Issues arising from observed fire behaviour in aspen cutblocks during the House River Fire in Alberta in May-June 2002: A Case Study

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Introduction

The House River Fire occurred at the same time recommendations for debris disposal was commencing for the east-central region of Alberta. It was opportunistic to use information from this fire in the development of these recommendations and to develop a case study on fire behaviour as influenced by debris management techniques.

The House River Fire began on May 17th and went on to burn an area of 248 243 hectares north of Lac La Biche, Alberta.[1] It was a man-caused fire and proved to be extremely difficult to control due to a number of wind shifts and the drought conditions. At least 100 cutblocks were involved and fire managers on-site believe these blocks contributed to containment difficulties. The cutblocks included pine, spruce and aspen areas. Harvesting aspen has become common only relatively recently in Alberta. Because little is known about fire behavior in aspen cutblocks, reason this case-study will focus on that topic. This case study will examine (1) the fire behaviour exhibited in the cutblocks, based on the debris arrangement and (2) investigate overnight fire behaviour attributable to the fuel arrangement. The House River Fire was important to Alberta, as the fire behaviour was somewhat unanticipated. The fire pointed out previously unknown and unstudied facets of fire behaviour in aspen areas.

The big question to be answered is: "is fire behavior in aspen slash different than in pine or spruce slash?" If so, why, how and when. This case study will attempt to answer these questions.

Fire Environment

Fuels

This region (Figure 1) is a mixed-wood area containing aspen, spruce and pine in both pure and mixed stands. The area has an active fire history, with evidence of many large fires and hundreds of smaller fires demonstrated through changes in forest type. Canadian Fire Behaviour Prediction (FBP) fuel types include M-2 boreal mixedwood (leafless and green), C-2 boreal spruce, C-3/4 mature/immature jack or lodgepole pine, and S-2 white spruce/balsam slash.

[1] The House River Fire now stands as the second largest fire in Alberta in the past 30 years.

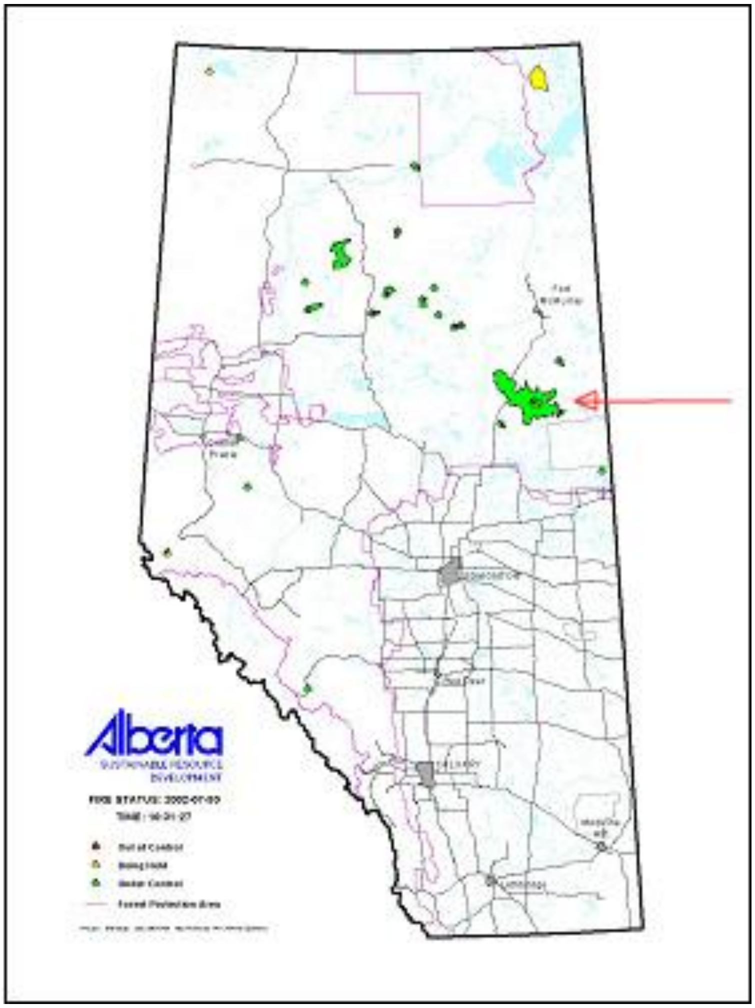

Figure 1. Location of the House River Fire. It is the large fire on the eastern side of the province, see arrow.

The fuel types not represented by the FBP model are deciduous slash, either spread or in combination with abundant grass. These types currently are not part of the model.

Aspen harvesting on a commercial basis is a relatively new development in east-central Alberta. Current fire behaviour prediction models do not adequately predict fire behaviour in aspen stands or aspen slash. Generally, deciduous stands resist fire spread when in leaf, however under extreme[2] conditions in early spring, they are able to carry fire. Although conditions were very dry, the overall fire weather conditions during the House River Fire were not as severe as those experienced during the big run at the start of the Chisholm fire in 2001.

The Canadian Fire Behaviour Prediction (FBP) system includes leafless aspen (D-1) and boreal mixed-wood (M-2) as fuel types and FBP output predicts less intense fire behaviour than in coniferous or slash fuel types under the same fire weather conditions

[2] Extreme fire behaviour – a level of fire behaviour that often precludes any fire suppression action. (CIFFC 2000 Glossary of Forest Fire Management Terms).

(Figures 2 and 3). Because the House River Fire was EXTREME, anecdotal evidence was required to estimate fire behaviour because close observations were unsafe.

Figure 2. An examples of fire behaviour in aspen stands and in aspen cutblocks. Note the aspen stands to the left remain green although damage may be present in the lower levels of the stand.

Figure 3. An example of fire behaviour (light surface fire) in an aspen stand near Conklin.

In the Conklin area, the forest industry has harvested mixed-wood stands as many small cutblocks. Under the conditions experienced in May 2002, it was found these cutblocks are located too close to each other with few landscape level firebreaks between them. These cutblocks now create an almost continuous fuel type from just west of Conklin to Janvier. The harvested areas exhibit different fire behaviour characteristics than pure aspen stands during extreme fire weather and the cured grass stage. Linear disturbances also contributed to fire behaviour and this issue is the subject of a FERIC study in 2003. In both linear disturbances and cutblocks, grass is the main concern as a contributor to hazardous fire behavior.

Topography
The area involved in the House River Fire is level to gently rolling, and contains mixedwood stands irregularly interrupted by changes in forest type reflecting the boundaries of large historic wildfires. The active fire history in this area means the probability of fires occurring is relatively high, and thus the chances of a wildfire involving a cutblock are also high. Historically, these fires burned primarily coniferous stands, but with the forest harvesting over the past 20 years, cutblocks are now also involved.

Fire Weather
The eastern side of the province had experienced dry conditions over a sustained period of time prior to the fire. The previous fall and winter (2001/02) were dry with little snow cover and during the spring of 2002 little precipitation fell. May and June received 56.7 mm less than their normal precipitation (Wandering River area)[3]. This drought allowed all fuels to contribute to the fire and thus the extreme conditions.

The following Fire Weather Index (FWI) values are from Conklin Tower. They represent conditions on the date of ignition (May 17) and those on May 30.

Date	**FFMC**	**DMC**	**DC**	**ISI**	**BUI**	**FWI**[4]
May 17	90	29	311	21.4	47	36
May 30	89	58	374	12.9	84	34

Chisholm May 27, 2001	90	95	380	15-39	117	60

The FWI values reflect the continuing drying of the larger fuels (>7cm in diameter) during the first 13 days of the fire, thereby increasing the fire danger conditions in the region.

To put these values into perspective, Edmonton Historical January—June Precipitation Anomalies (1881—2002) show the spring of 2002 was not the driest spring on record. In fact, similar conditions have occurred 9 times since 1949 or on average, once every six years. It is also interesting to note that, when viewing the data back to 1881, the extremes are seen to be greater since 1950.

Fire Behaviour

The primary condition influencing potential fire behaviour in the aspen cutblocks is the grass invading the cutblocks following harvest. The combination of abundant cured

[3] Sustainable Resource Development fire weather data.
[4] For a description of these indices please refer to the '2000 CIFFC Glossary of Forest Fire Management Terms'.

grass[5] and slash fuel loads creates problems to fire control efforts. Cured grass has characteristics that contribute to fire control problems. First, grass is a fine fuel with a high probability of ignition under dry conditions when cured. Cured grass is a very good receptor of embers that travel through the air, initiating spot fires and allow the continued propagation of the fire front. Secondly, grass allows fire to travel at high rates-of-speed (5+ km/h) in windy conditions. In Alberta, grass can exist in a cured state for up to five months of the year (snowmelt to early June, and then September to snow cover), with the spring season historically the time for problem fires in the region. Also, when winter snow is light, the grass does not compact and this has a strong influence on fire spread.

When grass with its easy ignition and high Rate of Spreads (ROS) combines with aspen debris, this fuel situation becomes a major concern to both the Forest Protection Branch and the forest industry. These slash fuel loads can be in the form of piles, windrows or spread debris within the block. On their own, grass fires are generally controllable. They can exhibit rapid rates of spread, but firebreaks can be built, and water or retardant drops are usually effective in controlling them. By adding slash loads, these fires are now capable of spreading at high speeds where control and extinguishment are far more difficult. The probability of control is lower. A situation has developed where the probability of ignition is high (in cured fuels), and the fire is able to spread rapidly within the block, pile to pile, and out of the blocks into standing timber.

From a fire perspective, unless there is complete disposal of the harvest debris, there will be the potential for problematic fire behaviour each spring (and in some falls) in the cutblocks. But this risk of fire must be balanced with ecosystem integrity. Debris spreading may be an alternative to modify both fire behaviour while meeting ecosystem objectives.

To understand potential fire behaviour between fuel types, an example is presented using 'the Red Book'[6]. These scenarios use FWI values calculated on the first day of the fire to estimate fire behaviour for the fuel types.

Example: O-1b standing grass
Degree of curing estimated to between 91 and 100%, and ISI = 21.4.
Equilibrium ROS (m/min) estimated to be 83 m/min or 5 km/h.
Fire intensities between 4000 – 10 000 kW/m.

This FBP model output is compared to fire intensities produced by mixedwood stands that are 75% hardwood in a leafed state and 25% coniferous. The 'M-2 boreal mixedwood – green' model estimates a ROS of 10 m/min or 0.6 km/h and an intensity around 4000 kW/m. These values are considerably less than even the grass fuel type. In a

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[5] Cured grass – the amount of dead grass compared to green grass based expressed as a percentage of weight. Grass is able to ignite when curing reaches 50%.
[6] Field Guide to the Canadian Forest Fire Behaviour Prediction (FBP) System. SW Taylor, RG Pike and ME Alexander. 1997. Fire Management Network, CFS, Northern Forestry Centre, Edmonton Alberta. Special Report 11.

leafless condition the rate of spread would be 15 m/min with an intensity between 4000 – 10 000 kW/m.

If the grass fire behaviour is combined with fuel loads created by harvesting, the resulting fire could have a ROS equivalent to grass fires with higher potential fire intensities.

It should be noted that when the grass is green (June-early September) potential fire behaviour in cutblocks is reduced.

Debris Arrangement, Age and Fire Behaviour

Debris was arranged in a number of ways in the cutblocks burned by the fire. Arrangement refers to the physical structure of the debris within the cutblocks, including windrowed debris, piled debris, recently-adopted smaller windrows, and debris spread over the block. Piles and windrows were composed of both aspen and coniferous debris, but were primarily deciduous. With the area experiencing extended dry conditions and the degree of curing estimated between 90 and 100%, most fuels were available to burn. Changes in fire behaviour may occur in these areas due to the stage of decomposition of the debris.

Windrowed Debris

Windrowed piles are long, narrow piles of harvest debris up to 30 m in length. The arrangement of these windrows led directly to control problems at the House River Fire. The fire was able to travel along the piles during the night and fire size increased. During the night, the relative humidity usually increased enough to retard fire spread through the grass, but the heavy fuels in the windrows produced fire intensities able to overcome the higher humidity and the fire spread along and between the piles during night hours (Figure 4).

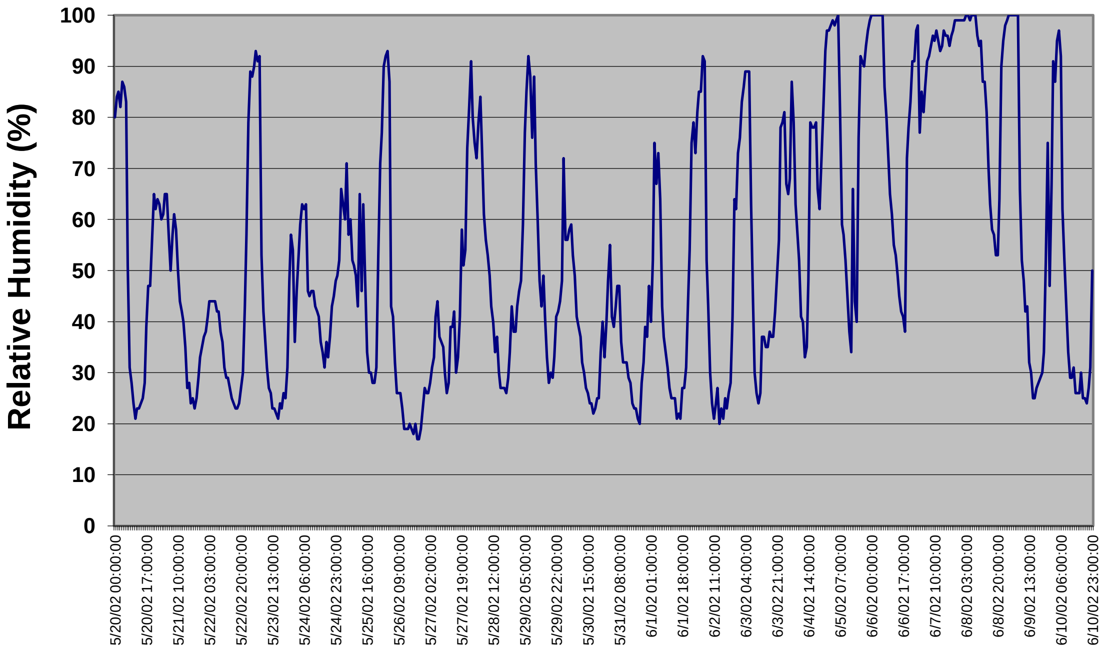

Figure 4. Data from May 20-June 10 2002. Christina Fire Automatic Weather station, (Alberta Sustainable Resource Development (SRD)).

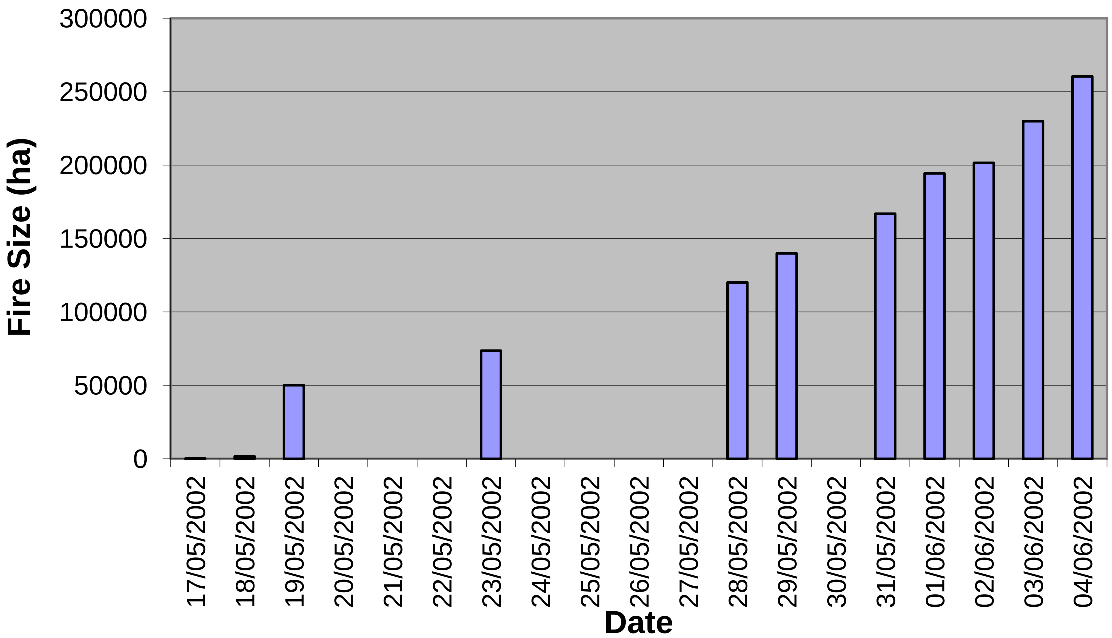

Figure 5. Daily fire area of the House River Fire.

On the days when the fire experienced substantial growth (and when we have overnight AWIS imagery), active burning in the cutblocks occurs when relative humidity values are 90+% (Figures 4 and 5).

Most of the piles were located within 4 m of each other, allowing the relatively easy spread of fire from windrow to windrow (Figure 6).

Figure 6. An example of fire spread from windrow to windrow due to the proximity of the piles to each other.

<u>Spread debris</u> – Before piling and windrowing was done, a common debris management technique was to spread the debris through the cutblock. This practice allows the debris to be in contact with the moister ground surface promoting more rapid decomposition. This technique may slow the aspen suckering process by covering a greater proportion of the soil surface)[7]. Although fuel loading is the same as in the cutblocks containing piles; the fuel load is spread over the entire block so fire intensity at a given point and spotting potential are lowered.

Piled Debris

Some cutblocks contained piles of aspen or coniferous debris. Fire behaviour centered on the ability of the piles to receive spotted embers as well as to produce them. Again, grass was important in moving fire from pile to pile and into and out of the cutblocks during the day. The piles continued to burn after the fire front had moved past the cutblocks (Figure 7). When the wind shifted, the piles were able to spot into unburned fuels. Increasing the distance between the piles from the edge of the cutblock would help to reduce the potential to spot into adjacent stands.

[7] Personal Communication. I. Whitby (Weyerhaeuser Slave Lake) 2002.

Figure 7. Piles burning after the fire has moved beyond the cutblocks.

Not only do the piles continue to burn after the fire front has moved on, they also burn down into the ground while consuming the piled debris. By burning into the duff layer the fire continues to burn even longer (Figure 8), increasing suppression difficulty and cost especially if the piles are situated in close proximity to the fire boundary.

Figure 8. An example of a deep hole left after a pile had burned. These holes can hold and hide fire for extended periods of time as they can during winter burning.

Overnight Fire Behaviour

During the House River Fire, a major concern to fire control efforts was the fire spread through the night under normal nighttime weather conditions. The conditions in cutblocks contributed to this problematic fire behaviour. The nightime spread of this fire can be viewed using *Airborne Wildfire Information System* (AWIS)™ images. These images are taken overnight and are used for planning purposes the following morning. AWIS uses infrared imagery to map fire boundaries and to locate hotspots along fire perimeters.

AWIS images[8] were obtained to show visual evidence of the role cutblocks played in the overnight fire spread (Figure 9). Due to pile-to-pile distances and the lack of a buffer between the cutblocks, on some nights the fire travelled up to 5-6 km[9].
Would the fire have spread differently with or without debris piles? Figure 9 shows overnight fire spread in cutblocks with debris piles stayed within the cutblocks. The fire had settled in for the night in other fuel types. Figure 4 shows overnight RH values – these impede fire spread at night, especially in fine fuels like grass that absorb any moisture in the air. Rates of spread were documented to be up to 1.0 km/h during some overnight periods. The majority of the 'hot' (or red coloured) areas in Figure 8 are cutblocks. Entire blocks appear to be involved in fire spread during the nights.

Fire movement during overnight hours was driven by the high fire intensities of the burning piles. The relatively close proximity of the piles to one another allowed the radiated energy to pre-heat and dry, and then ignites adjacent piles. Close range spotting also contributed to fire spread.

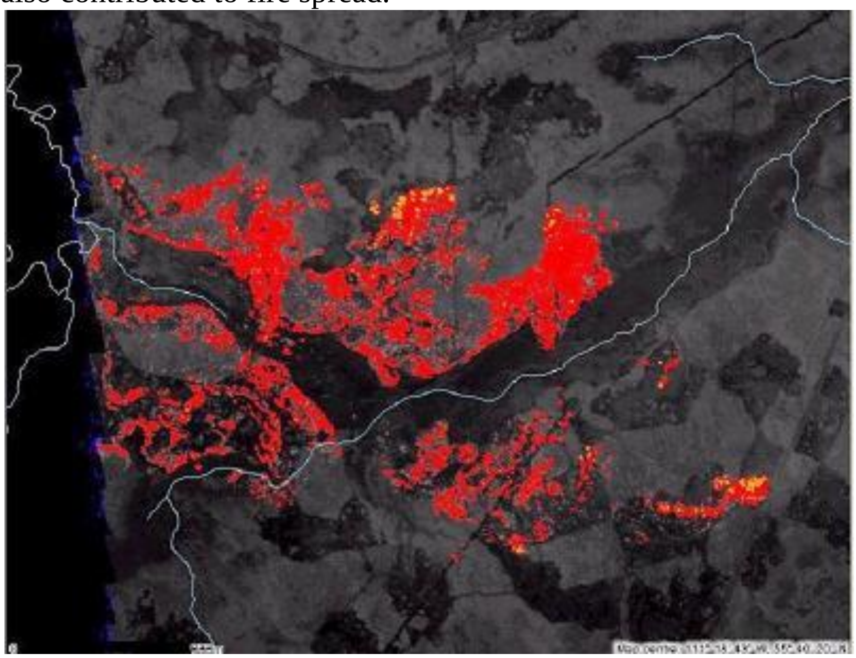

Figure 9. An AWIS image of the House River Fire from June 2 @ 02:00 in the morning. This image is taken just south of Leismer fire base (21 V-W). 77-9 W4. The darker areas are the cutblocks and the red areas are cutblocks which are actively burning.

Discussion

Fire Intensity

Fire intensity (kW/m) can be calculated by multiplying rate of spread by the available fuel load. Fire intensity is defined as the rate of heat energy release per unit time per unit

[8] courtesy of Bill Bereska (SRD) 2002.
[9] Distance estimated by fire behaviour officers.

length of fire front. Frontal fire intensity is a major determinant of certain fire effects and difficulty of control.[10] This equation is:

$I = 300 \cdot w \cdot r$ **Equation 1**

Where w = fuel load in kg/m^2 and r = rate of spread in m/min.

A grass fire travelling at 20 m/min (or 1.2 km/h) would have a fire intensity of 2100 kW/m (assuming the standard 3.5t/ha fuel loading or $0.35 kg/m^2$).[11]

If the fire was moving at the same rate of spread but there was and a slash fuel load of 1.5 kg/m^2 was present, the calculated fire intensity is 9000 kW/m – well above the 4000 kW/m used to describe EXTREME fire intensity.

These calculations show that combining heavy fuel loads of any type with the rapid rates of spread of grass fuels results in a higher fire intensity and therefore a greater efforts is required to control the fire. Fire intensity can reach levels where control is extremely difficult. At this level of intensity, suppression action is restricted to the flank of the fire, indirect attack, and aerial attack.

Pile to Pile Distance

To quantify fire spread from pile to pile, physical relationships can be used to describe the amount of radiation received by an object based on the distance from a heat source. Ackerman (1999) uses the equation:

$Q = (300/x+1)$ **Equation 2**.

Where Q is expressed in kW/m^2 and x = distance from heat source (in metres). Q describes the total radiation received by an object x metres away from the energy source. This physical relationship is based on measurements taken at the International Crown Fire Modelling Experiment in the NWT.

Using a pile-to-pile distance of 4-m (which was common at the fire) results in a radiation transfer of 60 kW/m^2 between the piles or windrows. To place this value into perspective, fibreboard will spontaneously ignite when receiving 52 kW/m^2 (Leicester 1985) of radiation energy. Spontaneous combustion could occur between piles or windrows spaced only 4-m apart, as they were in places at the House River Fire.

A second equation uses the intensity of the source and the distance to the receiving object to calculate the radiation intensity or energy transfer. This equation is from Leicester (1985)[12].

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[10] 2000 Glossary of Forest Fire Management Terms. Canadian Interagency Forest Fire Centre (CIFFC). 63 p.

[11] Forestry Canada Fire Danger Group. 1992. Development and structure of the Canadian Forest Fire Behavior Prediction System. Forestry Canada, Ottawa, Ontario. Information Report ST-X-3. 63 pp.

$$Q = 60(1-\exp[-I/3000 D])$$ **Equation 3**.

Where Q is expressed in kW/m^2
I is fireline intensity (kW/m), and
D is distance between source and receiving object in metres (m).

Alexander (1999) includes tables constructed from this equation. At a 4-m distance and with a fire intensity of 10 000 kW/m, the energy transfer would be roughly 30 kW/m^2. This is less than the 52 kW/m^2 required to spontaneously ignite fibreboard, but appears to have been enough to ignite aspen debris. Experimental burning could be used to determine an appropriate pile-to-pile distance.

Conclusions

The amount of grass increases in cutblocks following harvesting. This has become a primary concern to both Alberta Sustainable Resource Development (SRD) and the forest industry. Grass combined with the heavy fuel loads can create very difficult fire control conditions. This problem will exist for 8 –10 years regardless of current debris management techniques. Fire intensity may be reduced if less debris is left on site or if it is spread, although these do require investigation. It is difficult to say whether aspen debris on its own is different from coniferous debris. But, we cannot separate the effects of grass and aspen in terms of fire behaviour, and this case study has shown that the grass/aspen presents a difficult fire control situation.

Figure 10. Grass in a cured state allows easy ignition and rapid rates of spread. (Location: SE Twp81- Rge15)

Debris management and the implications to fire control efforts still requires study. How does debris arrangement (spread, piles, or windrowed) affect the rate of fire spread and fire? If debris is left in the cutblocks how it is left may be very important. At the House

River Fire, the cutblocks contained debris in a number of different arrangements. Because grass was the primary fire carrier during daylight hours, fire behaviour between spread or piled debris in the cutblocks tended to be similar (in terms of fire spread rates). Overnight, fires in the piled or windrowed debris spread at a faster rate than it did in blocks where the debris was spread. However, the observations at this fire do not adequately answer the question.
Does fuel type affect fire spread? Conversations with fire behaviour experts agree that in EXTREME conditions, daytime fire spread is rapid in all fuel types and arrangements of fuel (i.e., spread through cutblocks was problematic in aspen, spruce, and pine types). In less EXTREME conditions, differences in fire behaviour do exist between fuel types. Relatively speaking, fire behaviour at night through the cutblocks was a larger concern under these conditions. Recommendations should be directed at the EXTREME level of fire behaviour that can occur one in six years.

Fire behaviour resulting from the harvest of aspen is now better understood. Changes to forest management techniques may reduce fire control problems in aspen stands, if these techniques are developed in consideration of fire behavior. Special consideration should be given to reducing fire spread during the overnight hours; this spread creates serious problems for fire control efforts the following day.

The change in potential fire behaviour between aspen or mixed wood stands and cutblocks using current harvesting practices is a concern. Changes in harvesting techniques can slow the long-term impact of this change. For example, identify adequate fuel break distances between the cutblocks. Currently, fire could spread block to block in an almost unbroken line from Conklin to Janvier (40 km) under the right fuel moisture and wind conditions. This could imply larger cutblocks separated by larger breaks as a means of reducing overall risk of extreme fire effects.

The House River Fire has shown that smart landscape fire management solutions could help to alleviate the current problems and decrease fire sizes. These solutions include but are not restricted to:

- Manage the landscape to include larger fire breaks.
- Decrease the amount of debris in the cutblocks by mechanical means or by improving fibre recovery.
- Remove or spread debris within 2-5 km of a settlement based on the stand type between the block and the value at risk. This may also include the annual removal of grass. This would be a site-specific practice.
- Increase pile-to-pile distance and the distance from pile/windrow to the standing timber (cutblock edge). This would be a Heavy Fuel-Free zone that would allow these areas to be used in fire fighting efforts as firebreaks or as areas to set-up firefighting equipment.
- Work with industry to develop an experimental burn program to quantify debris disposal techniques in aspen blocks.

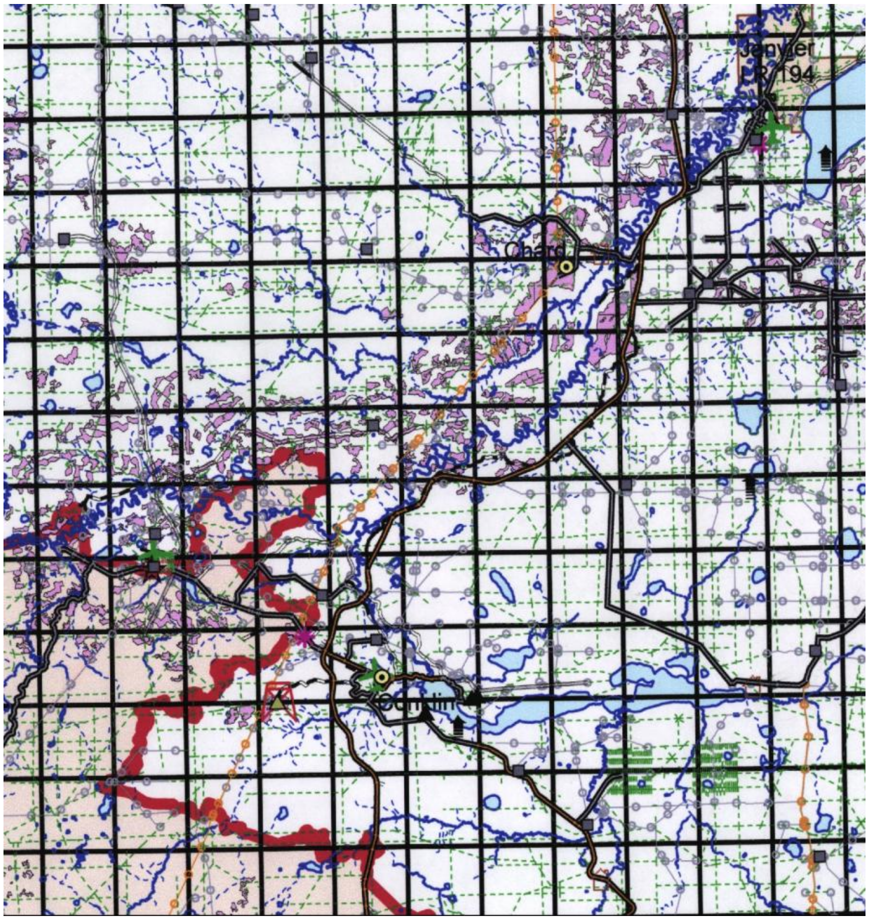

Figure 11. The pattern of all cutblocks from just north of Conklin to Janvier. The cutblocks are the purple areas. This figure is used to illustrate the landscape scale patterns that currently exist.

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