Project Note
January 2012

FPInnovations
Wildfire Operations Research
1176 Switzer Drive
Hinton, AB T7V 1V3

Evaluating the Effectiveness of *FireSmart*™ Priority Zones for Structure Protection

Stew Walkinshaw

Dave Schroeder

Steven Hvenegaard

Keywords

FireSmart™, vegetation management, fuel reduction, fuel treatment, wildfire, wildland urban interface

Abstract

During wildland urban interface wildfire events, homes and industry facilities, and other values are often threatened by encroaching wildfire. Vegetation management is one of the key principles recommended by the *Fire Smart* program to mitigate the risk of wildfire. In this project, FPInnovations studies and documents forest fuel removal and reduction as vegetation management strategies.

Introduction

Vegetation management within the *FireSmart* Priority Zones is promoted by Partners in Protection (2003) to reduce wildfire intensity and rate of spread as it approaches structures or developed areas to improve the probability of structure survival. The three priority zones (Figure 1) are defined as follows (Partners in Protection 2003):

> ***Priority Zone 1 (Zone 1):*** the area immediately adjacent to a structure extending a recommended minimum of 10 metres from the structure.
>
> ***Priority Zone 2 (Zone 2):*** the area beginning 10 metres from a structure and extending to 30 metres.
>
> ***Priority Zone 3 (Zone 3):*** the area beginning 30 metres from a structure and extending to 100 metres or further from the structure.

The primary vegetation management strategies within these zones are fuel removal, fuel reduction, and fuel conversion. The strategies are applied more aggressively closest to structures.

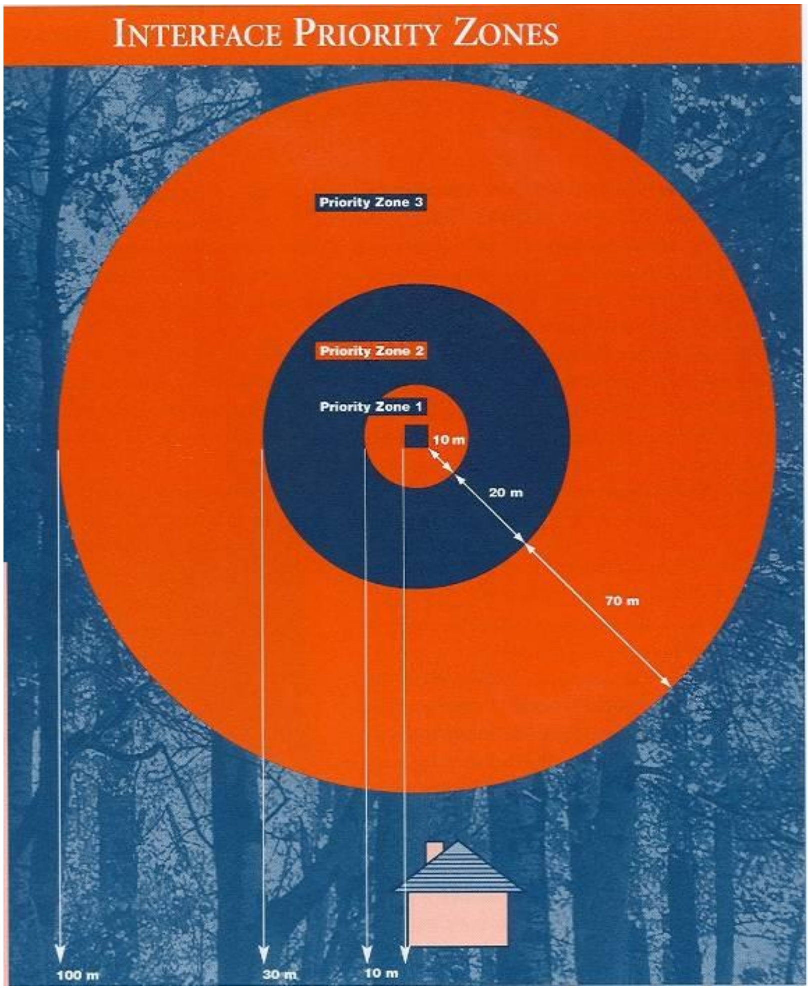

Figure 1: FireSmart Priority Zones

FPInnovations established two test plots with test cabins erected in each plot to evaluate the effectiveness of vegetation management within Zones 1 and 2 on structure survivability. Crown fire was initiated in a natural stand upwind of the plots and fire behaviour and its impact on the cabins were observed and documented as the fire moved through the fuel reduced zones surrounding the cabins.

Objectives

- Test the effectiveness of fuel reduction treatments in Priority Zone 1 and Priority Zone 2 for wildland/urban interface structure protection.
- Observe and document fire behaviour conditions during fire transition from an untreated natural stand to fuel-reduced Priority Zones.
- Observe and document the wildfire impact on structures surrounded by priority zones that have received varying fuel treatments.

Methods

Site Description

The research site is located at the Canadian Protection Trials (formerly International Crown Fire Modeling Experiment (ICFME)) near Fort Providence, NWT. Two separate plots were used to conduct the research (Fig 2). Vegetation on the plots is dominated by jack pine and black spruce in the overstory. Understory vegetation includes black spruce with sparse shrubs and surface vegetation is dominated by feathermoss. A detailed description of the ICFME fuel complex including forest vegetation and fuel loading is available in Alexander et al (2004). The vegetation in the natural stands surrounding the Plot 1 thinned area matches the fuel characterizations of the ICFME burns (fig 3). However, plot 2 does not have the same uniformity in tree species or fuel type. The Canadian Forest Fire Behaviour Prediction (FBP) fuel types that most closely represent the natural stands surrounding the Plot 2 cabin and *FireSmart* treatments are black spruce (C-2) in the north half and mature pine (C-3) in the south half (figure 5).

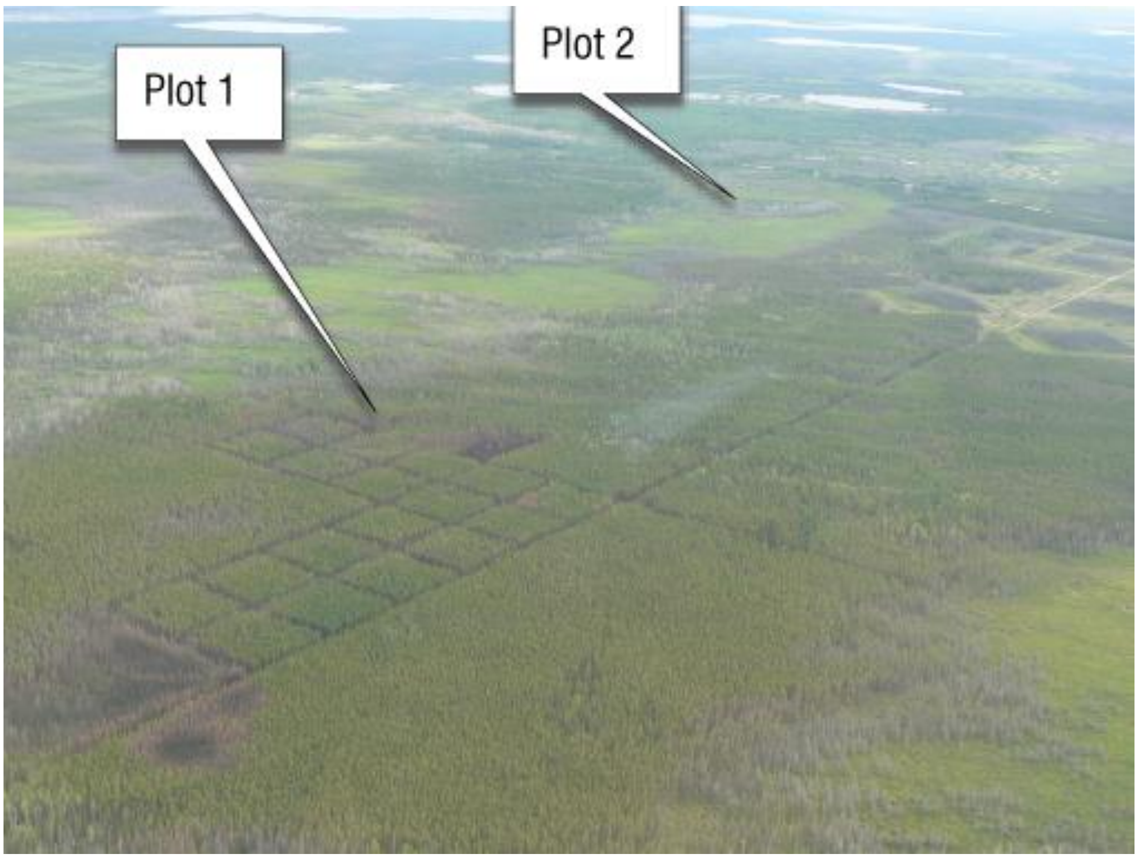

Fig 2. NWT research site looking east. Highway 3 is in the background.

Cabin Locations and Building Materials

Plot 1

Two cabins were erected in Plot 1. Cabin 1 was placed 10 metres from the natural stand and Cabin 2 was placed 30 metres from the natural stand (Figure 3). Cabins were constructed with asphalt shingle roofing materials and a 50% combination of vinyl and cedar siding (Figure 4). The cabins were also fitted with two double pane windows, a steel storm door and aluminum soffits. There was no foundation materials or flooring installed.

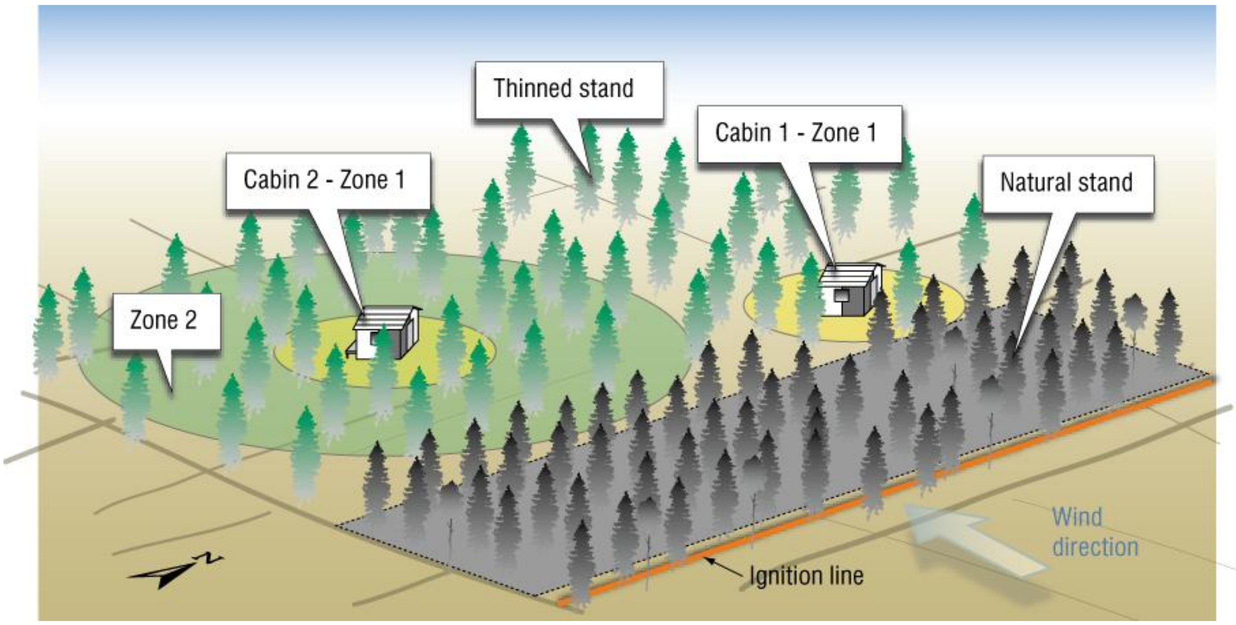

Figure 3. Plot 1 layout.

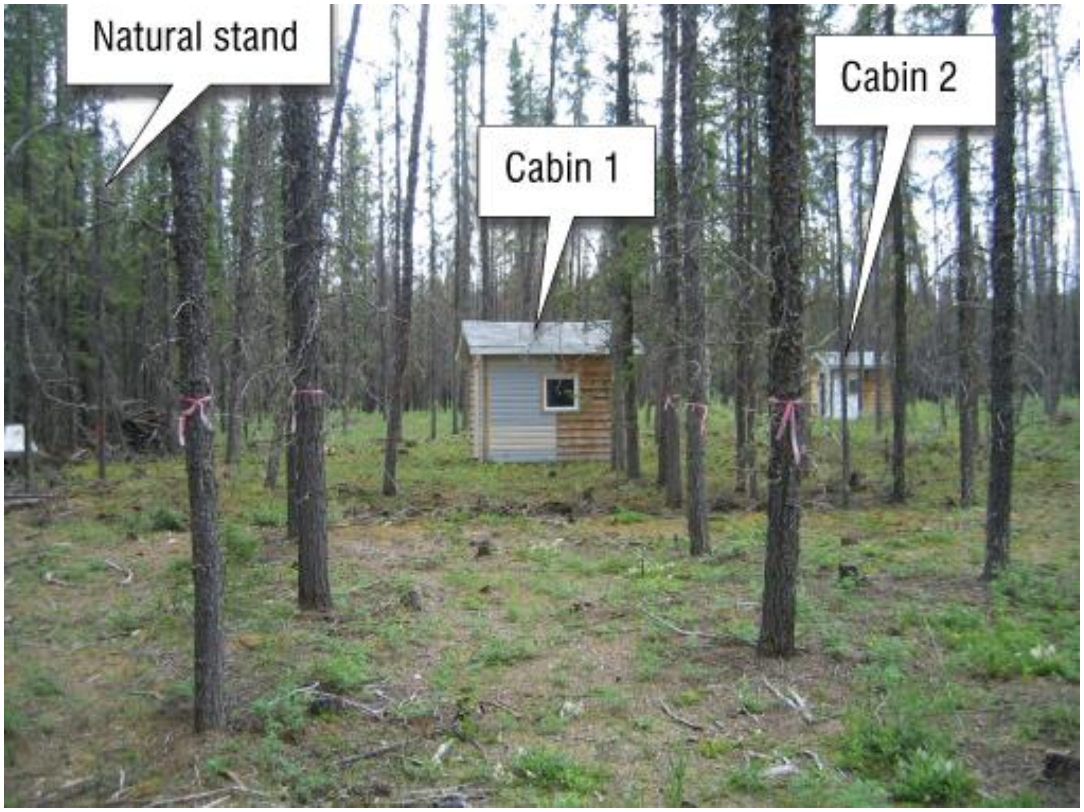

Figure 4: Plot 1 cabins

Plot 2

One structure, erected for earlier research, was used for this test. The cabin was 10 metres from the modified stand (Figure 5) and was constructed with the same exterior structural materials as the Plot 1 cabins (Figure 6).

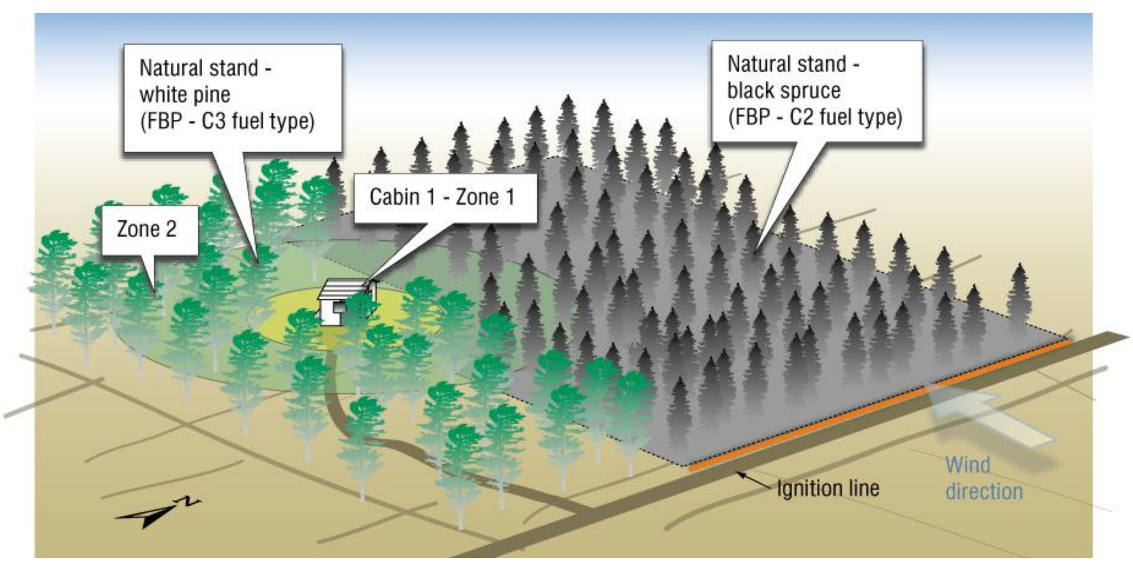

Figure 5. Plot 2 layout. Ignition was done along the north-south access trail.

Figure 6: Plot 2 cabin

Forest Fuel Treatment

The fuel treatments implemented in this research project were based on the guidelines prescribed in *FireSmart:* Protecting your community from wildfire (Partners in Protection 2003) but did not strictly adhere to these guidelines. It is beneficial to recognize these variations in fuel treatment tactics within the overall fuel environment and analyze the impact that the implemented fuel treatments had on fire behaviour and the structure survival.

The goal of *Fire Smart* vegetation management in Zone 1 is to create a fuel modified area in which flammable vegetation surrounding buildings is eliminated or converted to a less flammable species. The *Fire Smart* fuel treatment tactics prescribed to achieve this goal include:

- Regular mowing and irrigation of annual grasses
- Removal of ground litter annually
- Removal or reduction of fine woody fuels (branches)
- Remove, convert, or isolate combustible shrubs and small trees
- Removal of dead standing and downed trees
- Removal of flammable mature trees immediately adjacent to structures, aggressive thinning of flammable overstory that may carry fire toward the structure, and pruning of any remaining conifers

The goal of vegetation management in Priority Zone 2 is similar in terms of reducing fire intensity but more reliant on reduction and conversion than on removal strategies. Prescribed *Fire Smart* tactics to achieve this goal include:

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

The goals and recommended guidelines for vegetation management in Priority Zone 3 are similar to those of Priority Zone 2. Fuel treatments in Priority Zone 3 are an extension of those treatments in Priority Zone 2 where considered necessary due to sloping terrain or heavy, continuous forest.

Plot 1

Fuel treatments for Cabin 1 were completed in Zone 1 however fuel treatments in Zone 2 were only completed on the north, west, and south sides of the cabin (Figures 3 and 7). This would allow the fire coming from the east to encounter only a Zone 1 treatment before reaching the cabin. Fuel treatments for Cabin 2 were completed in Zones 1 and 2 (Figure 3 and 8). See details of the fuel treatments conducted in each plot as detailed in Table 1.

The nearest coniferous overstory trees to Cabin 1 were 2 metres from the cabin and for Cabin 2 were 3 metres from the cabin.

Figure 7 – Plot 1 cabin 1 fuel reduction

Figure 8 – Plot 1 cabin 2 fuel reduction

Plot 2

Complete overstory removal in Zone 1 and ladder and removal of ground fuels in Zone 2 was completed in 1998 in preparation for another research project[1]. Debris created from this fuel treatment was removed from the plot. No further work was conducted on Zones 1 or 2 fuels prior to the 2007 research burn. Consequently, Zone 1 was overgrown with sparse deciduous shrubs and grass that extended to the sides of the structure. Zone 2 had a moderate layer of dead needle litter with minor dead and down woody material.

Table 1: Plots 1 and 2 Zone 1 and Zone 2 fuel reduction prescriptions

Priority Zone	**Plot 1**		**Plot 2**
	Cabin 1	**Cabin 2**	**Cabin 1**
Zone 1	Crown Spacing 3.5 - 4.0 m Ladder Fuels – 2.0 m CBH* Surface Fuels – raked and removed.	Crown Spacing 3.5 - 4.0 m Ladder Fuels – 2.0 m CBH Surface Fuels – raked and removed	Overstory & understory completely removed (1998). Surface Fuels - unmaintained poplar shrub cover (1.5m) & native grass layer 10 cm tall.
Zone 2	Crown Spacing 3.5 - 4.0 m Ladder Fuels – 2.0 m CBH Surface Fuels – Dead/down woody removed.	Crown Spacing 3.5 - 4.0 m on north, west, and south sides, no treatment on east side. Ladder Fuels – 2.0 m CBH on north, west, & south sides, no treatment on east side. Surface Fuels –Dead/down woody removed on north, west, and south sides; no treatment on east side.	No overstory or understory thinning. Ladder fuels – 1.5 m CBH Surface fuels – minor dead/down, moderate needle litter layer in C2 and C3 stands.

** CBH – Crown Base Height*

Fire Behaviour and Structure Survival Documentation

Ground and aerial video and digital camera documentation were the primary tools used to observe the test results as well as direct observation during and after the tests. Rate of spread data loggers were also installed in the natural stands for both burns.

[1] This plot was part of Canadian Forest Service (M.E. Alexander) work to test NFPA 299 (NFPA 1144) – Protecting Life and Property from Wildfire

Zone 1 and 2 – Radiant Energy Exposure

Heat transfer from the head of a forest fire is primarily through radiant energy (Butler et al 2004) and can ignite structures. Sensors were installed in the thinned stand during the 2005[2] and 2007[3] burns to measure radiant energy at 10, 20 and 30 m from the boundary between the natural and thinned stands. Sensors were placed 1.5 m above the ground pointed toward the natural stand and into the oncoming fire.

[2] See Schroeder 2006 FERIC Wildland Fire Operations web report

[3] See Schroeder 2010 FPInnovations Advantage Report

Results and Discussion

The fires in Plot 1 and Plot 2 were ignited on June 27, 2007 and June 28, 2007, respectively. Fire weather conditions and indices were sufficient for extreme wildfire behaviour (Table 2). The Plot 1 burn resulted in destruction of Cabin 1 and only minor damage to Cabin 2. The Plot 2 burn the following day resulted in minor damage to the cabin.

Table 2: Plots 1 and 2 fire weather conditions and indices

Fire Weather Conditions and Indices	Plot 1 June 27	Plot 2 June 28
Temperature (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

* Noon weather readings. Weather station located approximately 2 km from Plot 1 and 1 km from Plot 2.
** Wind at time of both fires from East at 10-15km/h, gusting to 22 km/h

Fire Behaviour

Plot 1

The fire behaviour initiated in the untreated stand was characterized as active crown fire. Rate of spread ranged from 20 - 40 metres/minute and flame height was estimated at 30-40 metres.

As the fire spread from the natural stand into the thinned stand, the fire transitioned to a surface fire with flame heights estimated at 0.5 metre and rate of spread of less than 1 metre/minute.

Spot fires occurred throughout the thinned stand due to flying embers, and some trees candled (consumption of canopy fuels – needles and small twigs) individually after the transition.

Observed fire behaviour within the Zone 1 areas varied considerably for Cabins 1 and 2.

Cabin 1

In-fire video and post-fire analysis revealed that when the wildfire entered the Cabin 1 Zone 1 area, ignition of the modified aerial and surface wildland fuels resulted in direct flame impingement and ignition of the cabin (Figure 9).

Cabin 2

In contrast, when the wildfire entered the Cabin 2 Zone 2 area, ignition of aerial and surface fuels occurred but did not have sufficient energy to ignite fuels within the treated Zone 1 area (Figure 10). Firebrands entered Zone 1 but were not able to sustain flaming combustion due to lack of fuel. Zone 2 surface fire did ignite the firewood pile at the Zone1-Zone 2 boundary, resulting in surface fire extending an additional 3 metres into Zone 1. Cabin 2 sustained radiant heat damage to the vinyl siding on the front side facing the head fire.

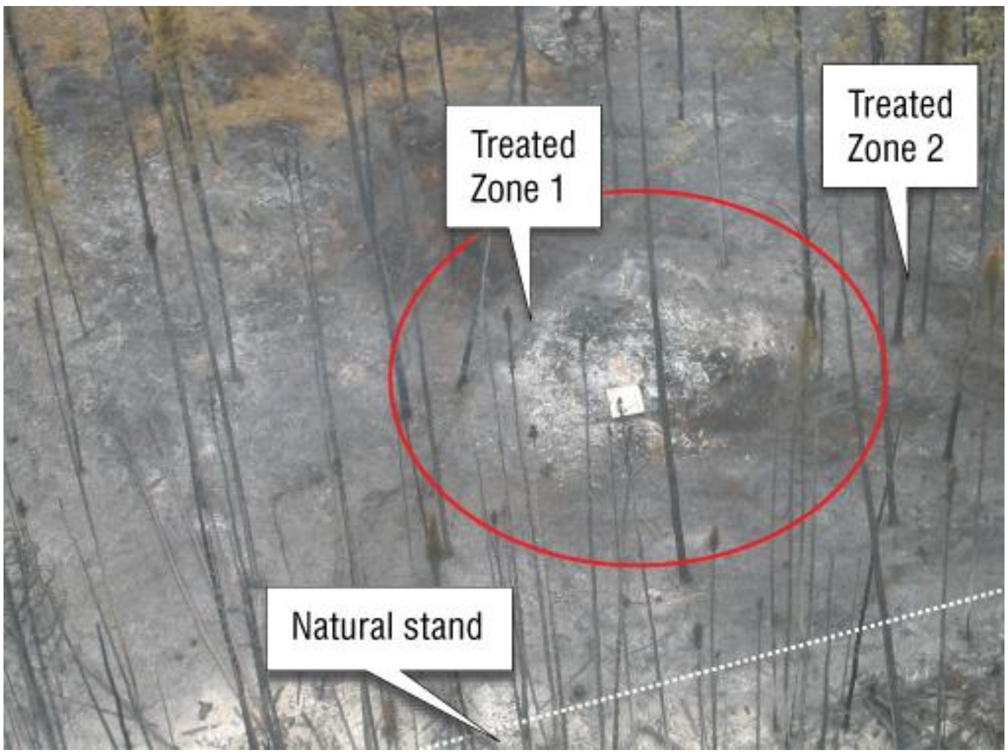

Figure 9: Plot 1 cabin 1 post-burn

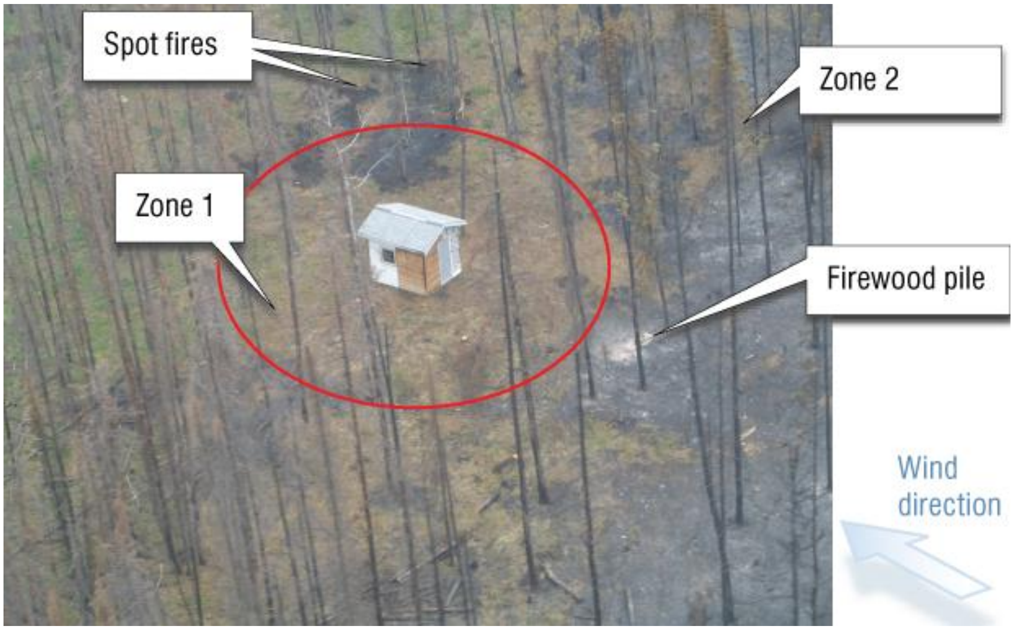

Figure 10: Plot 1 cabin 2 post-burn

Plot 2

Line ignition was initiated with a terra torch starting at the north end of the N-S 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. The rate of spread in the C-3 fuel type (less than 5 m/min) was much slower compared to the C-2 fuel type. Figure 11 shows a post-fire view looking west. The extreme intensity of an active crown fire through the black spruce stand is clearly visible on the right side of figure 11 and surface fire in the pine on the right. Due to wind direction and variation in fuel type upwind from the cabin, this cabin was exposed to a flanking fire instead of a head fire.

Figure 11: Plot 2 post-burn

Fuel conditions within the thinned but unmaintained (i.e. needles, litter and fine woody fuels not annually removed) Zone 1 area supported spot fire ignition of cured grass patches. Due to the absence of surface debris in the Zone 1 area flaming combustion was not sustained (Figure 12). Damage to the cabin included melting of vinyl siding on the north side of cabin from radiant heat in burning C-2 fuels and slight scorching of vinyl siding on southeast corner from surface grass fire burning up to cabin wall. The minimal Zone 2 fuels reduction (particularly in the C-2 fuel type) completed in 1998 did not appear to reduce fire intensity or rate of spread significantly compared to fire behaviour in the natural stand.

Figure 12: Plot 2 cabin 1 post-burn

Heat Flux Measurements

Results of the heat flux measurements were summarized by peak value, and amount of time when heat flux was greater than 16 kw/m^2 (Table 3). The 16 kw/m^2 level is the threshold below which ignition due to radiant energy will not occur for unfinished plywood (Quintiere1997). It should be noted that exposure time is also a factor and at 16 kw/m^2, plywood would need to be exposed for over three minutes before igniting. The threshold for vinyl siding was not chosen because video evidence from the 2007 fires shows the siding melting and falling off the building before the onset of peak heat flux, a characteristic also recorded by Dietenberger (1996). Measurements recorded in 2005 and 2007 indicate that at a 10 m distance from the natural stand, radiant heat flux ignition threshold is not sustained long enough to achieve ignition of the plywood. At 20 m distance, the heat flux was only above the plywood ignition threshold for one of the sensors, and at 30m the heat flux did reach the ignition threshold. Heat flux was not recorded within the natural stand; however, Butler et al (2004) recorded heat flux within crown fires burned as part of the International Crown Fire Modeling Experiment (Stocks et al 2004). They recorded a maximum energy flux of 290 kw/m^2 exposure and also found that sensor height was important with higher energy fluxes recorded at greater heights. Our sensors were 1.5m above ground whereas heat flux peak in the ICFME burns was recorded at heights of 3.1 to 13.8m above the ground. Therefore, it is reasonable to expect that the structures in the test fire (3 m tall at the roof peak) were exposed to greater heat flux than we recorded.

Table 3: Recorded heat flux in the thinned stand during the 2005 and 2007 test burns

Distance from sensor to border between thinned and natural stand	10 m			20 m			30 m	
Year of test burn	2007		2005	2007		2005	2007	2005
	Sensor 1	Sensor 2	Sensor 1	Sensor 1	Sensor 2	Sensor 1	Sensor 1	Sensor 1
Seconds of > 16 kw/m^2exposure	58	37	50	2	0	0	0	0
Max heat flux (kw/m^2)*	41.2	91.7	59.5	16.5	11.7	7.5	11.6	2.7

**Duration was not greater than 2 seconds for any of the readings.*

Conclusions

While the fuel treatments in these case studies did not conform entirely to recommended *FireSmart* (2003) guidelines, the results of this project strongly indicate that certain fuel reduction treatments were effective in reducing fire intensity and improving probability of structure survival. The experiment also validates the effectiveness of a fuels reduction standard that exists around many wildland/urban interface properties in Western Canada.
These two research burns showed that vegetation management within Priority Zones 1 and 2 can improve the probability of structure survival in coniferous fuel types subject to extreme intensity crown fire.

Review of in-fire video footage for plots 1 and 2 clearly reveals that under extreme wildfire conditions, fuel reduction treatments applied in both Priority Zone 1 and Priority Zone 2 provided the greatest reduction in fire intensity and rate of spread prior to reaching the structures. The combined fuel treatments in these two zones provided additional area between the natural stand and the cabin to support the 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, fuels reduction in Priority Zone 1 only provides less reduction in fire intensity and a reduced probability of structure survival. While limiting fuel reduction treatments to Priority Zone 1 may be adequate for lower intensity head fire (Plot 2) or flanking fire, our results demonstrate that this approach is not adequate to provide structure protection from extreme head fire assault. Results indicate that ignition and spread of fire through combustible surface fuels can result in structure loss (Plot 1 Cabin 1).

Results also indicate that relaxed implementation of fuel reduction guidelines in Priority Zone 2 results in minimal reduction of fire intensity which may not be sufficient for structure survival.

Heat flux measurements indicate a pronounced decrease in radiant energy with increased distance from the natural fuel stand. This decrease in radiant energy as fire moves through the thinned stands validates the implementation of the *Fire Smart* vegetation management strategy.

Implementation

The results of this study support the implementation of the *Fire Smart* vegetation management program (specifically fuels reduction) as a viable strategy for homeowners and other interface stakeholders to improve the probability of structure survival under extreme wildfire conditions in the boreal fuel environment. Even though other forest fuel environments differ from this environment under study, the potential for extreme fire behaviour exists in most forest fuel environments. Regardless of location and forest fuel type, interface stakeholders should consider vegetation management tactics as essential measures in a wildfire structure protection strategy in the wildland urban interface.

Practical guidelines to implement vegetation management strategies can be found in *FireSmart – Protecting Your Community from Wildfire* (2003) at www.partnersinprotection.ab.ca. Guidelines published in this manual are considered minimum treatments. Stakeholders must ensure that fuels management is conducted based on potential fire behaviour. To assess potential fire behaviour of a specific area and determine specific fuel treatments, stakeholders are advised to speak to a wildland/urban interface professional.

References

Alexander, M.E.; Stefner, C.N.; Mason, J.A.; Stocks, B.J.; Hartley, G.R.; Maffey, M.E.; Wotton, B.M.; Taylor, S.W.; Lavoie, N.; Dalrymple; G.N.. 2004. Characterizing the Jack Pine – Black Spruce fuel complex of the International Crown Fire Modelling Experiment (ICFME). Canadian Forest Service, Northern Forestry Centre. Edmonton, Canada. Inf. Rep. NOR-X-393

Butler, B.W., Cohen, J., Latham, D.J., Schuette, R.D., Sopko, P., Shannon, K.S., Jimenez, D., Bradshaw, L.S. 2004. Measurements of radiant emissive power and temperatures in crown fires. Can. J. For. Res. 34: 1577-1587.

Dietenberger, M.A. 1996. Ignitability analysis of siding materials using modified protocol for Lift apparatus. Fire and Materials. 20: 115-121.

FCFDG 1992. Development and structure of the Canadian Forest Fire Behavior Prediction System. Forestry Canada Fire Danger Group, Forestry Canada. Ottawa, Canada. Inf. Rep ST-X-3. 63 pp.

Partners in Protection. 2003.Fire Smart: Protecting your community from wildfire. 2nd edition. http://www.partnersinprotection.ab.ca/ (URL checked on Jan 30, 2008).

Quintiere, J.G. 1997. Principles of Fire Behavior. Delmar Publishers. New York. 258 pp.

Schroeder, D. 2006. Effectiveness of Forest Fuel Management: A Crown fire Case Study in the Northwest Territories, Canada. FERIC Wildland Fire Operations web report.

Schroeder, D. 2010. Fire behaviour in thinned jack pine: two case studies of Fire Smart treatments in Canada's Northwest Territories. FPInnovations Advantage Report.

Stocks, B.J., Alexander, M.E.; Wotton, B.M.; Stefner, C.N.; Flannigan, M.D.; Taylor, S.D.; Lavoie, N.; Mason, J.A.; Hartley, G.R.; Maffey, M.E. Dalrymple, G.N.; Blake, T.W.; Cruz, M.G.; Lanoville, R.A.. 2004. Crown fire behavior in a northern jack pine-black spruce forest. Can. J. For. Res. 34: 1548-1560.

Taylor, S.W., Pike, R.G., Alexander, M.E., 1997. Field guide to the Canadian Forest Fire

Behavior Prediction (FBP) System. Can. For. Serv., North. For. Cent., Edmonton, AB, Spec. Rep. 11.

Van Wagner, C.E. 1977. Conditions for the start and spread of crown fire. Can. J. For. Res. 7: 23-34.

Acknowledgments

The authors would like to thank the Government of Northwest Territories for their support of this project. Thanks to the Fort Providence fire crews for their work to prepare the plots and conduct the test burns.

Reviews of earlier versions of this document by A. Westhaver, A. Gossell, D. Small and G. Kettyle are appreciated.

Thanks to Mark Ackerman for support in measuring and compiling heat flux data.