Haines Junction Fire HJ-03-97
July 5, 1997

FIRE BEHAVIOUR CASE STUDY

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Introduction

The Haines Junction wildfire HJ-03-97 was of particular interest to both the resource management community as well as the residence of Haines Junction. Over the past 4 years much of the mature white spruce (*Picea glauca*) has been under extensive attack by spruce bark beetles (*Dendroctonus rufipennis*). Tree mortality has been extensive and the degree to which it has affected the wildfire hazard is a topic of ongoing debate.

On the day of discovery and initial attack of this fire the Fire Danger Class of the Haines Junction area was low. Normally, fires that ignite and burn under this danger class are of the surface fire type, within the range of direct attack with handtools and water. This however was not the case for this fire which clearly exhibited crown fuel involvement.

The HJ-03 fire burned a total of 6 hectares and was controlled and extinguished only as a result of an extensive fire suppression operation.

The initial investigation of this fire was to examine the degree to which the beetle killed spruce fuel component contributed to the observed fire behaviour. What the investigation revealed was two distinctly different fuel structures in the "mature beetle killed spruce" where the fire ignited and the "immature spruce regeneration" into which the fire spotted. Both of these fuel complexes contained structure anomalies which influenced the observed fire behaviour on July 5th and will influence future fires.

The affects of the beetle killed spruce from the mature spruce type and the dead and down fuel loading from the immature spruce regeneration type on fire behaviour serves as a lesson in fuel complex structure.

Fire Behaviour Case Study of the Haines Junction Fire HJ-03-97

Fire Location

The fire was located geographically at 60° 47' latitude and 137° 37' longitude. It was approximately 7.5 kilometers Northwest of the Community of Haines Junction (Figure 1.).

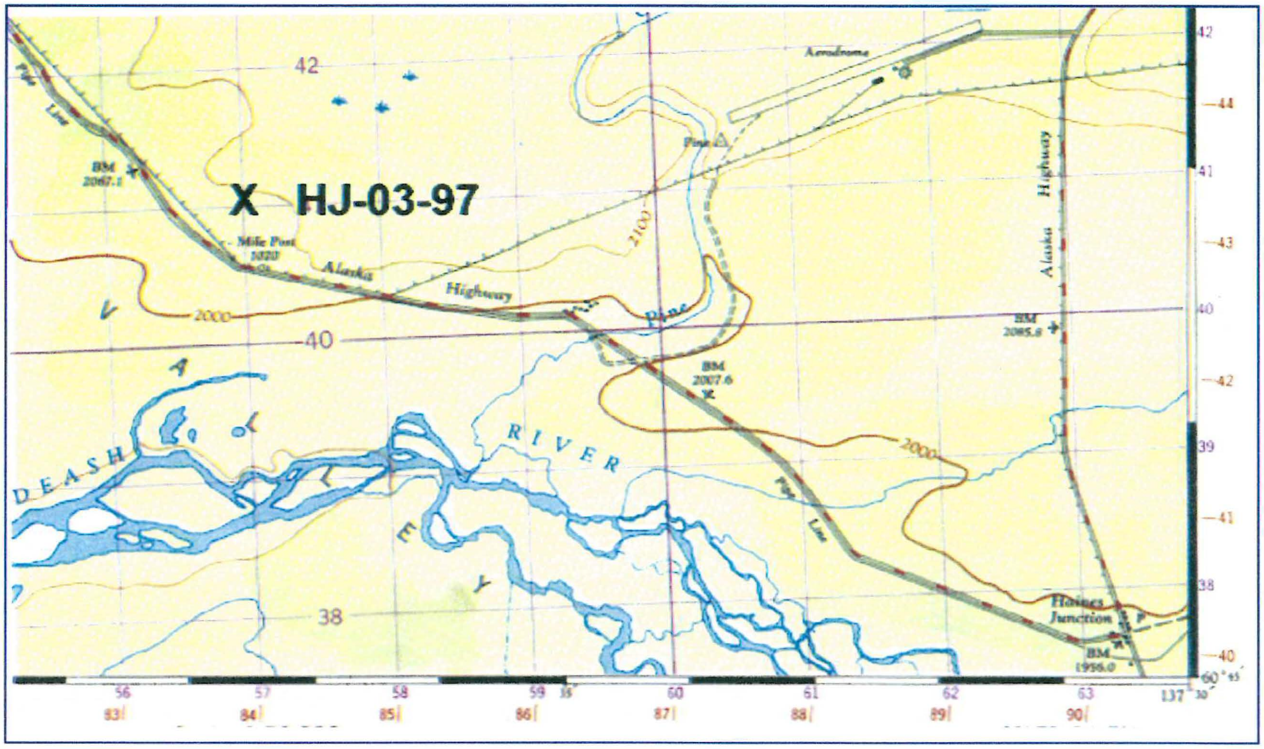

Figure 1. Map of HJ-03-97 fire location.

This area resides in the Ruby Range Ecoregion (Oswald and Senyk, 1977). It's climate is typified by long cold winters and short warm summers with mean annual temperatures ranging from -3° to -5° C. Located in the rain shadow of the St. Elias Mountains the Haines Junction area averages only 281 mm of yearly precipitation (Oswald and Senyk, 1977). The cold and dry climate broadly classifies this area as semi-arid continental.

Winds are strongly influenced by topographical features and are frequently strong along major valleys.

Fire Regime

The fire regime of this area has been studied more extensively than any other area of the Yukon (Hawkes, 1983 and Francis, 1996). A review of these reports plus a stand age analysis would best fit this area into Heinselman's Fire Regime 5. *"Very long return interval crown fires and severe surface fires in combination (100 to 300 year intervals). Usually stand replacement fires."*

Fire is most severe in ecosystems where it is infrequent but at high intensity (Averill *et al*, 1994). In these ecosystems a greater biomass is available for consumption so fires burn with greater intensity. Given the cold and dry climate of the HJ-03-97 study area the decomposition of dead organic material is slow. This is supported by the abundance of combustible, dead and down fuel present in the immature spruce regeneration type from a wildfire sometime in the early 1940s.

Topography:

Topography did not influence the fire behaviour on this fire other than which the surrounding terrain affected the winds.

Fuel:

The fire burned in two distinctive fuel complexes (Photo 1.). It ignited in a stand of mature white spruce comprised of approximately 30% standing beetle killed trees. From the ignition point the fire spotted into an area of 55 +/- year old white spruce regeneration. This younger forest stand was regeneration from a fire estimated through dendrochronologic sampling to have occurred sometime in the early 1940s.

Mature Spruce Complex (30% spruce beetle mortality)

Overall this site has the characteristics of a dry pine site. The forest cover could be classified as uneven aged, "C" density (50-75% crown closure) approximately 1,300 stems per hectare. Dendrochronology measurements produced an average stand age of 105 years with ages ranging from 76 to 154 years. The average stand height was 16.5m with an average diameter breast height (dbh) of 36.2cm. The majority of the beetle killed spruce were in the gray dead stage (Photo 3.). There was ample evidence of past fire in the form of charred stumps and charcoal remanence.

The grey dead stage of mortality exists between 2 and 5 years following a lethal spruce beetle attack. Distinctive features of the grey dead stage include full needle loss with the remaining twigs, dry throughout the crown (Savaria and Henry, 1994).

Stand structure and composition for the mature spruce stand most closely resemble that of the Fire Behavior Prediction (FBP) System, C3 (Mature Pine) fuel type. The forest floor was dominated by feather moss with a shallow organic layer (4 - 9cm), what might be expected in a C4 (Immature Pine) or C7 (Ponderosa Pine Douglas Fir) type. Surface fuels were sparse to moderate with little understory and light to moderate dead and down fuels. Ladder fuels were more prominent than a classic C3 with a lower height to crown base, but not to the extent of the C1 (Spruce Lichen Woodland) or C2 (Boreal Spruce) fuel types.

The rational for a C3 classification was the compensating of a lower Critical Surface Fire Intensity (Equation 1.) by a lower Surface Fire Intensity. While the lower crown base height would reduce the critical surface fire intensity required for crowning, the reduced surface fire intensity from a lower surface fuel load would produce a crown fire transition more similar to the C3 type. A comparison of the crown base heights and live versus dead crown fuel moisture is shown in Table 1.

$$\mathbf{CSI = 0.001 \times CBH^{1.5} \times (460 + 25.9 \times FMC)^{1.5}}$$

where: **CSI** = critical surface fire intensity required for crowning (kW/m)
CBH = height to the live crown base (m)
FMC = foliar moisture content (%)

Equation 1. Critical Surface Fire Intensity Equation.

	CSI(kW/m)	**CBH(m)**	**FMC(%)**
Live Crown	4,823	8	120%
Live Crown	1,705	4	120%
Dead Crown	559	8	15%
Dead Crown	198	4	15%

Table 1. Critical surface fire intensities (live and dead crown).

In a comparison to the M3 (Dead Balsam Fir/Mixedwood - Leafless) and M4 (Dead Balsam Fir/Mixedwood - Green) the mature spruce type in it's current structure is missing a number of features. The most notably of which is the comparatively sparse surface fuels and the absence of arboreal lichen covered ladder fuels. Over time the present standing dead spruce will contribute more and more to the dead and down fuel load. Given the slow decomposition rates of this area the future impacts will likely be significant and persistent.

A C3 fuel type classification must account for the element of dead standing spruce. While the crown fuel load (CFL) for the live spruce would certainly surpass the 1.15 kg/m^2 designation of a C3 fuel type, the CFL of the gray dead stage spruce would be reduced by the weight of the fallen needles. However, the 1.15 kg/m^2 CFL factor of the FBP System is a measurement of the weight of the needles and fine twigs (<0.5cm) of live tree canopy. The assumption being that only the needles and twigs <0.5cm will be consumed by the fire (Hirsch, 1996). Post fire observations revealed that in the case of the beetle killed spruce, twigs and small branchwood in excess of 0.5cm were consumed. Consequently the CFL for the beetle killed spruce has not been quantified and would be difficult to estimate.

Regardless of the needle loss there does remain a significant presence of fine aerial fuels ($\leq$ 0.5cm) in the from of the remaining fine twigs (Photo 4.). The crown structure is such that there is good vertical arrangement and continuity (Photo 3.), sufficient for crown fuel involvement as was experienced.

With the crown fuel structure established, the impact which the beetle killed spruce may have upon fire behaviour becomes an analysis of live versus dead fuel moisture content. Under the climatic conditions leading up to and existing at the time of the fire, the live foliar (needles and twigs <0.5cm) moisture (FMC) content would be approximately 120% (as a percent of dry weight). Where as the fuel moisture content for the fine dead aerial fuels of the beetle killed spruce would compare with the Fine Fuel Moisture Code (FFMC) (Equation 2.). On June 5th this would have translated to a fine dead fuel moisture content of between 9.6% and 15.8% (Table 2.).

$$m = 147.2(101-F)/(59.5+F)$$

where: **F** = Fine Fuel Moisture Code
m = fine fuel moisture content (%)

Equation 2. Fine fuel moisture content vs FFMC

Time	m(%)	FFMC
2400	9.6%	91.2
2300	9.6%	91.2
2200	9.7%	91.1
2100	10.0%	90.8
2000	10.4%	90.4
1900	10.7%	90.1
1800	11.5%	89.4
1700	12.2%	88.7
1600	13.0%	88.0
1500	14.1%	87.0
1400	15.0%	86.2
1300	15.8%	85.4

Table 2. Fine fuel moisture content versus FFMC.

The question becomes, how relevant is the Critical Surface Fire Intensity equation (developed from live fuel empirical data) to a fuel complex containing standing dead, needles off, spruce? A comparison of critical surface fire intensities for live and dead crown fuels (Table 1.) shows considerable sensitivity to both crown base height and fuel moisture content. The dead crown CSI was calculated using the 1400 hour fuel moisture content, as spot fires (requiring crown fuel involvement) were first reported at 1458 hours. The head fire intensity for the C3 fuel type (Table 4.) for 1400 and 1500 hours was 141 and 293 kW/m respectfully. Within the range of potentiality for torching to occur given a FMC of 15% and a reduced CBH. A visual inspection of the burn site clearly revealed a greater involvement and burn severity of crown fuels in the standing dead spruce (Photo 2.).

Immature Spruce Regeneration Complex

As with the mature spruce type, this site has the characteristics of a dry pine site. The structure and composition for this fuel complex would most closely fit that of the a C4 fuel type. The 6,000 stems per hectare however would likely modify crown fire Rate of Spread (ROS). Stand height averaged 5m with an average DBH of 7.3cm. While this fuel complex has a very clean forest floor and shallow organic layer (3 - 4cm) there are significant surface fuels in the form of dead and down fuels (Photo 5.). The dead and down fuel component is primarily comprised of the tree stems remaining from the early 1940s fire. These stems are surprisingly sound as was evident by the degree of fuel consumption (Photo 6.). Additionally, there is a secondary component of dead and down fuels in the form of "clumps" of dead willow (*salix sp.*). It appears that the willow may have pioneered the 1940s fire and has since been shaded out by the spruce regeneration.

Both of these surface fuel components would fall into a medium or heavy fuel classification and would not contribute significantly to rate of spread beyond a pre-heating effect. This fuel component would however have a significant impact upon the surface fuel load and as a result would impact surface fire intensity and crown fire transition. The availability of this fuel to the combustion process is dependent upon fuel moisture content as represented by the Duff Moisture Code (DMC) and Drought Code (DC). Given low DMC and DC values this fuel complex lacks the fine surface fuels sufficient to generate surface fire intensities for crown fire transition comparable to a C1 or C2 fuel type.

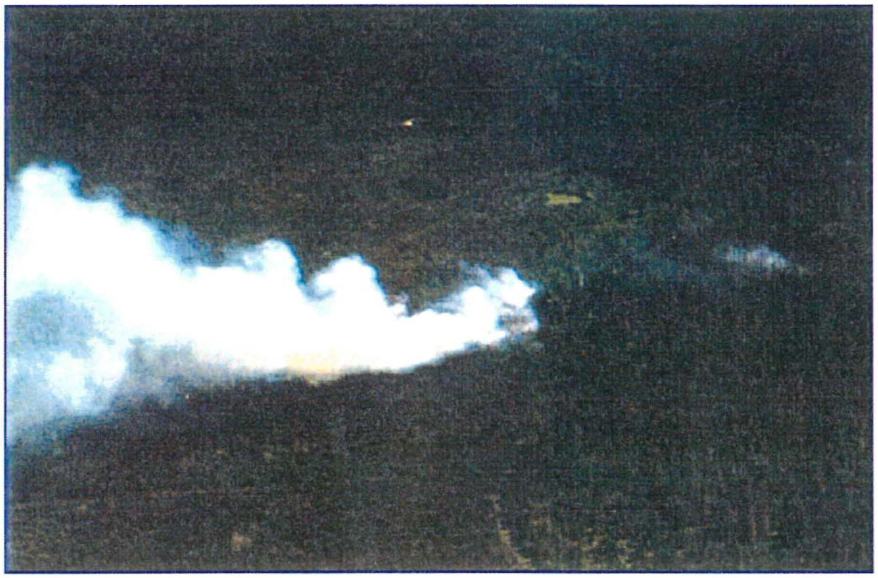

Photo 1. Aerial photograph of HJ-03-97 fire. Photo: B. Moerkoert

Photo 2. Mature spruce burn site. Photo: A. Beaver

Photo 3. Grey dead stage beetle killed spruce. Photo: A. Beaver

Photo 4. Fine twig structure on grey dead stage spruce. Photo: A. Beaver

Photo 5. Dead and down fuels in immature spruce type. Photo: A. Beaver

Photo 6. Consumed dead and down fuels in immature spruce type. Photo: A. Beaver

Weather:

CFFDRS Fire Weather Indices were calculated from Haines Junction airport weather station inputs. Wind speeds were factored by 0.6 according to Turner and Lawson, 1978. Rainfall from April 1st to July 5th, 1997 showed 104.1mm for the season which is more than double the average of 50.63mm over the same period for the years 1990 to 1996. While the timing and duration of rainfall can be as important as volume, 200% of the past seven year average should be considered significant.

Day	Time	Temp	RH	Dir	Wspd	HFFMC	DMC	DC	HISI	BUI	HFWI
5	1300	22.0	34.0	120	2.4	85.4	50	304	2.5	71	9.2
5	1400	23.0	34.0	270	3.6	86.2	50	304	3.0	71	10.6
5	1500	23.0	33.0	270	6.6	87.0	50	304	3.8	71	13.1
5	1600	25.0	28.0	270	9.0	88.0	50	304	5.0	71	16.1
5	1700	23.0	29.0	270	9.0	88.7	50	304	5.5	71	17.3
5	1800	24.0	27.0	270	7.8	89.4	50	304	5.7	71	17.8
5	1900	24.0	24.0	180	9.0	90.1	50	304	6.8	71	20.1
5	2000	22.0	26.0	225	2.4	90.4	50	304	5.1	71	16.3
5	2100	22.0	26.0	90	12.0	90.8	50	304	8.7	71	24.0
5	2200	23.0	26.0	180	4.2	91.1	50	304	6.1	71	18.7
5	2300	21.0	30.0	90	5.4	91.2	50	304	6.6	71	19.7
5	2400	18.0	37.0	120	6.6	91.2	50	304	7.1	71	20.7
6	100	15.0	60.0	45	4.2	90.8	50	304	5.9	71	18.2

Table 3. Hourly Weather and FWI values, Haines Junction Airport Weather, July 5, 1997

Ignition

Ignition of the HJ-03-97 fire was by lightning, estimated from lightning activity on July 3rd, between 1300 and 1500 hours (Figure 2.). A standing dead snag with a burned out top characteristic of a lightning strike was found in the fire origin area (Photo 7.). Ignition from human sources was ruled out due to the location of the fire's origin and a lack of any resemblance to historic human ignition characteristics of this area.

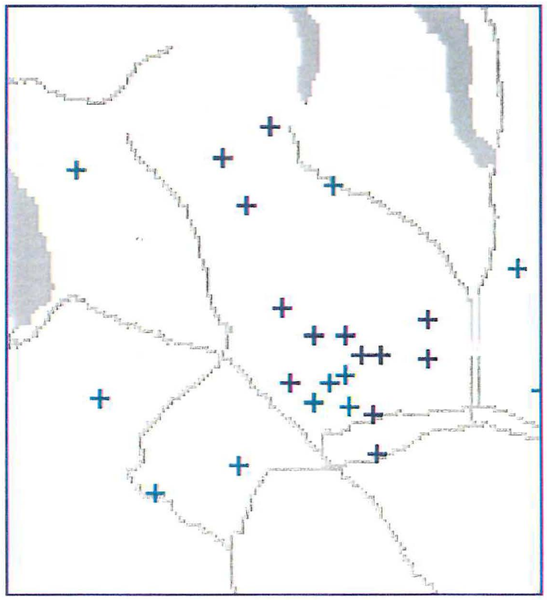

Figure 2. Lightning data from July 3, 1997, 1300 - 1500 hours.

Photo 7. Suspected lightning ingition source.

Probability of Sustained Ignition

Hourly probabilities of sustained ignition (PSI) were calculated for three forest types, (Lawson, *et al*, 1993) (Figure 3.) using hourly FWI values for 1300 to 2400 hours, July 5th and 0100 hours, July 6th. Of the probabilities for the three forest types calculated, the strongest correlation was with the dry lodgepole pine forest type through all diurnal calculations. The equation for the dry pine type is driven by the Initial Spread Index (ISI) and is consequently sensitive to changes in temperature, relative humidity, wind speed and precipitation.

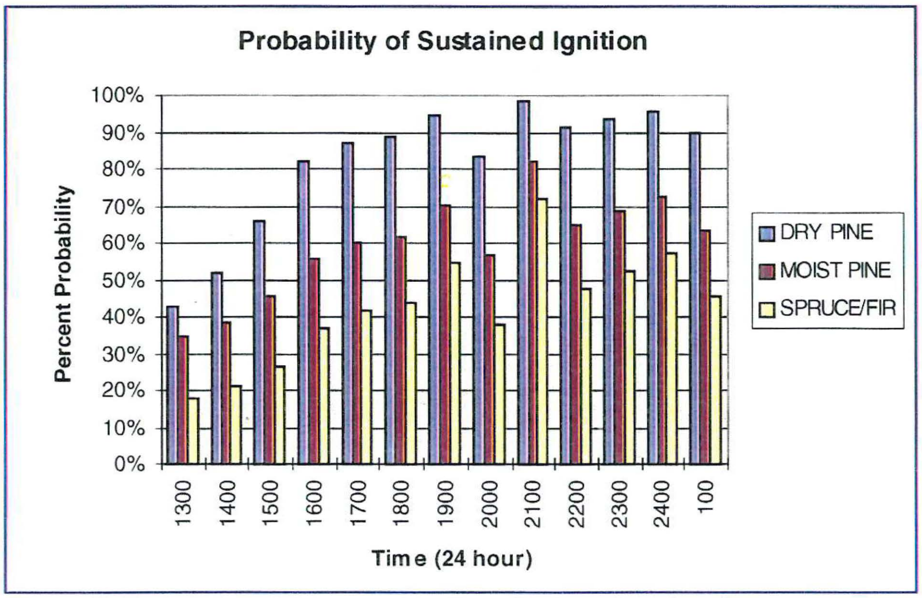

Figure 3. Probability of Sustained Ignition (Haines Junction Airport Weather (July 5, 1997).

Predicted Fire Behaviour

Fire behaviour outputs were calculated for C3 (Table 4.), C4 (Table 5.) and M3 (Table 6.) fuel types using REMs FBP93 software. Point source ignition was used for 1300 and 1400 hours only, after which it was assumed the fire would have reached equilibrium Rate of Spread (ROS). To avoid the diurnal FFMC adjustment from the FBP93 software and incorporate the calculated hourly FFMC from Weather Pro, time of ignition was set at 1700 hours (daylight saving time) for all calculations. Hourly FFMC and wind speed was input manually. Figure 4. shows a graphic representation of predicted fire intensities for 1300, 1600, 1900, 2100 and 2400 hours for the C3 fuel type. Elliptical fire area calculations were included for interest purposes only. As this fire received extensive fire suppression upon detection, and area growth outputs are for free burning fires, predicted and actual burned area will bear no relevance.

Fire Behaviour Input Values

- C3 & C4 fuel types & M3 fuel type
- 30% dead for M3 fuel type
- Hourly FFMC
- 71 BUI
- Hourly wind speeds
- 1700 ignition time
- Day light savings time
- 0% slope
- 60 minutes spread time
- Point ignition for 1300 and 1400 hours
- Line ignition for all hours after 1400
- Closed acceleration model for 1300 and 1400 hours

Time	Rate of Spread (m/min)	Elliptical Fire Area (ha)	Head Fire Intensity (kW/m)
1300	0.1	0.0	87
1400	0.2	0.0	141
1500	0.5	0.1	293
1600	0.9	0.2	600
1700	1.2	0.3	784
1800	1.3	0.5	871
1900	2.0	1.0	1,323
2000	1.0	0.6	619
2100	3.8	2.7	2,487
2200	1.6	1.1	1,024
2300	1.9	1.4	1,243
2400	2.2	1.6	1,451

Table 4. Predicted Fire Behaviour for C3 Fuel Type.

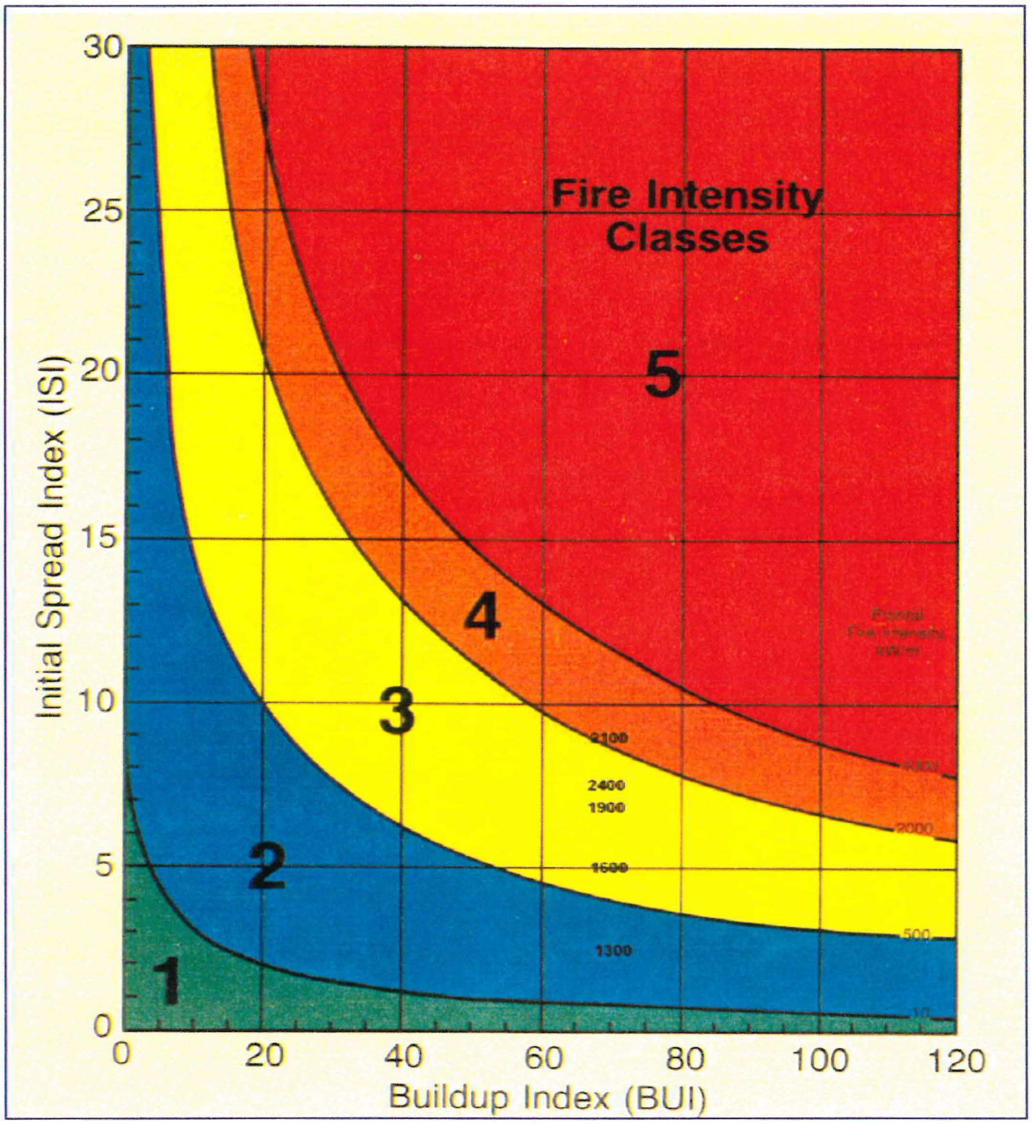

Figure 4. Fire Intensity Class Chart for Pine Fuel Type. Adopted from Alexander and DeGroot, 1988.

Time	Rate of Spread (m/min)	Elliptical Fire Area (ha)	Head Fire Intensity (kW/m)
1300	2.1	3.5	1,366
1400	2.7	4.9	1,767
1500	3.9	6.9	2,922
1600	5.8	10.7	4,739
1700	6.6	14.2	5,653
1800	6.9	18.4	6,056
1900	8.6	24.8	7,918
2000	5.8	27.1	4,837
2100	12.1	34.8	11,672
2200	7.5	35.7	6,725
2300	8.3	37.1	7,610
2400	9.1	37.2	8,391

Table 5. Predicted fire behaviour for C4 fuel type.

Time	Rate of Spread (m/min)	Elliptical Fire Area (ha)	Head Fire Intensity (kW/m)
1300	0.6	0.3	517
1400	0.8	0.4	676
1500	1.3	0.6	1,016
1600	1.8	1.0	1,517
1700	2.1	1.4	1,765
1800	2.2	1.8	1,873
1900	2.8	2.6	2,379
2000	1.8	2.7	1,544
2100	4.1	3.9	3,508
2200	2.5	3.7	2,054
2300	2.7	3.8	2,295
2400	3.0	3.9	2,509

Table 6. Predicted Fire Behaviour for M3 fuel Type.

Spot Fire Distance Prediction

One of the observed characteristics of the HJ-03 fire was the spotting activity and the spotting distance in particular (Photo 8.). Hourly spot fire distance predictions were calculated using the Behave Program, Spot Module. The spotting model does not make predictions as to the probability of an ignition occurring should a burning ember reach the ground nor does it predict the density of spot fire ignitions. It is restricted to calculating only the distance that a fire brand can travel and still retain the possibility of starting a fire (Albini, 1979).

Spot Fire Prediction Inputs.

CONDITION	INPUT
Mean Stand Height	16.5m
6 metre Wind	Hourly km/h
Valley/Ridge Elevation	0.0m
Species	Engelmann Spruce
DBH of Torching Trees	36.2cm
Torching Tree Height	17.1m
Number of Trees Torching	15

Table 7. Maximum Spot Fire Distance Prediction Inputs.

Time	6 metre Wind (km/h)	Maximum Spotting Distance (m)
1300	5.1	200m
1400	9.4	300m
1500	12.8	400m
1600	12.8	400m
1700	11.1	400m
1800	12.8	400m
1900	3.4	200m
2000	17.0	500m
2100	6.0	200m
2200	7.7	200m
2300	9.4	300m
2400	6.0	200m

Table 8. Maximum Spot Fire Distance Prediction.

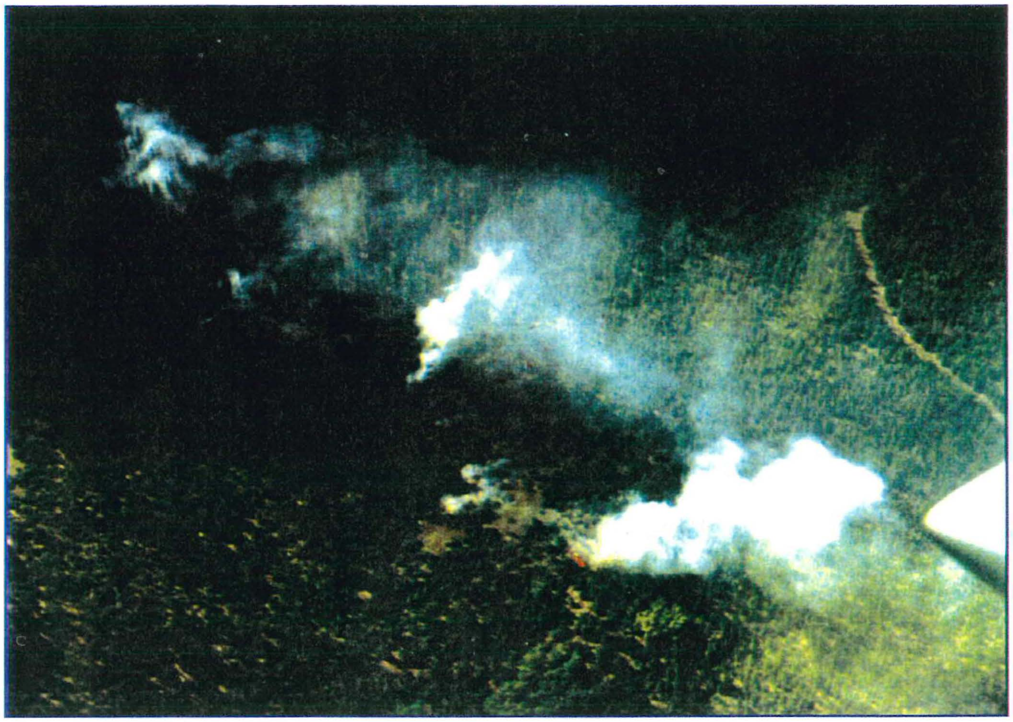

Photo 8. HJ-03-97 spot fire development. Photo: B Moerkeort

The first spot fires were reported by the Paint Mountain Lookout at 1458 hours. The Albini, Spot Fire Distance Prediction model calculated spotting distances of 300m to 400m at 1400 and 1500 hours respectively. Maximum spotting distances were measured at up to 800m from the ignition source to the furthest known spot fire, double the maximum predicted distance. While the probability of sustain ignition for dry pine was moderate for this period the forest floor fuels were clearly in a condition to sustain combustion.

Observed Fire Behaviour

Various reports of the fire's behaviour were consistent at the lower intensity classes such as intensity class 2 and 3. At 1434 hours the Paint Mountain Lookout reported visible flames, consistent with a 1516 hour report for intensity class 2 by Birddog 51. A predicted head fire intensity of 293 kW/m for the C3 fuel type at 1500 hours is near midpoint of the intensity class 2.

Discrepancies in fire description did existed at the higher intensity levels as burning conditions accelerated. However, the transition zone between intensity class 4 and 5 fires is most subjective. The description criteria defining intensity class 4 and 5 fires is the degree of crown involvement. The first report of the "spot fires starting to go" was at 1611 hours. The predicted fire description and head fire intensity for this time was "intermittent crown fire" and 4,739 kW/m in C4 fuel types. Given the number of variables affecting fire behaviour and the intensity class 4 to 5 threshold of 4,000 kW/m any debate over intensity class designation would be a meaningless exercise.

HJ-03-97 Chronology

1432 Fire reported by public via phone call to district DDO on yellow alert.

1432 H.J. I.A. Crew dispatched via pickup.

1434 Paint Mountain Lookout reports flames visible, white smoke column going straight up.

1458 Paint Mountain Lookout reports small spot fires spreading around area ahead of main fire.

1516 Birddog 51 over fire reports 0.2 ha, spot fires present, rank 2 in mature spruce with values at risk.

1611 Birddog 8 reports spot fires are starting to go.

1618 Birddog 8 reports fire is starting to rock and roll.

1637 Craig Worsfold reports fire is rolling.

1657 Birddog 8 reports fire is 6 ha with spots 200 to 300 m ahead

1913 Birddog 7 advises fire boss that tankers are inbound for Whitehorse and main fire is surrounded by retardant with spot fires outside retardant to be bucketed upon by R/W.

Discussion

Examination of the mature spruce burn site clearly showed increased crown fuel involvement of the grey dead spruce over the live spruce (Photo 2.). The absence of crown fuel involvement by the live spruce is consistent for C3 fuel types with fire intensities of 141 and 293 kW/m for the hours of 1400 and 1500 respectfully. With respect to this observation the FBP C3 fuel type appears to be the "best fit" for the live mature spruce forest. The degree of torching exhibited by the grey dead spruce would however not be expected of C3 fuel types until fire intensities of approximately 2,000 kW/m. Intensity levels which were not achieved until well after the fire had been contained.

There were a number of factors which contributed to the control and extinguishment of the HJ-03-97 fire. Early detection and rapid initial attack contributed significantly as did favourable weather conditions. The Haines Junction area had received over double the average amount of precipitation from April 1st to July 5th. It is typically an area of warm dry summers, subject to strong afternoon winds. The fire was detected and reported as a spot, under low wind conditions. Initial attack was extensive with six airtankers delivering a total of 18 loads of long term retardant (3,600 litres/load), over a four hour period in addition to fire crews plus a medium and a light rotorwing for transport and bucketing.

Had this fire ignited under conditions for extreme fire behaviour the outcome would have been quite different. During the 1995 fire season alone there were 44 occasions where the Build Up Index (BUI) exceeded 100. Under these conditions, 1300 hour weather parameters of 21°C, 45% RH and 18km/h wind would produce conditions for extreme fire behaviour in "live" C3 fuels with predicted spot fire distances of up to 400m. By accounts from Haines Junction residents, afternoon winds can regularly exceed 18 km/h.

The fire control implications for this threshold is "Extremely Difficult", "Suppression action must be restricted to back and flanks of the fire. All efforts at direct control of the fire likely to fail. Indirect attack with aerial ignition , if available, may be effective," (Alexander and Lanoville 1989).

Following a lethal spruce bark beetle attack a number of changes take place in fuel moisture content, fuel loading and fuel arrangement of the infested forest. As the needles die and drop off, the forest canopy opens up, increasing the in-stand wind field as well as solar radiation to the forest floor. This serves to increase the surface fine fuel load in the form of the fallen needles as well as creating a drier forest floor as a result of the increased wind and solar radiation. The increased in-stand wind field has an added affect on the acceleration of new fire starts or ignitions such as spot fires.

The presence of such an extensive area of standing dead trees (snags) raises the possibility of increased risk of lightning caused ignitions. The relationship between lightning caused fires and snags as an ignition point is well recognized in the fire management business. It is an association of a heat source (lightning) coming in contact with a combustion supporting material (snag). The HJ-03-97 fire is an example of just such an association. Given the abundance of snags, it stands to reason that the potential for increased lightning ignitions exists.

While the loss of needles will decrease the crown fuel load the remaining dense fine twig structure plus lower fuel moisture content is sufficient to support crown fuel involvement, as was observed. As crown fuels become involved the potential for spot fires increases. The potential for spotting is accentuated by increased availability of fire brand material such as the proliferation of dead twigs, branchwood material, and bark fragments (Alexander, 1997). While there are no models which will predict numbers or density of spot fires, logic suggests that a greater number of airborne embers landing in drier forest floor fuels will generate more spot fires. Prolific spotting was a well documented contributing factor to control problems experienced on HJ-03-97.

Over time, climatic degradation will convert the fine aerial fuels, branchwood and eventually the standing dead stems to surface fuels. However, a study of older beetle killed trees from the Bear Creek Summit area indicates that this is not likely to happen any time soon. Nor will it mitigate the existing hazard. The transition from aerial to surface fuels will reduce crown fire potential (in the standing dead) but substantially increase the surface fuel load and associated surface fire intensity. This increase in surface fire intensity then serves to accelerate the transition to crown fire in remaining canopies. Likewise, as the forest regenerates, the fine aerial fuels will reestablish over what will amount to a massive fuel loading of dead and down combustible material. As was apparent from the immature spruce site, these dead and down surface fuels will be available to the combustion process for sometime. This fuel component will be particularly troublesome during periods of high BUI's, greater than 70. Build Up Index levels which are easily surpassed given average seasonal weather conditions for this area. Observations from the immature spruce site noted near total consumption of 55 +/- year old dead and down fuels under a BUI of 71.

The high volume of fuel available to the combustion process during seasonally dry periods will produce high intensity fires with very high resistance to control. Fire crew effectiveness will be severely limited by the obstructive ground fuels in terms of access and tactics. Fireline construction be it mineral soil or blackline in this fuel type will be slow and arduous. The high resistance to fireline construction will preclude handline construction, as so the accessibility to water and fire intensity restricts the tactical use of water. Fireline construction by heavy equipment such as bulldozers is unlikely to meet with much success as construction rates slowed by the heavy ground fuels will not match the fire's rate of spread and long distance spotting.

Indirect attack by aerial ignition may have some success providing there are tactically available barriers to work from. This tactic becomes increasingly more difficult to apply in strong or erratic winds and one should not take too much comfort in its use as a suppression option.

Conclusion

Dead forest fuels played a role in the fire behaviour of the HJ-03-97 fire in both the beetle killed spruce type and the immature spruce regeneration type. As was observed, there is sufficient structure in the remaining fine dead aerial fuels, even in a needles off stage to support crown fuel involvement. The fuel complex is a critical factor to fire behaviour. Components such as fuel moisture content, fuel loading and fuel arrangement have major influences on fire behaviour. The degree to which the spruce bark beetle killed trees has, and will continue to impact the fuel complex is extensive and enduring. While the arrangement of fuels associated with the beetle killed forest will change over time, a reduction in the total fuel load is likely to be a slow process. The Haines Junction, HJ-03-97 fire demonstrated present and future fire hazards which can be expected from the beetle killed forest in this area.

Conflagration level fires require the components of fuel, topography, and weather aligning with an ignition source in space and time. The fuel and topography components are in place now. The weather component has been present on numerous occasions. An ignition source has been the only missing component.

To look upon the initial attack and suppression of the HJ-03 fire as an overwhelming success would be a far too myopic view. Reality is that it only served to postpone the inevitable until such time as the weather factors predispose all likelihood of control.

Typically it is this type of uncontrollable, high intensity wildfire which absorbs the majority of public dollars through extensive but futile suppression campaigns. Of greatest concern to fire managers and firefighters are the safety implications of engaging in fire suppression operations under these conditions. Over the past fifty years there have been more deaths and injuries to firefighters in the protection of life, property and resource values than to the general public. Firefighters are exposed to the hazards of extreme fire behaviour plus the environmental hazards presented by the standing and down and dead snags. The dilemma that fire managers face under these conditions is the extreme risk to fire suppression personnel in relation to the high expenditure of public funds versus a dubious probability of success.

The boreal forest is subject to uncontrollable, high intensity crown fires. While much attention has been given to the impact which the beetle killed spruce is likely to have upon fire behaviour, people should not take comfort in residing in non-infested boreal forest areas. It cannot be over emphasized that non-infested mature and climax boreal forests are high hazard situations.

Of the three main factors affecting fire behaviour (fuel, weather, and topography) fuel is the only component over which some measure of management may be exerted. Extensive fuel management is the only option for mitigating potential losses. "Living with fire" in the boreal forest ecosystem is a reality. Left to itself the problem of high hazard forest fuels, be they live or dead, will self correct in the form of an uncontrollable, high intensity crown fire.

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