Evaluating the effectiveness of FireSmart priority zones for structure protection

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Keywords

FireSmart, Vegetation control, Wildfires, Thinning, Fire behaviour, Forest site classification, Fire control, Structure protection, Wildland–urban interface, Fire effects.

Abstract

When wildfire escapes into the wildland–urban interface, homes, industrial facilities, and other urban values can be threatened or destroyed. As recommended by the FireSmart Canada program, vegetation management is a key principle in mitigating the risk of wildfire affecting urban values. In 2007, at a forested test site in the Northwest Territories, Canada, FPInnovations evaluated the effectiveness of using vegetation management—i.e., removal and reduction of forest fuels from the vicinity of a small building—as a strategy for protecting the building from wildfire.

INTRODUCTION

When wildfire escapes into the wildland–urban interface, homes, industrial facilities, and other urban values can be threatened or destroyed. To address the issue of wildfire in the wildland–urban interface, Partners in Protection was established. Partners in Protection is an Alberta-based, multidisciplinary association that aims to reduce the risk of loss due to fire in the wildland–urban interface. In 1999, Partners in Protection created the FireSmart brand and published the first edition of its technical manual *FireSmart: Protecting Your Community from Wildfire*. The second edition was published in 2003, and fire agencies in Canada, Australia, and New Zealand have adopted the standards described in the manual to address wildland–urban interface fire issues.

A goal of FireSmart is to decrease the amount of vegetation that can fuel a wildfire. One of the key recommendations in the FireSmart manual is to manage the vegetation around a structure in order to reduce the intensity of wildfire as it approaches, thus improving the probability of that structure surviving. The manual describes three priority zones around a structure, within which vegetation management should take place (Figure 1):

Priority Zone 1: 10 m radius around the building (or structure).

Priority Zone 2: 10–30 m radius around the building.

Priority Zone 3: 30 to ≥100 m radius around the building.

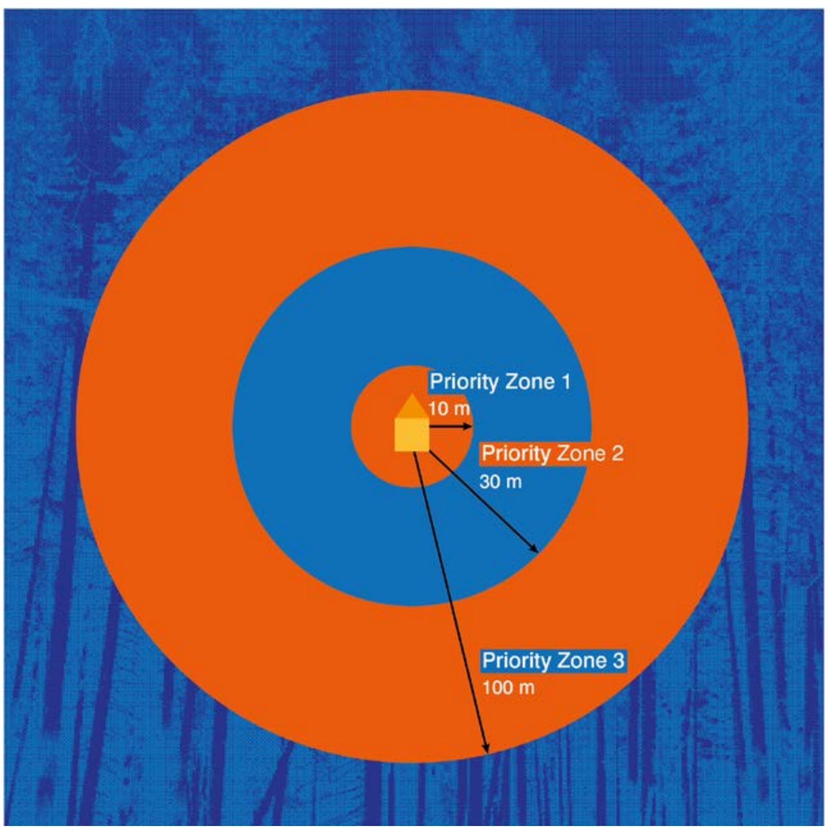

Figure 1. FireSmart priority zones (adapted from Partners in Protection 2003).

The general vegetation management strategies—vegetation removal, vegetation reduction, and vegetation conversion—are applied more aggressively in the zones closest to the structure.

Although the theory behind vegetation management is well understood and accepted among wildfire practitioners, very little empirical evidence exists to support it. In 2007, at a forested test site in the Northwest Territories, Canada, FPInnovations used experimental crown fire to evaluate the effectiveness of vegetation management (i.e., removal and reduction of forest fuel within Priority Zones 1 and 2) to protect a small building from wildfire.

STUDY OBJECTIVES

- Test and document the effectiveness of fuel reduction treatments in Priority Zones 1 and 2 in the wildland–urban interface in terms of protection to the structure during a wildfire.
- Document fire behaviour as the wildfire moves from the untreated natural stand to the fuel-reduced priority zones.

STUDY METHODS

FPInnovations established Test Plot 1 and Test Plot 2 in a northern boreal forest (Figure 2) with the aim of examining structure survivability during a wildfire. Small cabins were installed on each test plot, and vegetation management was conducted around each cabin. The test plots were ignited at 16:00 on June 27 and 28, 2007, and a crown fire was allowed to develop in a natural stand upwind of each plot. Weather data were collected at 12:00 from a remote-access weather station located 2 km from Test Plot 1 and 1 km from Test Plot 2. The station recorded hourly temperature, relative humidity, wind speed, and wind direction. The fire weather conditions observed on June 27 and 28 were sufficient for extreme wildfire behaviour (Table 1). On both days, the wind was from the east at 10 to 15 km/h, gusting to 22 km/h.

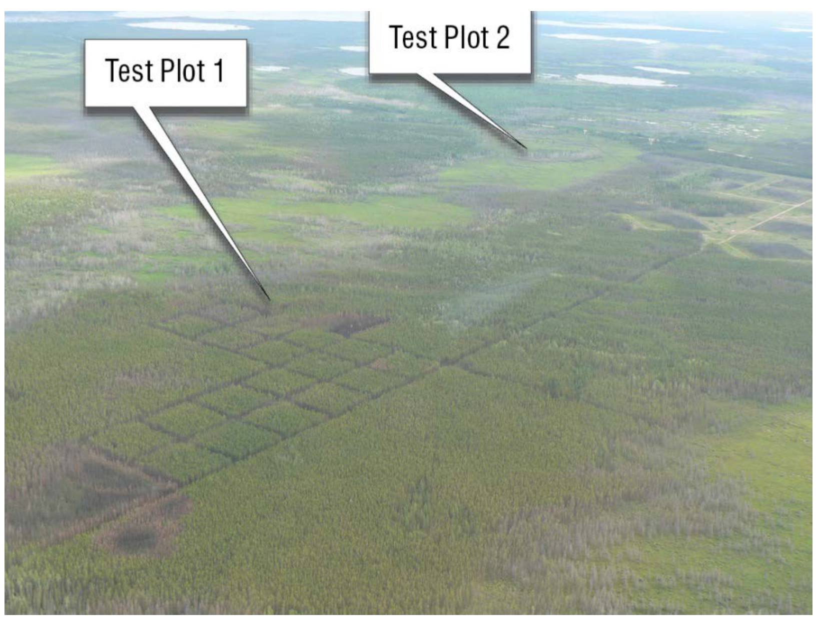

Figure 2. Eastward view of the two test plots located at the site of the Canadian Boreal Community FireSmart project near Fort Providence in Northwest Territories.

FPInnovations observed and documented fire behaviour and the fire's effects on the cabins as it moved through the fuel-reduced zones surrounding the cabins.

Table 1. Weather conditions and indices on the burn days

Conditions and indices	Test Plot 1 Noon, June 27, 2007	Test Plot 2 Noon, June 28, 2007
Temperature (^{o}C)	24	24
Relative humidity (%)	31	45
Wind (km/h)	E 11	E 8
Fine fuel moisture code	93	91
Initial spread index	11	7
Duff moisture code	132	136
Drought code	490	498
Build-up index	157	161
Fire weather index	41	31

Site description and layout

The study was conducted in a northern boreal forest at the site of the Canadian Boreal Community FireSmart project near Fort Providence. Fort Providence is about 300 km southwest of Yellowknife.

The overstorey vegetation in the natural stand was dominated by jack pine and black spruce. The understorey vegetation included black spruce and sparse shrubs. Feathermoss dominated the surface vegetation. The Canadian Forest Fire Behaviour Prediction System describes 16 fuel types common to Canadian forests (Forestry Canada Fire Danger Group 1992). The natural stand surrounding Test Plot 1 was characterized as a C-2 (black spruce) fuel type. The fuel types that most closely represented the natural stand surrounding Test Plot 2 were C-2 (black spruce) in the northern half and C-3 (mature jack pine) in the southern half.

Two small cabins were placed in Test Plot 1. Cabin A was placed 10 m from the natural stand, and Cabin B was placed 30 m from the natural stand (Figure 3). The cabins' features included: basic wood construction, asphalt roof shingles, vinyl siding (50% of exterior), cedar siding (50% of exterior) (Figure 4), a steel door, two double-pane windows, aluminum soffits, no foundations, and no flooring.

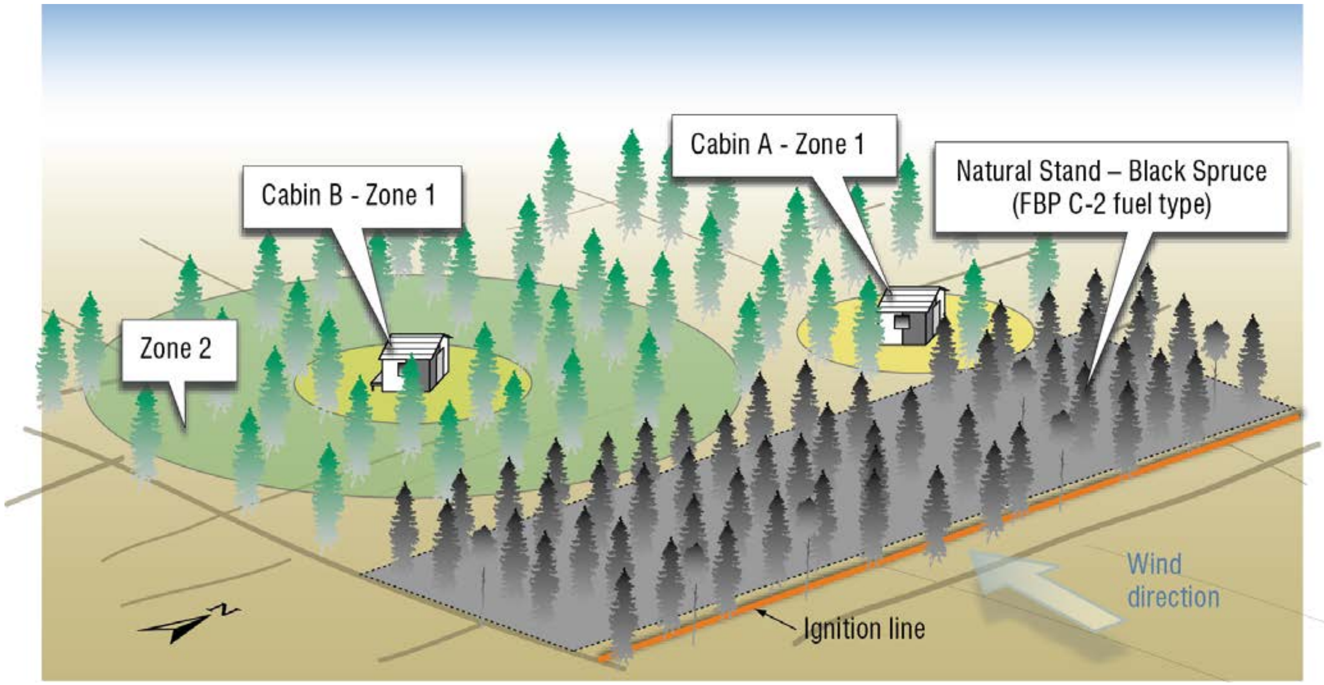

Figure 3. Layout of Test Plot 1, showing positions of Cabins A and B relative to the natural stand.

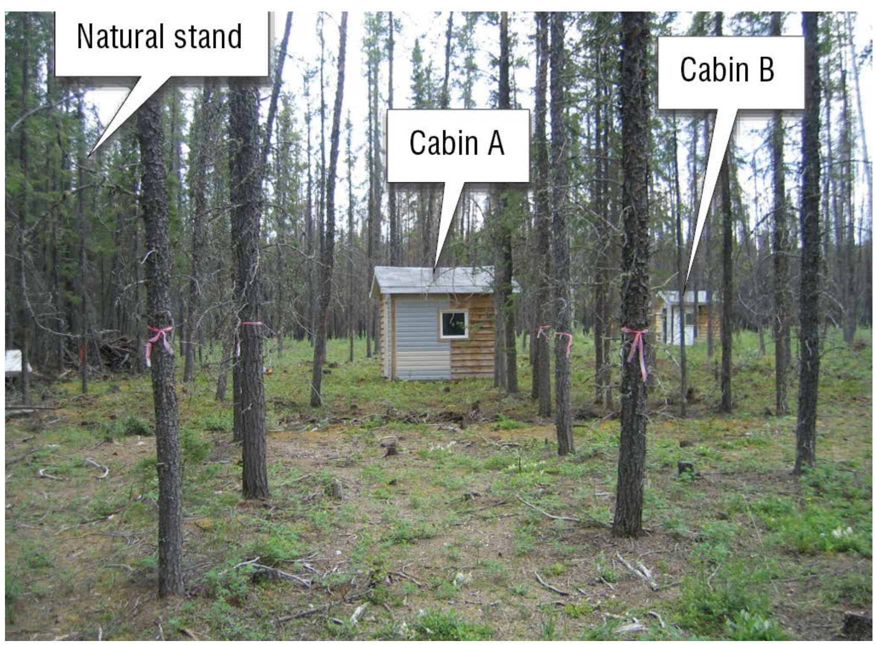

Figure 4. Cabins A and B in Test Plot 1 were constructed with wood, asphalt roof shingles, 50% vinyl siding, and 50% cedar siding.

Only one cabin was installed on Test Plot 2, and it was placed 10 m from the natural stand (Figure 5). Cabin C was larger than the two cabins on Test Plot 1 and was constructed in the same manner (Figure 6).

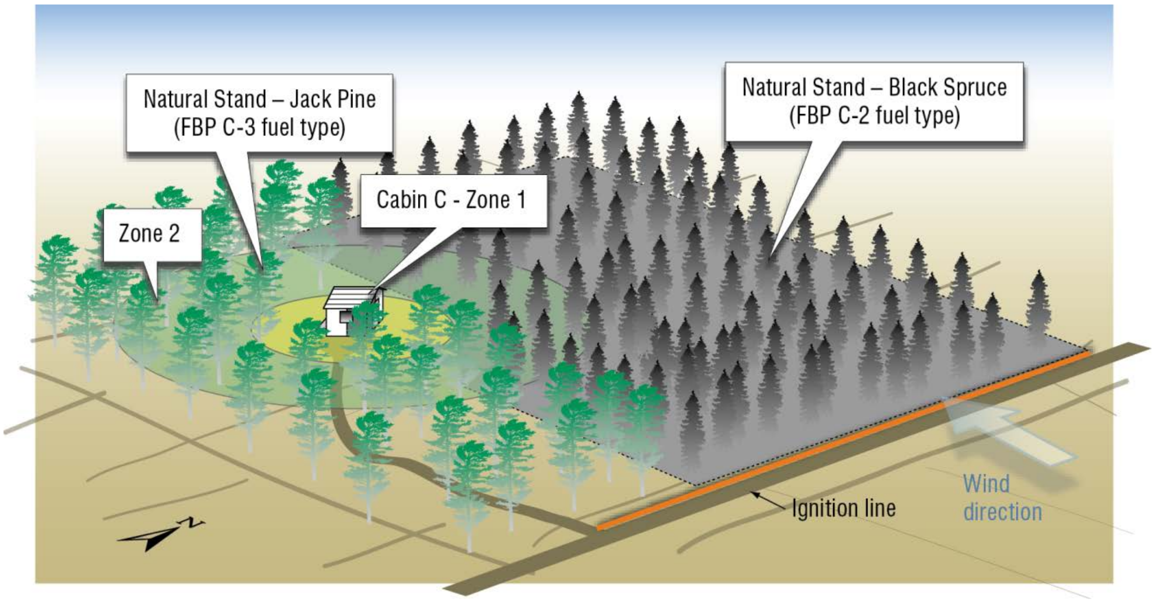

Figure 5. Layout of Test Plot 2, including fuel composition. Ignition was done along the north–south access trail.

Figure 6. Cabin C in Test Plot 2 had the same construction as the cabins in Test Plot 1 but it was somewhat larger.

Table 2. Fuel reduction prescriptions for Priority Zones 1 and 2 in Test Plots 1 and 2

	Test Plot 1		Test Plot 2
	Cabin A	**Cabin B**	**Cabin C**
Priority Zone 1			
Crown spacing	3.5 to 4 m	3.5 to 4 m	all trees removed in 1998
Ladder fuels	2 m crown base height	2 m crown base height	all removed in 1998
Surface fuels	raked and removed	raked and removed	all removed in 1998, but unmaintained; shrubs 1.5 m; grass 10 cm
Priority Zone 2			
Crown spacing	3.5 to 4 m	3.5 to 4 m	none
Ladder fuels	2 m crown base height	2 m crown base height	1.5 m crown base height
Surface fuels	dead and down removed	dead and down removed	unmaintained; sparse dead and down; moderate needle layer

Forest fuel treatments

The forest fuel treatments conducted in this project (Table 2) were based on the FireSmart guidelines (Partners in Protection 2003). The goal of FireSmart vegetation management in Zone 1 is to eliminate, or convert, any flammable vegetation surrounding the structure(s). The tactics for achieving this goal include:

- Regular mowing and irrigation of annual grasses
- Annual removal of ground litter
- Removal or reduction of fine woody fuels (fallen branches)
- Removal, conversion, or isolation of combustible shrubs and small trees
- Removal of dead standing and downed trees
- Removal of flammable mature trees that are immediately adjacent to structures
- Aggressive thinning of flammable overstorey
- Pruning of any remaining conifers (removal of live branches)
- Removal of forest debris created by thinning and pruning operations

The goal in Priority Zone 2 is to reduce fire intensity before it reaches a structure. The tactics rely more on fuel reduction and conversion than on fuel removal:

- Annual reduction of excessive ground litter and fine woody fuels
- Thinning, isolation, and pruning of immature conifers
- Thinning or spacing of flammable mature trees throughout the zone to prevent the spread of crown fire towards the structure
- Pruning of all mature conifers
- Removal of forest debris created by thinning and pruning operations

The goals and recommended guidelines for vegetation management in Priority Zone 3 are the same as those for Priority Zone 2 and are required when the terrain is sloped, or when the forest fuels are particularly dense and continuous.

The fuel treatments in Test Plot 1 were originally conducted in 2004; any remaining surface fuels were removed in 2007. All of Priority Zone 1 around Cabin A was treated, but in Priority Zone 2 the treatments were conducted only on the north, west, and south sides of the cabin (Figures 3 and 7). This allowed the fire (coming from the east) to encounter only a Zone 1 treatment before reaching the cabin, and provided researchers an opportunity to evaluate the effectiveness of a Priority Zone 1 treatment against a crown fire. For Cabin B in Test Plot 1, fuel treatments were completed in all portions of Zones 1 and 2 (Figures 3 and 8). A small firewood pile was placed on the eastern boundary between Zones 1 and 2. The nearest coniferous tree was 2 m from Cabin A and 3 m from Cabin B.

Figure 7. Fuel reduction in Priority Zones 1 (foreground) and 2 (background) surrounding Cabin A in Test Plot 1.

Figure 8. Fuel reduction in Priority Zones 1 (foreground) and 2 (background) surrounding Cabin B in Test Plot 1.

Test Plot 2 had been treated in 1998. At that time the overstorey, ladder fuels, and surface fuels were completely removed from Priority Zone 1 around Cabin C, and the ladder fuels and surface fuels were removed from Priority Zone 2. No other clean up of the surface fuels in Priority Zones 1 and 2 was conducted prior to this study.

RESULTS AND DISCUSSION

The fire in Test Plot 1 resulted in the destruction of Cabin A and only minor damage to Cabin B. The fire in Test Plot 2 resulted in minor damage to Cabin C.

Fire behaviour

Test Plot 1

Using a Terra Torch, a line ignition was started at the north end of the north–south access trail (Figure 3). The fire behaviour in the untreated stand was characterized as an active crown fire. The rate of spread ranged from 20 to 40 m/min, and flame height was estimated at 30 to 40 m. As the fire spread from the natural stand into the treated stand, the fire transitioned to a surface fire; the rate of spread was <1 m/min, and flame heights were estimated to be 0.5 m. Spot fires occurred throughout the treated stand due to flying embers, and some individual trees candled. The consumption of canopy fuels was limited to needles and small branches.

The observed fire behaviour within the Zone 1 areas varied considerably between Cabins A and B. In-fire video footage and post-fire analysis revealed that when the wildfire entered Zone 1 of Cabin A, the aerial and surface fuels ignited. This resulted in direct flame contact and subsequent ignition of the cabin (Figure 9). In contrast, when the wildfire entered Zone 2 of Cabin B, the aerial and surface fuels ignited, but they did not have sufficient energy to ignite fuels within Zone 1 (Figure 10). Firebrands entered Zone 1, but were not able to sustain flaming combustion. The surface fire in Zone 2 ignited and consumed the firewood pile at the boundary of Zones 1 and 2, which caused the surface fire to extend an additional 3 m into Zone 1. Cabin B sustained radiant heat damage to the vinyl siding on the side facing the oncoming fire.

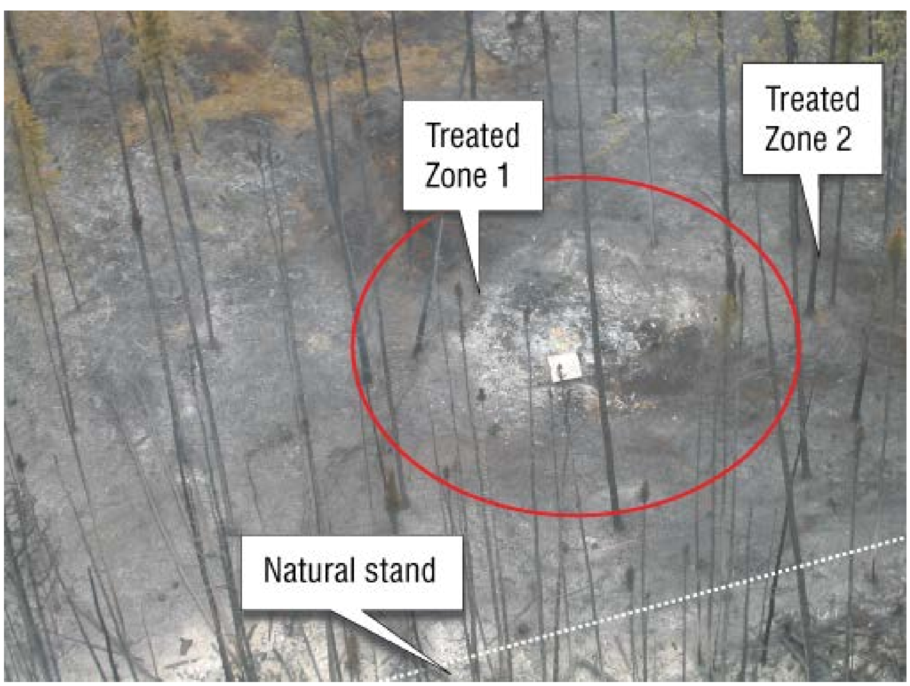

Figure 9. Cabin A in Test Plot 1: post-burn.

Figure 10. Cabin B in Test Plot 1: post-burn.

Test Plot 2

Using a Terra Torch, a line ignition was started at the north end of the north–south access trail (Figure 5). An active crown fire (continuous flaming front from surface to canopy fuels (Van Wagner 1977)) developed and moved with a rate of spread of approximately 22 m/min through the untreated portion of the C-2 stand. However, the ignition line generated only a passive crown fire (incomplete crown consumption, individual trees candling) within the C-3 portion of the untreated stand with a rate of spread of less than 5 m/min.

Figure 11 shows a post-fire view looking west. The extreme intensity of the active crown fire through the C-2 black spruce stand is clearly visible on the right side of the photo. Surface fire with minimal crown involvement in the C-3 jack pine stand can be seen on the left. Because of the wind direction and the variation in fuel type upwind of the cabin, Cabin C was exposed to a flanking fire instead of a head fire.

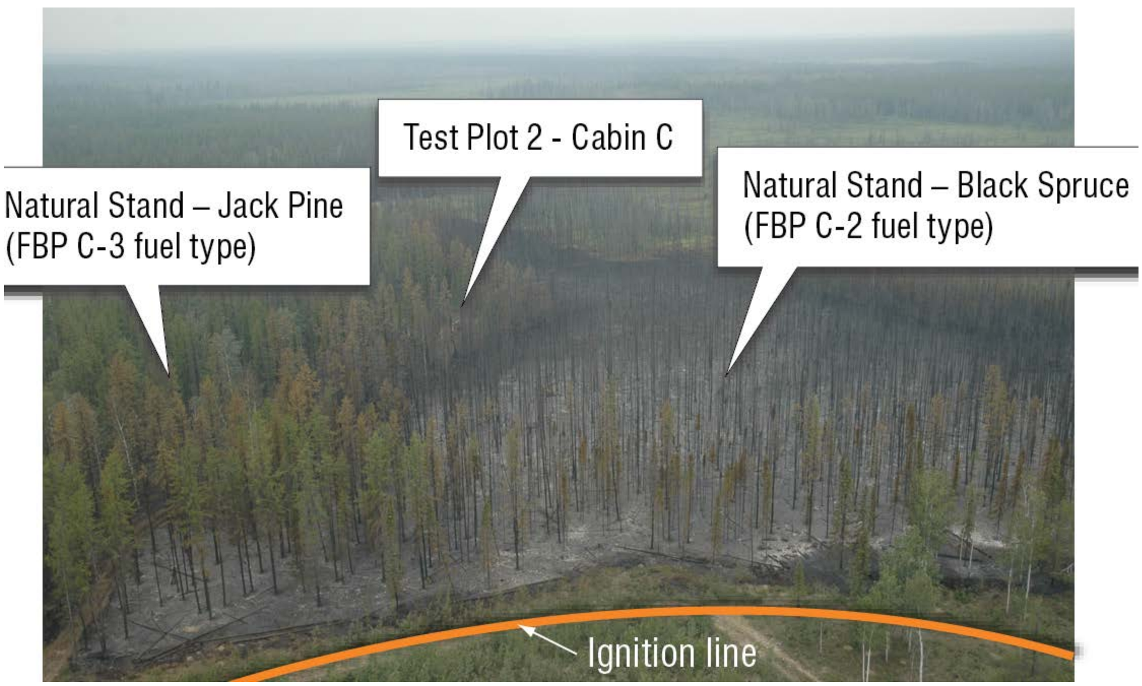

Figure 11: Cabin C in Test Plot 2: post-burn.

Fuel conditions within the treated, but unmaintained (i.e., needles, litter, and fine woody fuels not annually removed) Zone 1 supported spot fire ignition, but flaming combustion was not sustained (Figure 12). The vinyl siding on the north side of the cabin melted due to radiant heat from burning C-2 fuels. On the southeast corner of Cabin C, the vinyl siding was slightly scorched due to a grass fire that burned up to the wall. The minimal reduction in fuels in Zone 2 (particularly in the C-2 fuel type) that was completed in 1998 did not appear to significantly reduce fire intensity or the rate of spread compared to that in the natural stand.

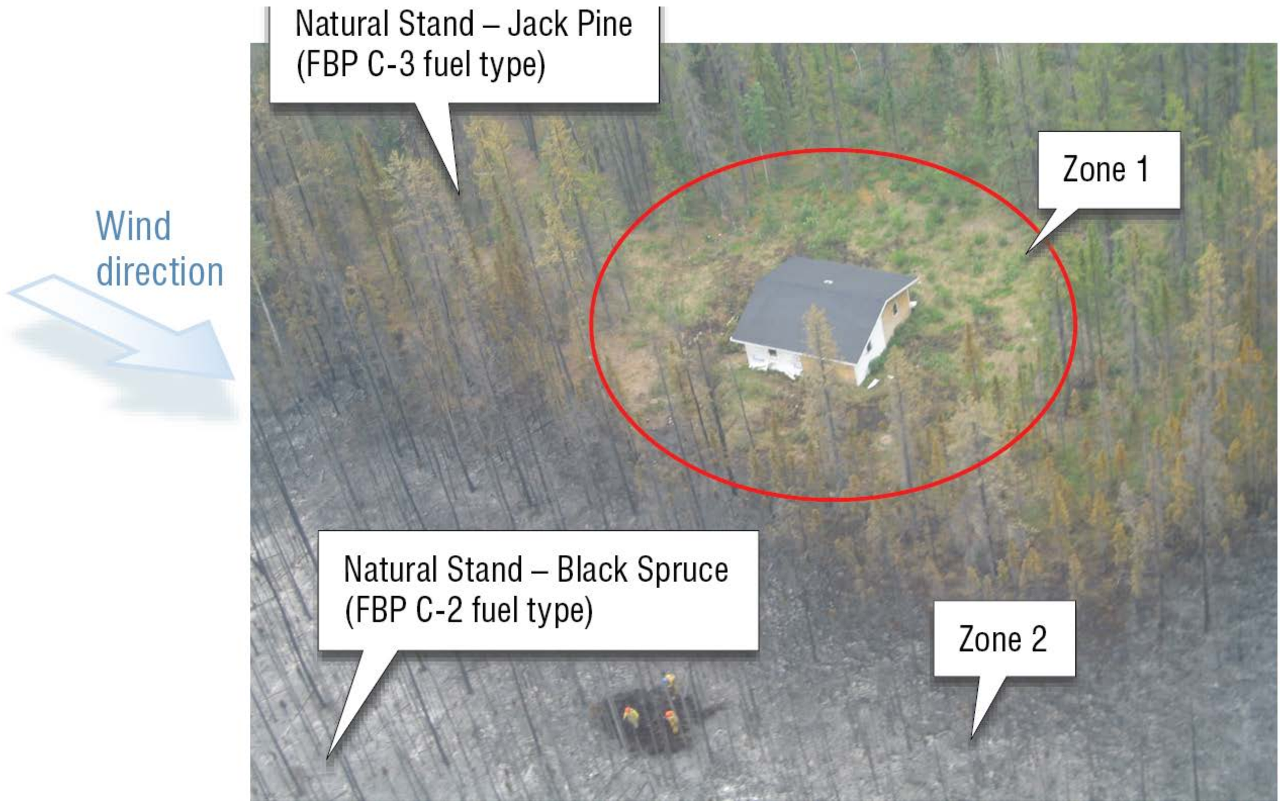

Figure 12: Cabin C in Test Plot 2: post-burn.

Radiant energy: heat flux measurements

If heat flux is <16 kW/m^2, the radiant energy is insufficient to ignite unfinished plywood (Quintiere 1997). If heat flux is ≥16 kW/m^2, plywood would need to be exposed for more than three minutes to ignite. The threshold for vinyl siding was not considered because our video footage showed the siding melting and falling off the building before peak heat flux—an event that had also been recorded by Dietenberger (1996). Our heat flux measurements (Table 3) showed that at 10 m from the natural (untreated) stand, the radiant heat flux measured >16 kW/m^2, but it was not sustained longer than one minute. At 20 m from the natural stand, only one of two sensors measured a radiant heat flux of >16 kW/m^2. At 30 m, the radiant heat flux was <16 kW/m^2. Heat flux was not recorded within the natural stand; however, Butler et al. (2004) recorded a maximum heat flux of 290 kW/m^2 within crown fires in the International Crown Fire Modelling Experiment (Stocks et al. 2004), and the heat flux peak was recorded at 3.1 to 3.8 m above the ground. Because our sensors were positioned 1.5 m above ground, it is reasonable to expect that the structures—with a height of 3 m at the roof peak—were actually exposed to greater heat flux than what we recorded.

Table 3. Heat flux measurements in Priority Zones 1 and 2 in Test Plot 1

Distance	Sensor	Maximum heat flux[a] (kW/m^2)	Time above threshold (seconds)
10 m	A	41.2	58
	B	91.7	37
20 m	A	16.5	2
	B	11.7	0
30 m	A	11.6	0

[a] Duration was not greater than 2 seconds for any of the maximum readings.

CONCLUSIONS

The results of our experimental burns strongly indicate that certain fuel reduction treatments were effective in reducing fire intensity and improving probability of structure survival. This experiment also validated the effectiveness of what has become the standard for fuel treatments within many wildland–urban interface properties in western Canada. This study showed that undertaking vegetation management within Priority Zones 1 and 2 (Figure 1) can improve the probability of structure survival in coniferous fuel types subjected to extreme intensity crown fire.

The in-fire video footage for Test Plots 1 and 2 clearly revealed that under extreme wildfire conditions, fuel reduction treatments that had been applied in Priority Zones 1 and 2 provided the greatest reduction in fire intensity and rate of spread. The combined fuel treatments in these two zones increased the open, or non-vegetated, area between the natural stand and the cabin, thus giving the fire space to transition from crown fire to low intensity and sporadic surface fire. With the resulting reduction in radiant heat exposure, the probability of structure survival is increased. However, conducting fuel treatments only in Priority Zone 1 provides less reduction in fire intensity and a lower probability of structure survival. While limiting fuel reduction treatments to Priority Zone 1 alone may be adequate for a lower intensity fire (Test Plot 2) or a flanking fire, our results demonstrated that this approach is not adequate for protecting a structure from an extreme fire. These results show that ignition and spread of fire in combustible surface fuels— whether from advancing fire (Cabin A in Test Plot 1) or flying embers—could result in structure loss. This reinforces the importance of eliminating flammable surface fuels within Priority Zone 1. These results also indicate that relaxed implementation of fuel reduction guidelines in Priority Zone 2 results in a minimal reduction of fire intensity, which may not be sufficient for structure survival.

The heat flux measurements indicated a pronounced decrease in radiant energy with increased distance from the natural stand. This decrease in radiant energy as fire moves through the treated stands validates the need to implement the FireSmart vegetation management strategy.

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