Advantage

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Contents

Travel rates by Alberta wildland firefighters using escape routes on a moderately steep slope

Abstract

When fire behaviour becomes threatening, firefighters disengage the fire and travel along escape routes to reach safety zones to avoid being entrapped or burned over. The Forest Engineering Research Institute of Canada (FERIC) studied the travel rates of various types of Alberta fire suppression crews using simulated escape routes. This report focuses on the travel rates of Type I firefighters on a moderately steep slope (26%) in two different fuel complexes—grass on a powerline and a white spruce stand. This report also discusses the influences of using a marked trail or escape route and dropping one's pack and tool on travel rates, and the effect of slope steepness on fire spread in relation to firefighter travel rates upslope.

Keywords

Escape routes, Fire behavior, Firefighters, Fire protection, Fire suppression, Fuel types, Safety, Travel rates, Wildfires.

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Introduction

Escape routes and safety zones are, along with establishing lookouts, anchor points and communications, integral components of the safety system for Alberta wildland firefighters (Thorburn and Alexander 2001).

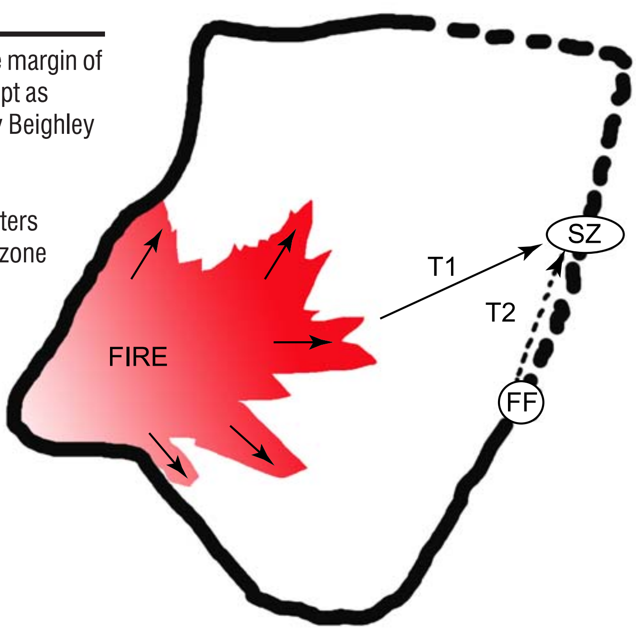

Figure 1. The margin of safety concept as described by Beighley (1995).

FF = firefighters
SZ = safety zone

Escape routes are predetermined pathways used by firefighters to reach a safety zone, which offers a refuge from being entrapped or burned over when threatening fire behaviour occurs (Beighley 1995). The safety margin measures the ability of a wildland firefighter to reach a safety zone before being overtaken by spreading fire.

A safety margin is defined mathematically as follows (Beighley 1995):

Safety margin ($\pm$) = T1 – T2

where T1 = the time for a fire to reach the safety zone

T2 = the time for a firefighter to reach the safety zone

This concept is illustrated in Figure 1. T1 is dictated by the distance involved and the fire's rate of spread. T2 depends not only on the fire crew's rate of travel but other factors such as the delay in recognizing the need to use an escape route as a result of a change or anticipated change in fire behaviour, and the time required to communicate this decision to the crew members (Cheney et al. 2001). A positive (+) safety margin implies that the firefighter can reach the safety zone before being overtaken by the fire, whereas a negative (-) safety margin implies that the fire can overtake a firefighter before the firefighter can reach the safety zone. The greater the positive difference between T1 and T2, the greater the margin of safety.

Another approach to determining margins of safety with respect to escape routes is described in Butler et al. (2000), which compares the rates of fire spread for various fuel, slope, and weather combinations directly with firefighter travel rates to define the boundary between positive and negative margins of safety. This approach assumes that the fire and firefighters are equidistant to the safety zone.

FERIC undertook a project to investigate the travel rates of firefighters on escape routes for several fuel and slope conditions and crew characteristics. Dakin (2002) described the first-year results in an interim report. This report supplements the interim report, and documents the travel rates of Type I fire crews[1] on a moderately steep slope in two of the four general fuel types studied in the interim report. Appendix I of this report also includes data collected for Type III firefighters travelling through two fuel types on level ground during the trials described by Dakin (2002). The results can be used by fire suppression personnel to determine when firefighters might be at risk by working too far away from their safety zones or other areas of safe refuge.

Objective

The objective of the project was to document the travel rates of various types of Alberta fire suppression crews in different fuel types and slope conditions. The following questions were initially posed:

- At what rate does a fire crew travel?
- Do travel rates vary depending on crew type?
- Do travel rates differ for individuals with and without equipment and packs?
- Do travel rates differ between an improved route and a natural escape route?
- How does slope influence travel rates?
- How closely do test results reflect an individual's maximum physical performance?

Field work undertaken in the fall of 2001 as described by Dakin (2002) addressed the first four questions. This report further addresses them while focussing on the last two questions.

Previous research

Butler et al. (2000) used two published wildfire case studies to determine general travel rates for firefighters over rough terrain. Firefighters working on the 1949 Mann Gulch fire in northwestern Montana travelled cross-slope and upslope (18%) at an average rate of 51 m/min and at one point increased their rate to between 110 and 146 m/min (Rothermel 1993). This latter rate is presumed to be possible for only a short period of time and is probably not sustainable by most firefighters for any significant distance when travelling upslope over rough terrain (Butler et al. 2000). Firefighters working on the 1994 South Canyon fire in west-central Colorado travelled at an average rate of 73 m/min over the rough but relatively flat portions of the fireline they were using

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1 Type I firefighters can be members of rappel crews or heli-attack crews and have more training and higher physical fitness requirements than Type II (contract) or Type III (emergency) firefighters.

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as an escape route (Butler et al. 1998). Their average rate of travel decreased to 55 m/min on the 10–30% upslope sections of the fireline and to 37 m/min on the steeper 30–50% slopes.

On the basis of the reconstructed travel rates of firefighters involved in the Mann Gulch and South Canyon fires, Butler et al. (2000) suggested that the average sustainable travel rates for firefighters over rough but flat terrain would average about 80 m/min, with faster rates as high as 128 m/min possible given stable footing. They pointed out that as the slope steepens, a firefighter's rate of travel decreases proportionally. They considered an average rate of travel for a relatively gentle slope (i.e., 10–20%) to be approximately 55 m/min, and the average sustainable rate for slopes of 20–40% to be approximately 37 m/min. For slopes greater than 40%, they suggested that travel rates would diminish to less than 18 m/min. These firefighter travel rates should be considered applicable to daylight hours only. At night, rates are affected by reduced heat stress and poorer vision.

Methodology

The methodology used to gather firefighter travel rate data for a slope situation was the same as described in Dakin (2002). A travel route near Hinton, Alberta was selected that had an average slope of 26% (Figure 2). The site was situated at an elevation of approximately 1220 m above mean sea level.[2] Firefighters travelled upslope over open ground (i.e., a powerline trail) and through an adjacent white spruce stand, best corresponding to Canadian Forest Fire Behavior Prediction (FBP) System Fuel Types O-1b (standing grass) and C-2 (boreal spruce), respectively (Forestry Canada Fire Danger Group 1992; De Groot 1993; Taylor et al. 1997).

Unlike the data collected by Dakin (2002) in forest stands, an improved course route in the white spruce stand on the 26% slope in this portion of the study was not undertaken (i.e., only a natural route was investigated). The route was 250 m in length and firefighters travelled directly upslope. Therefore, neither downslope nor cross-slope rates of travel were examined in this study.

Each firefighter made four runs in total. These consisted of two routes (i.e., the powerline and the white spruce stand), each with and without a pack and tool. The runs were done in random order. A standard issue pack consisting of 6.8 kg of gear and a fire shovel was carried as an equipment complement. Travel times were measured at the 100-m mark and again at the termination of the 250-m run. Only one firefighter was on the course at any given time.

Like the previous data collected as a part of this project (Dakin 2002), all runs were conducted during daylight hours under moderate ambient air temperatures (12–16°C

[2] The elevation of the sites selected for the course runs in the earlier work on this project as reported by Dakin (2002) were approximately: 813 m (FBP System Fuel Type C-2), 760 m (FBP System Fuel Type O1-b), 760 m (FBP System Fuel Type C-3), and 815 m (FBP System Fuel Types S-1 and S-2).

Figure 2. Looking down the slope course of the open powerline (a) and the adjacent white spruce stand (b) located west of Hinton, Alberta. The average slope steepness was 26% over the 250-m routes.

range) and without the hindrance to firefighters that would be posed by smoke (Butler et al. 1998).

Only Type I firefighters participated in the trials. Thirty-two runs were completed in total (i.e., eight individuals). Shuttle runs[3] were completed prior to slope travel to simulate firefighter fatigue (i.e., at 4 PM after having worked for five hours) and to collect baseline heart rate (HR) data to compare firefighters' efforts during the trials.

Results and discussion

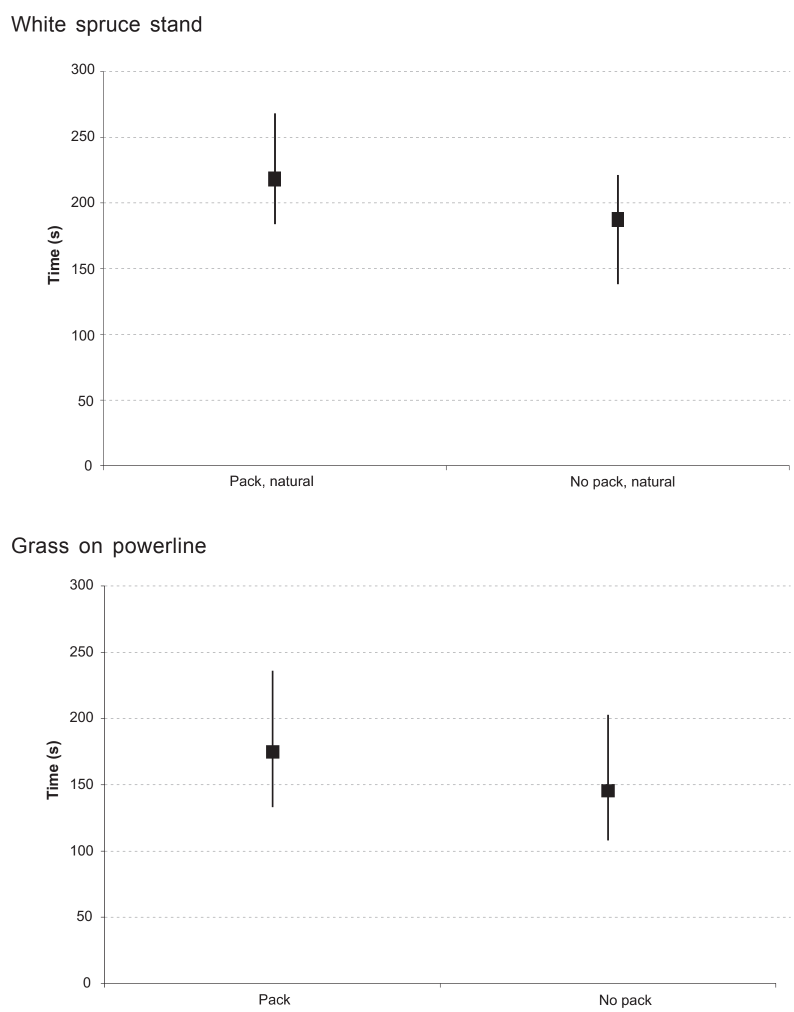
Field trial results

Appendix II presents the data for each subject involved in this trial and for the earlier trials reported by Dakin (2002). Appendix III summarizes the firefighter travel rates for all the situations examined in the project. A comparison of the data collected on the slope courses with those reported by Dakin (2002) suggests that slope steepness has a dramatic influence on travel rates of firefighters. The HR data indicate that the firefighters participating in this FERIC project completed the course runs at 95% maximum effort compared to their shuttle run results for all fuel type/slope scenarios (Appendix II).

The mean course times for the Type I firefighters through the white spruce stand (FBP System Fuel Type C-2) on a 26% slope with and without pack/tool were 217 and 194 s (Figure 3), respectively, with corre-

[3] A multistage fitness test, also known as the 20-m shuttle run test, is a very common test of aerobic fitness (Leger and Lambert 1982). It involves continuous running between two lines 20 m apart in time to recorded beeps. The time between recorded beeps decreases each minute (level), thus increasing the running speed. Type I Rappel crew members must get to level 10.

Figure 3. Mean and range of travel times for Type I firefighters to complete a 250-m course in two different fuel types on a 26% slope.



sponding rates of travel of 69 and 77 m/min (Appendix III). The mean course times over open ground in the grass and other herbaceous vegetation (FBP System Fuel Type O-1b) along the powerline with and without pack/tool were 174 and 145 s (Figure 3), respectively, with corresponding rates of travel of 86 and 103 m/min (Appendix III).

By comparison, the mean travel times for Type I, II, and III firefighters to complete the 250-m course through a black spruce stand (FBP System Fuel Type C-2)[4] on level terrain with pack/tool were 157, 159, and 174 s (Table 1), which correspond to overall rates of travel of 95, 94, and 85 m/min, respectively (Appendix III). The mean travel time for Type I, II, and III firefighters to complete the same 250-m course without pack/tool were 136, 150, and 131 s (Table 1), which correspond to overall rates of travel of 110, 100, and 113 m/min (Appendix III), respectively. Thus, the travel rates on the 26% slope were about half as fast as on level ground in the most difficult fuel type.

In the grass (FBP System Fuel Type O-1b) situation on level terrain, the mean travel times for Type I, II, and III firefighters with pack/tool over the 250-m course were 112, 118, and 162 s (Table 1), corresponding to mean travel rates of 134, 127, and 93 m/min, respectively (Appendix III). Without a pack/tool the times averaged 77, 96, and 126 s (Table 1), corresponding to mean travel rates of 197, 156, and 119 m/min, respectively (Appendix III).

Effect of dropping gear on firefighter travel rates

Dakin (2002) reported on travel times for Type I and Type II firefighters with and without pack/tool on natural and improved routes in four different fuel types on level terrain. A key finding was that firefighters without pack/tool can travel up to 40% faster on flagged (Beckley 2001) or improved routes, compared to natural routes.

Dakin (2002) also reported that by dropping their pack/tool, firefighters could travel approximately 20% faster, regardless of the fuel type or trail condition. In this study involving slope, firefighters who travelled the course without pack/tool achieved only 11% and 17% time savings in the white spruce stand and powerline (grass) routes, respectively, compared to firefighters who travelled the same routes with pack/tool.

In 1997, Ruby et al. (2000, 2003) carried out a field simulation at the site of the South Canyon fire similar to the present study by comparing firefighter travel rates with and without pack/tool along a 660-m hiking trail exhibiting a 21% slope. They found on average a 22% increase in travel

4 Dakin (2002) rated the black spruce stand (FBP System Fuel Type C-2) as the most difficult of the four fuel types in terms of ease of travel.

Table 1. Mean travel times through a 250-m natural course in a black spruce stand and in standing grass on level terrain [a]

	Black spruce stand FBP System Fuel Type C-2		Standing grass FBP System Fuel Type O-1b	
Crew type	Pack/tool	No pack/tool	Pack/tool	No pack/tool
I	157	136	112	77
II	159	150 [b]	118	96
III	174	131 [b]	162	126

[a] From Dakin (2002).
[b] The apparent anomaly between Type II and Type III firefighters in regards to FBP System Fuel Type C-2 evident here (i.e., one would expect the reverse to be the case) illustrates the variation that can exist among fire suppression crews.

rates among eight males and a 26% increase among five females. The average rates of travel with a 16-kg pack, Pulaski tool, and fire shelter for males and females were 63 and 49 m/min, respectively. The average rates of travel with just a Pulaski tool and fire shelter for males and females were 80 and 66 m/min, respectively.

In 1994, fire equipment specialist Dr. Ted Putnam and exercise physiologist Dr. Brian Sharkey with the USDA Forest Service's Missoula Technology and Development Center, conservatively calculated that firefighters could travel at least 15–20% faster and possibly higher (30%) without their packs and tools (Putnam 1995; Butler et al. 2000; Ruby et al. 2000, 2003). Based on Putnam and Sharkey's unpublished analyses and the Ruby et al. (2000, 2003) study, Anderson (2001) suggested that firefighters could increase their travel rates by 15–30% if they dropped their packs and tools. Subsequently, Anderson (2003) stated, "Firefighters have died carrying packs and tools while climbing a hill to escape fires. You can move up to 30 percent faster without your gear" and "this can easily mean the difference between life and death" when travelling along an escape route.

The notion of dropping one's pack and tool to increase travel speed raises several interesting psychological issues. As pointed out by noted psychologist Dr. Karl Weick, "The problem is, it feels very unnatural to firefighters to drop their tools—for them, it is almost like losing their identities" (Coutu 2003). Other psychological issues have been explored (Weick 2001), including admission that the situation has truly become life threatening (Kuo 1998). Dr. Weick noted that to overcome this reluctance or hesitancy to drop one's gear, firefighters need to train with and without their packs and tools (Putnam 1996; Kuo 1998) to obtain a first-hand feel of what it is like to be both "encumbered and unencumbered" (Coutu 2003). According to Dr. Ted Putnam, without training you are not likely to have the thought to drop your pack/tool when under stress.[5]

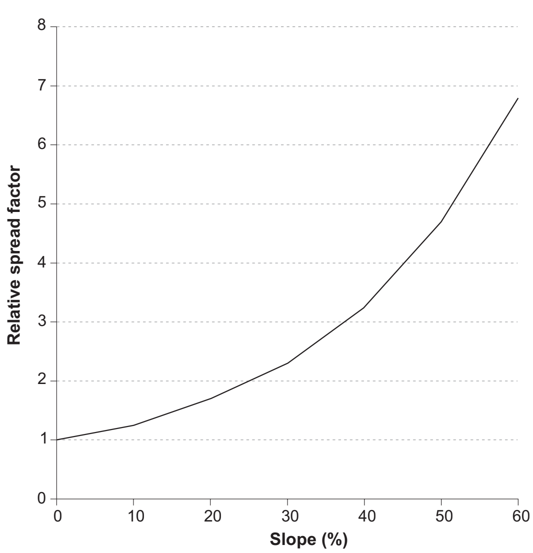


Figure 4. Relationship between slope steepness and relative rate of fire spread, as used in the FBP System (Forestry Canada Fire Danger Group 1992) based on Van Wagner (1977).

Firefighter travel rates in relation to fire spread on slopes

Wildland fire behaviour research from laboratory test fires and field observations has established the relationship between rate of fire spread and slope steepness (Figure 4). Slope dramatically increases the rate of spread and intensity of wildland fires by exposing the fuel ahead of the advancing flame front to additional convective and radiant heat. As slope steepness increases, the flames tend to lean more and more toward the slope surface, gradually becoming attached at approximately 50 percent slope (Rothermel 1985) with the result being a sheet of flame moving parallel to the slope. Fires in mountainous terrain are thus capable of making exceedingly fast upslope runs and over time are able to surpass the distances firefighters can travel (Wilson 1977; Rothermel 1993; Butler et al. 1998; USDA Forest Service 2003). Therefore, firefighters should avoid situations where their escape routes and safety zones are directly upslope of a potentially active fire edge or fire perimeter that could be breached. Otherwise, they are compromising their safety.

According to Van Wagner (1977), a free-burning fire on the 26% slope in this study would spread about two times faster than a fire on level terrain for the same burning con-

[5] Personal communication, April 2004.

ditions, and increases exponentially with increasing slope (Figure 4). Thus, a fire spreading at 10 m/min on the level terrain would advance at 20 m/min up a 26% slope under identical fuel and weather conditions. Firefighters travelled at an average rate of 107 m/min over the first 100 m of the course.[6] However, this pace slows considerably past the 100-m mark, approaching very slow rates of travel. Comparing these travel rates to fire rates of spread upslope shows that a fire would generally catch up to and overrun most firefighters in a relatively short period of time (Figure 5). Any wind that is present would increase fire spread rates and exacerbate the situation.

Firefighter endurance

If the escape route distances involved in firefighters reaching their safety zones are short, then travel rates have direct significance. However, when the distances are long, endurance and decreases in travel rates become issues. This study did not set out to determine the maximum distance that firefighters could sustain without resorting to a brief rest period to recover and thus a corresponding reduction in the overall rate of travel. At some point, firefighters will experience an anaerobic collapse where they are physically not able to move any further. While it was not possible to establish an aerobic-anaerobic threshold for firefighters travelling along escape routes, some qualitative and quantitative observations did emerge from the study.

The data indicated that after 100 m, travel rates consistently decreased on average by about 26 m/min as firefighters gradually tired. After completing the 250-m slope course, many of the firefighters commented that they felt they had approached the limits of their physical endurance after travelling at a reasonable pace for about 2.5 to 3.5 min (Figure 6). Furthermore, FERIC researchers casually observed that the recovery times between runs of the individuals were far greater on the slope course than on flat ground.

Figure 5 attempts to simulate the travel distance in relation to time as firefighters gradually become tired from physical exertion.[7] A fire spreading upslope at 60 m/min

[6] By comparison, world-class runners in 100 or 200, 400, 800 and 1500 m races would under ideal conditions on their best days be travelling at approximately 600, 550, 475, and 435 m/min, respectively.

[7] In constructing the firefighter travel distance versus elapsed time graph, the travel rates for the two segments of each of the 250 m courses were calculated (i.e., 0–100 m and 100–250 m) and estimated in between based on the rate of change. After 250 m, travel distances were reduced by 20, 30, 40 and 50 m/min for each minute up to 9 min.

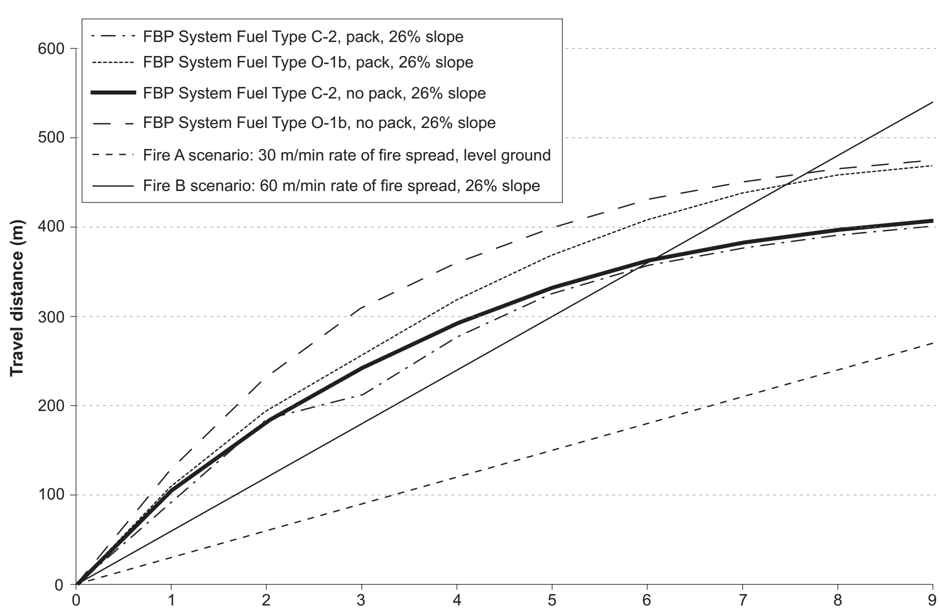


Figure 5. Simulation comparing various firefighter travel distances to time on a moderate slope (26%) versus fire spread on level ground and on a 26% slope.

Figure 6. State of exhaustion of a firefighter after completing one run on the slope course.

would overrun firefighters in 6–7.5 minutes depending on the fuel type. A spread rate of 60 m/min on a 26% slope would not be considered unrealistic, even under moderately severe burning conditions (Taylor et al. 1997). Figure 5 assumes that the fire and firefighters are equidistant from a safety zone and that the fire is spreading as a line source (i.e., there's no time allowed to reach a steady-state rate of spread as would be the case with a single point source fire from the moment of ignition). It also assumes identical fuel and weather conditions for each scenario.

Ruby et al. (2003) has shown that firefighter travel rates are related to aerobic fitness. The slope course was completed by only Type I crew firefighters which have a higher level of fitness than other types of firefighters. This difference in fitness levels was noted during the shuttle runs associated with the course runs described by Dakin (2002), where the mean levels for Type I, II, and III firefighters were 9.0, 5.4, and 3.6 respectively, based on 31 observations (Appendix II). The Type I crew members who took part in the slope portion of the project had a mean level of 11.0.

Heightened awareness

FERIC researchers found that the firefighters developed an increased awareness and appreciation for the importance of escape routes as a result of taking part in the trials. The project has also raised the awareness of the importance of escape routes among fire managers in Alberta and elsewhere in Canada.[8] These outcomes were unforeseen but constitute a value-added aspect to the research undertaken by FERIC.

Conclusions and implementation

The following conclusions and implementation remarks are based on the results of the research described in this report and in Dakin (2002).

Although the concept of escape routes has been a formally recognized element of wildland firefighter safety for almost 50 years (McArdle 1957; Moore 1959), there is little quantitative data or information available on firefighter travel rates using escape routes. This report and Dakin (2002) represent the first formal quantification of firefighter travel rates not only in Alberta but also in Canada. There is opportunity for additional work in Alberta (e.g., aspen and mixedwood stands, spruce-lichen woodlands) and in other Canadian fuel types and terrain conditions.

Travelling with packs and tools slows the firefighters whether they are on an improved escape route or in a standing timber cover type. Dropping packs and tools to reach the safety zone was shown to improve travel rates of firefighters by an average of 20% under the conditions tested. Roughly the same relationship exists on level ground as well as on slopes. *Firefighters should immediately drop their packs and tools once they have made the decision to use an escape route to reach a safety zone—it could mean the difference between life and death.*

Any work to improve escape routes, even by simply marking or flagging a route (Beckley 2001), decreases the time required to reach the safety zone. Travel times de-

[8] For example, Al Beaver, Science & Planning Supervisor, Yukon Wildland Fire Management, has indicated that the project findings "… certainly brings to light the need to get a good head start over the fire in an escape. There is no such thing as a fair start or false start when you're running for your life and your competition doesn't have an anaerobic limit. It is better to get out 5 minutes too soon than 5 seconds too late." (Personal communication, April 2004.)

creased by 40% on improved trails. Thus, by using a marked escape route and dropping their packs and tools, firefighters can travel up to two times faster.

Travelling upslope decreases firefighter travel rates to dangerously low levels. Fires burning upslope generally have the potential to spread at a rate greater than what a firefighter is typically capable of travelling at, and certainly greater than what a firefighter can sustain for any significant period of time to avoid being overtaken by an advancing flame front. Thus, establishing escape routes and safety zones upslope for any significant distance away from the fire should be avoided because travel rates of firefighters decrease rapidly with increasing slope steepness, and fire rates of spread can dramatically escalate with increasing slope, thereby constituting a potentially lethal situation for firefighters.

Even the most fit individuals experience a marked decrease in their rates of travel when moving upslope. This would presumably be even more pronounced for those individuals not in peak physical condition. The rate of spread of a fire burning upslope generally has the potential to be greater than the rate of travel of a firefighter, especially over any significant period of time.

In actual operational practice, escape routes should be timed (NWCG 2004) rather than relying solely upon personal judgments. Given an estimated distance or one derived from a map or aerial photo, the values contained in Appendix III should be regarded as simply approximations for general planning or simulation purposes for gauging the minimum time required for firefighters to reach a given safety zone. To determine the true value of T1 (i.e., the time for firefighters to reach the safety zone) in calculating the margin of safety, allowances have to be made for the time taken to make the decision to use an escape route and to communicate this to all crew members. These kinds of assessments should presumably be based on the slowest moving members of a crew (i.e., the minimum values given in Appendix III) rather than on the average rate of travel. Dakin (2002) reported that there was less variation in travel times and, in turn, travel rates among individual crew members on the improved routes.

Determining the time taken for the fire to reach the safety zone (i.e., T2) will depend on the distance involved and the fire's rate of spread. Potential rates of fire spread would typically be garnered from fire behaviour guides such as the FBP System "red book" (Taylor et al. 1997) based on the predominant fuel type, slope steepness, current moisture status, and forecasted or observed weather conditions, supplemented by observation and experienced judgment (Alexander and Thomas 2004). Distances would be based on measurement such as from maps or aerial photos, or on ocular estimates, with their inherent potential for major error, either from the ground or air. Some fire researchers believe there is a common tendency to overestimate the distance to a fire when observing through the forest, which may lull firefighters into thinking there is more time available for an orderly exit than is actually the case (Cheney et al. 2001).

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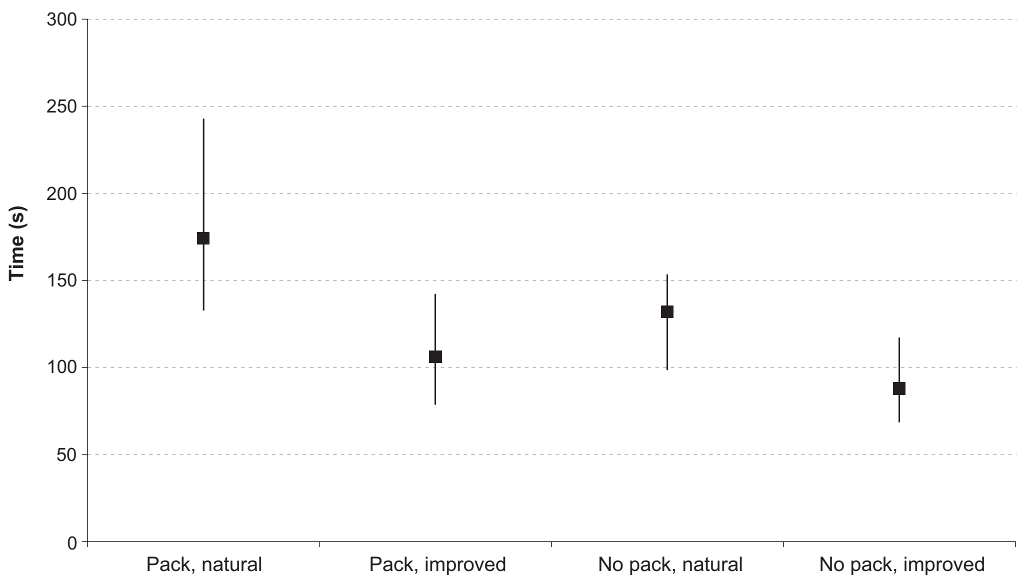
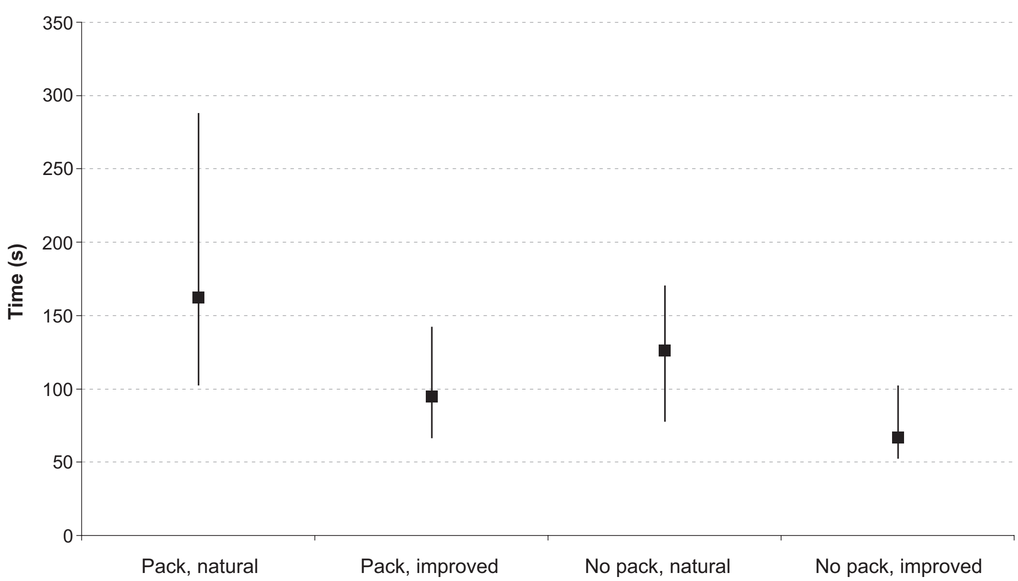
Appendix I

Mean travel times and range of times for Type III firefighters to complete a 250-m course in two different fuel types on level terrain based on eight individual runs

Black spruce (FBP System Fuel Type C-2)



Standing grass (FBP System Fuel Type O-1b)



Appendix II

Physical characteristics of the firefighters by crew type that completed the slope and level ground course runs in this project

Type I firefighters - completed 26% slope course only					
Sex	Age	Height in metres (feel/inches)	Weight in kilograms (pounds)	Shuttle run HR	Shuttle run level
M	27	2.05 (6’2”)	93 (205)	195	9.0
M	24	1.91 (5’9”)	77 (170)	186	13.0
M	24	1.94 (5’10”)	84 (185)	185	8.0
M	22	2.11 (6’4”)	92 (203)	185	10.0
F	25	1.97 (5’11”)	72 (158)	186	12.0
M	26	1.97 (5’11”)	77 (170)	195	14.0
M	32	1.88 (5’8”)	75 (165)	188	11.5
M	28	1.91 (5’9”)	75 (165)	182	10.5

Type I firefighters - completed four fuel types on level ground courses only					
Sex	Age	Height in metres (feet/metres)	Weight in kilograms (pounds)	Shuttle run HR	Shuttle run level
M	30	1.80 (6’0”)	- [a]	203	10.5
F	20	1.70 (5’8”)	- [a]	192	9.5
M	21	1.88 (6’3”)	- [a]	212	6.8
M	20	1.73 (5’9”)	- [a]	188	7.5
M	25	1.80 (6’0”)	83 (183)	170	9.0
M	20	1.85 (6’2”)	85 (188)	204	- [a]
M	25	1.80 (6’0”)	83 (183)	168	9.0
M	25	1.82 (6’1”)	84 (185)	187	11.0
M	27	1.78 (5’11”)	- [a]	180	5.5
M	30	1.70 (5’8”)	- [a]	173	4.0
M	19	1.83 (6’1”)	- [a]	203	10.5
F	22	1.67 (5’7”)	- [a]	188	5.0
M	27	1.80 (6’0”)	80 (177)	197	8.5
M	29	1.77 (5’11”)	83 (182)	192	6.5
M	21	1.92 (6’5”)	84 (186)	186	8.0

[a] Data not collected.

Appendix II - continued

Type II firefighters - completed four fuel types on level ground courses only					
Sex	Age	Height in metres (feet/inches)	Weight in kilograms (pounds)	Shuttle run HR	Shuttle run level
M	34	1.97 (5’11”)	93 (204)	171	4.2
M	35	2.05 (6’2”)	91 (200)	179	5.0
M	27	1.97 (5’11”)	91 (200)	185	5.5
M	25	2.00 (6’0”)	89 (196)	215	5.0
M	25	2.00 (6’0”)	77 (169)	212	6.5
M	29	1.94 (5’10”)	89 (196)	201	6.0
M	20	1.97 (5’11”)	89 (196)	209	6.0
M	37	1.97 (5’11”)	100 (220)	- [a]	- [a]

[a] Data not collected.

Type III firefighters - completed two fuel types on level ground courses only					
Sex	Age	Height in metres (feet/inches)	Weight in kilograms (pounds)	Shuttle run HR	Shuttle run level
M	52	2.05 (6’2”)	85 (188)	169	1.5
M	26	2.02 (6’1”)	84 (185)	198	3.5
M	29	1.80 (5’5”)	75 (165)	193	4.5
M	54	1.80 (5’5”)	75 (165)	174	2.5
M	40	2.05 (6’2”)	85 (188)	189	3.5
M	37	1.83 (5’6”)	76 (168)	184	5.5
M	34	1.97 (5’11”)	82 (180)	170	3.5
M	26	1.97 (5’11”)	82 (180)	200	4.5

Appendix III

The mean, standard deviation (SD), and range (minimum and maximum values) of Alberta wildland firefighter travel rates (m/min), and number of observations for all the combinations sampled

			Travel rate (m/min)								
			Pack/tool				No pack/tool				
			Natural		Improved		Natural		Improved		Course
Crew type	Fuel type(s)	Slope (%)	mean ± SD	range	mean ± SD	range	mean ± SD	range	mean ± SD	range	runs (no.)
I	C-2	0	95 ± 12	63–131	168 ± 17	100–227	110 ± 18	69–163	202 ± 10	142–254	12
II	C-2	0	94 ± 13	76–165	158 ± 13	109–192	100 ± 11	79–135	197 ± 5	167–230	7
III	C-2	0	85 ± 12	62–113	143 ± 13	105–190	113 ± 8	98–151	172 ± 10	128–217	8
I	C-2	26	69 ± 7	56–81	- [a]		77 ± 9	67–108	- [a]		8
I	O-1b	0	134 ± 16	96–234	238 ± 7	87–272	197 ± 11	143–241	268 ± 12	187–333	8
II	O-1b	0	127 ± 12	98–174	217 ± 9	168–283	156 ± 11	113–195	268 ± 5	220–300	9
III	O-1b	0	93 ± 21	52–145	159 ± 15	105–223	119 ± 14	88–192	224 ± 12	147–283	8
I	O-1b	26	- [a]		86 ± 14	64–112	- [a]		103 ± 16	74–139	8
I	C-3	0	129 ± 16	97–227	195 ± 9	165–268	136 ± 11	103–181	217 ± 10	180–288	7
II	C-3	0	115 ± 9	90–151	181 ± 7	158–224	143 ± 6	125–155	223 ± 8	174–268	8
I	S-1/2	0	141 ± 12	103–176	227 ± 11	165–272	185 ± 11	141–234	238 ± 19	141–294	7
II	S-1/2	0	124 ± 15	79–168	197 ± 9	167–242	174 ± 5	156–191	246 ± 5	220–278	8

[a] Combination not sampled.