessful strategy has been to try and run away from the fire an continue running until exhaustion or the radiant heat load from the fire front fells the victim and allows the flame front to pass

over him or her.” Thus, trying to outpace a fire for any significant distance, but especially uphill, is “courting disaster” (Luke and McArthur, 1978). For this reason, escape routes involving travel upslope but should generally not be selected.

2.2 *Survival Option 2: Burn Out a Safety Area*

Burning out fuels to create an area of safety or to enlarge an existing burned area is a viable survival technique or option in some situations (e.g., light fuels and having sufficient time to implement). As Australian bushfire research pioneers Harry Luke and Alan McArthur (1978) have noted, “Carrying a box of matches is part of survival planning” (in this regard, windproof type matches would be ideal); nowadays most wildland firefighters carry fusees which would be infinitely more reliable and effective than a match. Undoubtedly the most publicized example of this survival strategy being used in modern times occurred on the 1949 Mann Gulch Fire (Maclean, 1992; Rothermel, 1993). However, the technique was known to have been used by American Indians in the early 1800s (Pyne, 1982; USDA Forest Service, 2000a) and undoubtedly by aboriginals in other parts of the world as depicted, for example, in the 1989 movie *the Gods Must be Crazy II*. Here’s how Wag Dodge described his escape fire during his testimony at the board of review investigation into the 1949 Mann Gulch Fire as follows:

After setting a clump of bunch grass on fire, I made an attempt to start another one, but the match had gone out and upon looking up, I had an area of 100 feet square that was ablaze. I told the man nearest to me that we would wait a few seconds to give it a chance to burn out inside, and then we would cross through the flames into the burned area, where we could make a good stand and our chances of survival were more than even.

Interestingly, Dodge’s statement was printed in the letters to the editors section of the September 1949 issue of *Life* magazine following publication of an article on the Mann Gulch fire entitled “Smokejumpers Suffer Ordeal by Fire” from the previous issue. Interestingly, in that letter, the reader stated: “I am sure that there are many people throughout the country who would appreciate and perhaps benefit sometime by a more detailed account of how Foreman Wagner Dodge, who kept calm and did not become panic-stricken, saved himself”.

2.3 *Survival Option 3: Hunker in Place*

When caught in the open, survival may depend on taking advantage of every possible source of cover or protection from radiant and convective heat – for example, depressions in the ground, large rocks or logs (Foster 1976). If a root cellar (Winston, 2000) or cave is used to take refuge in, it is important to vacate into the open at the earliest opportunity due to potential problems associated with accumulations of smoke and carbon monoxide. One of the earliest and best known examples of survival during wildland fire within the global wildland fire community occurred when U.S. Forest Service Ranger Ed Pulaski led 42 men and two horses to the entrance of a mine tunnel in northern Idaho to seek refuge during the “big blowup” on August 20-12, 1910 (Pyne, 2001). One man failed to get into the tunnel was burned beyond recognition. All the men in the tunnel evidently were unconscious for a period of time. Five men died inside the tunnel, apparently from suffocation. The remainder of the crew was evacuated to the hospital in Wallace, Idaho, where all recovered from their ordeal.

In selecting this option, the importance of staying as flat as possible with ones nose and mouth pressed down into the ground cannot be overemphasized. Lying prone minimizes ones radiation profile and cooler, denser air will always be present at ground level. In selecting this option, bear in mind the following advice offered by Mr. Phil Cheney, a noted Australian bushfire research scientist (personal communication, 2005):

When a fire passes over a point, the air temperature near the ground is higher than the air above it and remains higher for longer. So if someone is sheltering from radiation at ground level, they need to stand up as soon as possible after the fire passes to breathe cool, fresh air. This is most apparent in grass fires where air at ground level is hot and smoky for several minutes whereas at 2 m it is cool and breathable within 10-15 seconds of the flames passing.

While there have been reported cases of firefighters surviving in on large rockslides during a wildfire entrapment or burnover, most notably two smokejumpers on the 1949 Mann Gulch Fire (Maclean, 1992; Rothermel, 1993) there have also instances where these apparently safe, fuel-free areas contained enough combustible materials to cause injury or death such as occurred on the September 1996 Shephard Mountain Fire in western Mountain on September 4, 1996 (USDA Forest Service, 1996). Four firefighters died on a rockslide during the 2001 Thirtymile fire in north-central Washington due in part to the accumulation of duff and rotting wood lodged in the rock crevices that ignited from airborne firebrands (USDA Forest Service, 2001; Brown, 2002; Lynch, 2002).

In selecting this survival option, maximum use should be made of any clothing or other readily non-burnable material to protect exposed skin. You may have to improvise (USDA Forest Service, 2000b). **Again, it must be emphasized that synthetics, including undergarments, should not be used.** During the 1983 Ash Wednesday fires in Victoria, Australia, two individuals wearing only summer clothing who covered themselves with a synthetic blanket perished while two other individuals right next to the two victims covered themselves with a wet woolen blanket and survived the burn-over (Krusel and Petris, 1999).

A good example of using this survival option was the Wandilo Fire that occurred in an exotic pine plantation near Mount Gambier, South Australia on April 5, 1958. Eleven firefighters found themselves trapped on a narrow firebreak during a “blowup” (McArthur *et al.*, 1966; Luke and McArthur, 1978). Eight in the group attempted to run back along the firebreak, but perished after exposure to extreme radiant heat levels and direct flame contact. Of the three that survived, two remained in the cab of their firefighting truck to shelter from the worst of the firestorm and only left this cover when the vehicle was well alight and the fire’s peak intensity had abated. The remaining survivor sheltered in a deep wheel rut in the soft sand of the firebreak with his coat over his face during the peak period of extreme fire behavior.

Taking refuge in a natural water body such as a pond, lake or river must be done with caution but for other reasons (e.g., swimming ability). For example, in 1986 three firefighters in the province of Quebec, Canada, drowned as a result of being forced to enter a lake with a steep drop off when their camp location was overrun by fire (Alexander, 1998). The risk of hypothermia must also be considered (Butler and Horthofer, 2002). Dion (1979) described an incident that occurred in west-central Saskatchewan, Canada, in May 1919 in which 11 Cree Indians perished because they were not able to reach a nearby lake or find deep enough water to avoid radiation burns. Of the twelve that survived the

ordeal, 11 “bore the marks of their burns for life”. One adult member of the group “escaped severe burns by staying under the water” as much as was possible.

2.4 *Survival Option 4: Pass Through the Fire Edge into the Burned-Out Area*

Luke and McArthur (1978) have suggested that “running through flames cannot be generally recommended and should certainly not be attempted when flames are more than 1.5 m in height or depth”. Nevertheless, a number of firefighters have done this very thing and survived – for example, on the 1991 Tikokino grass fire in New Zealand (Rasmussen and Fogarty, 1997). In fact, the five members of the group of young hikers that survived the 1957 bushfire in the Blue Mountains of New South Wales mentioned earlier on did so successfully but suffered considerable discomfort. A similar incident occurred on the Warm Springs Indian Reservation in central Oregon in June 1985. Fire behavior analyst Jim Roessler (personal communication, 2005), a fire behavior analyst with the U.S. Department of Interior’s Bureau of Indian Affairs, has indicated that those individuals who tried to outrun a grass fire on a moderately steep slope were killed, while at least one person who passed through the flame front survived. In contrast, during the blowup of the 1937 Blackwater Fire, the “five horsemen” made the decision to move downhill through the advancing flames (Brauneis, 2005). Three didn’t make it, no doubt due in part to the heavy fuel conditions. Of the two that did survive, one died later of burn injuries. A group of 41 on another section of the fire road out the blowup on a ridgeline clearing as the fire progressed upslope; three were badly burned and eventually died of their injuries.

It has been suggested that a person could theoretically survive passing through flames 3.0 m high and 37 m in depth and still survive (Chandler *et al.*, 1983). It is presumed that the person would be immersed in flames for less than 7.5 seconds and would require ideal running conditions (e.g., good footing, no obstructions) and be properly clothed to withstand the direct flame contact. While it’s reasonable to expect a person to be able to hold his/her breath for this long, the very notion of attempting such a drastic or “draconian” like (Chandler *et al.*, 1983) feat seems unimaginable. Nevertheless, it is worth noting that firefighters have lived, albeit while suffering severe burns as result, by running through high-intensity flame fronts. One of the most notable examples of this involved a prescribed fire (PB-3/79) in heavy logging slash near Geraldton, Ontario, Canada, on August 22, 1979 (McCormack *et al.*, 1979; Mutch 1982; Alexander and Thomas, 2006). As a result of a complex set of unforeseen circumstances, eight members of the firing crew found themselves encircled by fire. One member of the party, a local fire technician, realizing that there was no other option except to run through the advancing flame front or face what appeared to be certain death, tried to get seven seasonal employees to follow him. They failed to heed his urgings and were eventually engulfed by the fire, while he survived but did suffer serious burn injuries. This outcome is hauntingly reminiscent of the 1949 Mann Gulch fire and Dodge’s escape fire in which 15 firefighters failed to follow his lead and 13 ended up perishing. In this regard, as Dr. Karl Weick (personal communication, 2005), a renown professor of organizational behavior and psychology at the University of Michigan points out, there is good evidence to support the notion that when people are threatened, their thinking becomes much more rigid and difficult to change. Furthermore, they tend to seek out and talk only to those who are most familiar to them (Shaw *et al.*, 1981).

The survival technique or option of moving through the flame front on to previously burned ground would logically be most suitable in light, discontinuous fuel types that fail to produce deep, uniform flame fronts, and significant post-frontal smouldering/isolated

flaming, such as afforded by certain grasslands (e.g., heavily grazed areas). Furthermore, if one has the good fortune to take advantage of a lull in the wind, this would lessen the momentary rate of spread and in turn the flame depth (Table 1); Residence time represents the period of active flaming. An area along the flanks of the fire would be preferable to the head. One may only have to travel a relatively short distance before reaching previously burned ground that has “cooled” down sufficiently to serve as a safe area.

Table 1. Nominal flame front residence times for four broad fuel complexes and computed maximum theoretical flame depths associated with variable rates of fire spread.

Broad fuel type	Residence time ^a		Rate of Fire Spread		
	(sec)	(min)	10 m/min	20 m/min	40 m/min
			----- Flame depths -----		
Grassland	10	0.17	1.7	3.4	6.8
Shrubland	20	0.33	3.3	6.6	13
Forest stand	45	0.75	7.5	15	30
Logging slash	90	1.5	15	30	60

^aNumerically equal to the residence time multiplied by the rate of fire spread (in compatible units).

Having reached the burned area, a person would still have to be cognizant of the danger posed by fire-weakened trees and falling snags, hot ash pits and burnt-out stump holes, and rolling rocks or logs (Leuschen and Frederick, 2004). This would also apply to the other survival options as well.

3.0 Concluding Remarks

Wildland fire management agencies have developed safety guidelines for their firefighters. For example, the LACES (Lookout(s) – Anchor point(s) – Communication(s) – Escape routes – Safety zone(s)) wildland firefighter safety system (Thorburn and Alexander, 2001) has been adopted by the Forest Protection Division staff of the Alberta Sustainable Resource Development and other fire management agencies, both nationally and internationally (Pearce *et al.*, 2004). Adherence to safe work practices by wildland firefighters and implementation of FireSmart strategies (Partners in Protection, 2003) amongst the general public in the wildland-urban interface will no doubt alleviate the vast majority of potential fatalities and injuries related to entrapments or burnovers by wildfires and prescribed fires. Ideally no will ever find themselves in a situation where they would have to rely on any of the survival options as discussed in this paper. Nevertheless, the periodic review and reflection on these survival is strongly encouraged, especially just prior to the fire season. It could save your life someday!

It’s worth noting that the Canadian Council of Forest Ministers (2005) recently signed off on a *Canadian Wildland Fire Strategy Declaration*. “Public safety – including the safety of firefighters – is paramount” constitutes one of the guiding principles of the strategy. Wildland firefighters are trained in entrapment avoidance. However, I think we would remiss not to include the material on survival options as covered in this paper, supplemented by localized examples or case studies. Unfortunately, the general public generally does not receive this kind of training and information, although it could be made available. Considerably more work needs to be done with respect to wildland fire safety education and the general public on a global basis (Alexander, 2003). I believe that we as

fire managers and fire researchers have a societal responsibility to see to it that this transfer of knowledge take places in order to avoid as many unnecessary deaths and serious injuries from wildfires amongst the general public as possible. The represents a challenge to the wildland fire community.

Have you personally experienced a “close call” or “near miss” during a wildland fire incident? I was somewhat amazed during the reviews I obtained earlier on of the material contained in this paper, to learn of a number of instances amongst my friends and colleagues. I think we need a forum to more freely share these kinds of stories. Perhaps the “neighborhood” concept established by the Wildland Fire Lessons Learned Center on their MyFireCommunity.Net (<http://www.myfirecommunity.net/GuestHome.aspx>) website could serve this purpose.

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