Fire Behaviour Case Study of Two Early Winter Grass Fires in Southern Alberta, 27 November 2011

by Martin E. Alexander, Mark J. Heathcott, and Randall L. Schwanke

The "Killer" Potential of Grass Fires

Soon after a fire starts and it is small in size, aggressive containment action can generally be safely and effectively attempted.

However, once a fire has "escaped", it can be a threat to your personal safety and well-being if you elect to try and engage it.

Fires in cured grass are especially responsive to sudden changes in the strength and direction of the wind. Given their precarious nature, grass fires need to be afforded a healthy dose of respect. Both firefighters and civilians have been seriously burned and also killed from being overrun by a grass fire.

The Lethbridge and Milk River Ridge fires of November 27, 2011, travelled at an overall ***average*** rate of around 8 kilometres per hour (5 miles per hour); peak rates could have easily been twice this fast. This is not unusual for the conditions that prevailed at the time.

This rate of advance is equivalent to about 130 metres per minute. A fire could thus cross a one mile (1.6 km) section of land in just 12 minutes!

Entrapment avoidance should be paramount in everyone's mind when confronted with any kind of wildland fire.

High Winds + Exposed Grass Fuels + Human Ignition Source =

A Recipe for a Potential Wildfire Disaster

What precautions can you take?

- While we have no control over the weather one can **monitor snow cover conditions** and **listen to weather forecasts** for high winds when bare ground situations exist.
- One can **reduce the grass fire fuel hazard** around your place to a certain extent (e.g., through grazing, mowing or creating mineralized firebreaks by ploughing).
- Finally, **don't be an ignition source**! Take the time, for example, to check that your burning barrel is tied down and if you've burned debris piles in the open recently, check to see that they are dead out.

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Working Together For Safer Communities in the Wildland/Urban Interface

2013

View of the Lethbridge Fire having spread across the Blood Indian Reserve from its point of origin on 27 November 2011.

A copy of this report is also available for downloading from the Resources Library at:
https://www.firesmartcanada.ca/

FireSmart Canada

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LIST OF ABBREVIATIONS

AGDM – Agriculture Drought Monitoring

CFFDRS – Canadian Forest Fire Danger Rating System

FBP System – Canadian Forest Fire Behaviour Prediction System

FFMC – Fine Fuel Moisture Code

FWI System – Canadian Forest Fire Weather Index System

HFROS – Head Fire Rate of Spread

ISI – Initial Spread Index

L:B – Length-to-Breath Ratio

MDT – Mountain Daylight Time

MST – Mountain Standard Time

RH – Relative Humidity

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Abstract

On November 27, 2011, two wildfires – the Lethbridge Fire and the Milk River Ridge Fire – starting within approximately an hour of each other, advanced in a north-easterly direction some 12 km and 32 km, respectively, from their point of origin in a relatively short period of time. Fortunately, no lives were lost. However, a few home properties were destroyed in the Lethbridge Fire. Similar threatening occurrences have taken place in the past and subsequently.

The purpose of this report is to provide a detailed account of the behaviour of these two fires in relation to their associated environment (i.e., fuels, weather, and topography) and accordingly examine the implications for human safety and wildland fire protection in the southern region of Alberta. From our analysis of these two wildfire incidents, the following "facts" emerge:

1. While lightning-ignited fires occasionally occur on the Canadian prairies, both of these fires were suspected of being caused by human carelessness (although not of a malicious nature) and thus, technically preventable.

2. A lack of snow cover in early winter exposed fully-cured grassland and agriculture cropland fuels, thus leaving the landscape susceptible to fire spread. Once the Chinook winds commenced (southwest >60 km/h), the only remaining ingredient needed for a major fire run to take place was an ignition source.

3. Considering the fuel and weather conditions, grass or crop fires are capable of quickly achieving forward spread rates of 8 km/h and producing flame heights of 3 metres at the leading edge or "head" of the fire front. In these situations, the rate of fire growth easily overwhelms the capability of any fire suppression force. A 30 metre or 100 feet plus barrier to fire spread and/or a significant drop in the strength of the winds would be required to stop such a fire's headlong assault.

4. From an analysis of the historical weather records for the Lethbridge area and existing models for predicting particular aspects of grassland fire behaviour, the fuel and weather conditions that prevailed on November 27, 2011, happen far more often than one would think. With this recurring potential for fire spread, the only missing ingredient for a large, fast spreading wildfire incident to occur is some form of ignition which is ever present in the fire environment (i.e., people).

A monitoring and early warning system for grassland fire danger that meets the needs of the general public and emergency services coupled with education and training is required to avert the potential for any future wildfire disasters.

Authors' Preface

What is a case study? Case studies (also known as case histories) provide a systematic method for looking at events, collecting data, analyzing information, and reporting the results (Alexander and Thomas 2003a, 2003b; Alexander 2009; Alexander and Taylor 2010).

The value of documented case studies has been repeatedly emphasized by both fire managers and fire researchers. Over the years, they have proven valuable as training material and as sources of research data. Case studies also provide a mechanism for formalizing the basis for *experienced judgment* in predicting wildland fire behaviour (Gisborne 1948). As Thomas (1994) has noted, "We are continuing to learn, and relearn, from … case studies. They will only seem to become dated if we don't use them."

Why make the effort to write a case study or case history in the first place? Luke and McArthur (1978) give a good rationale for writing wildland fire behaviour case studies, even on small incidents:

> *Inquiries should be made into all fires as soon as possible after they have been controlled. Even short descriptions of very small fires have a value. Recording the details of large fires is vital because success in the future depends largely on knowledge gained in the past.*
>
> *A map showing the perimeter of a fire at progressive time intervals provides the best basis for a case history analysis. This should be accompanied by descriptions of fire behaviour related to weather, fuel and topography, and details of the manning arrangements, strategy and tactics employed during each suppression phase. Particular attention should be given to initial attack action.*
>
> *At the conclusion of the analysis it should be possible to prepare a précis of the reasons for success or failure, not for the purpose of taking people to task for errors of judgment, but solely to ensure that the lessons that have been learnt contribute to the success of future suppression operations.*

Alexander and Thomas (2003b) have offered a more or less standard approach to the preparation of a wildland fire case study or history report. That approach has been adopted in preparing this report for publication.

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1.0 INTRODUCTION

On Sunday, November 27, 2011, two actively spreading wildfires in southern Alberta burned through fully-cured rangelands and post-harvest agriculture croplands during the afternoon period under the influence of strong winds (Alexander *et al.* 2012a). The Lethbridge Fire started on the Blood Indian Reserve, jumped the Oldman River, and burned into the outskirts of the city of Lethbridge, a distance of about 12 km from its origin (Figure 1). The Milk River Ridge Fire started just off Highway 62 and spread unimpeded in a northeast direction for over 32 km (Figure 1). Fortunately, no one was injured or killed as result of these early winter wildfires, although there were some “close calls”. Nevertheless, the situation presented by these two fires was a serious matter from the standpoint of both public and firefighter safety as well as threatening other values-at-risk.

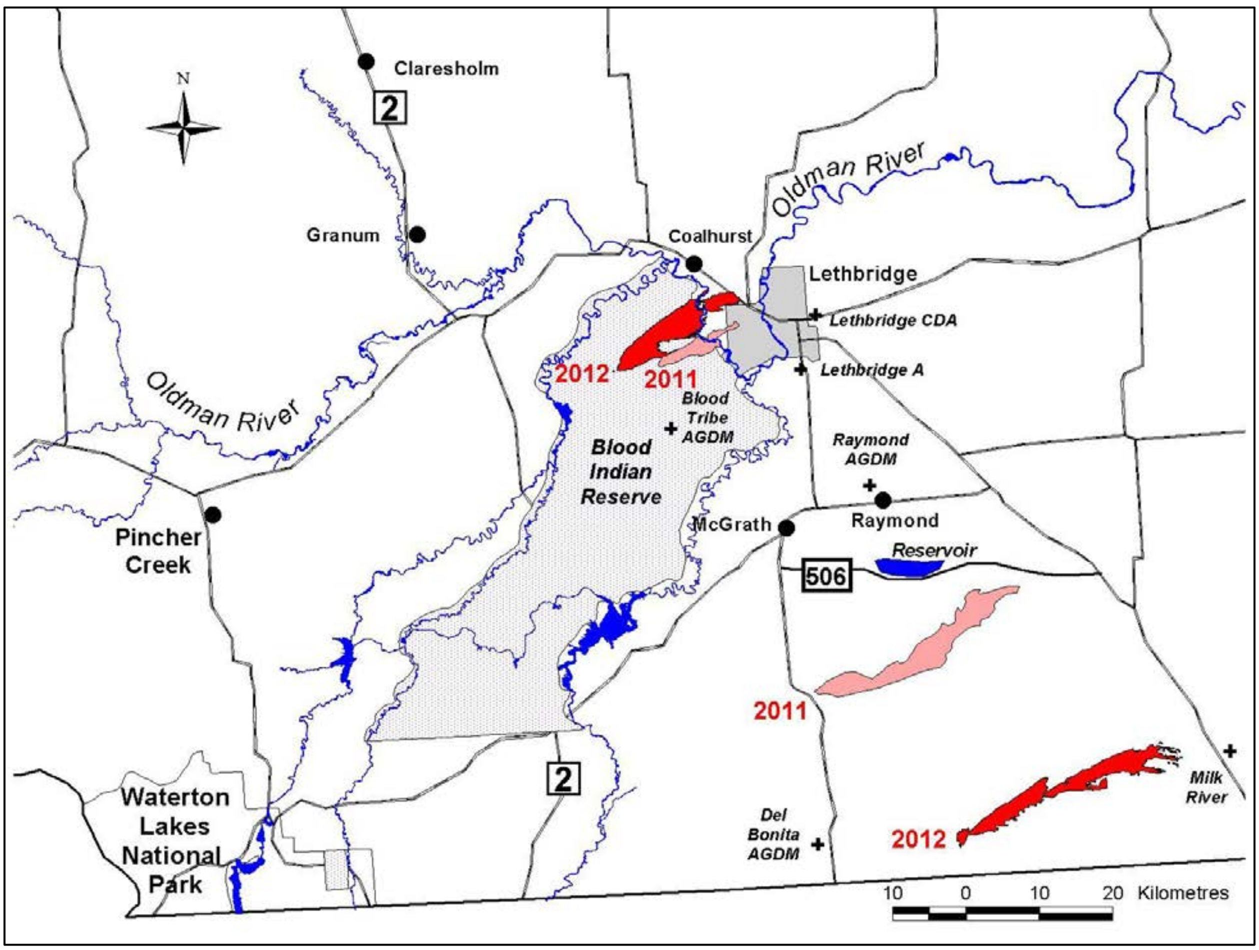

Figure 1. Final perimeters of the Lethbridge and Milk River Ridge fires of November 27, 2011 and September 10, 2012. The six weather stations utilized in this wildfire case study are noted by the symbol **+**.

Wildfires in the southern region of Alberta are not a unique occurrence (Murphy 1985; Arthur 2012). Nor are wildfires occurring during the winter months.

The region witnessed a major wildfire event on December 14, 1997, for example (Haftl 1998). Driven by strong Chinook winds, a fire that started west of Claresholm in the Porcupine Hills from a burning barrel for garbage disposal that got tipped over in the high wind. The fire then spread in a northeasterly direction towards the towns of Granum and Claresholm, burning a path some 15 km wide and 35 km long in the space of four hours before being held at Highway 2, a four-lane highway (Partners in Protection 2003).

The Granum Fire encompassed an area of 21,500 ha[1]. Six houses were destroyed and over a 100 head of livestock perished. The fire forced the evacuation of 350 people from the town of Granum.

Other wildfires occurred in grassland areas of southern Alberta during the winter of 2011-2012. While this case study report focuses on the two wildfires that made major runs on the afternoon of November 27, 2011, much of the information presented here will in fact have a lot in common with other significant fires that have occurred in the past in southern Alberta. The occurrence and behaviour of the 2011 Lethbridge and Milk River Ridge fires will be analyzed in the context of historical fire danger.

Some familiarity with the fundamentals of grassland fire behaviour and the Canadian Forest Fire Danger Rating System on the part of the reader is presumed. Nevertheless, background information is given on both of these subjects in Appendix 1 and 2, respectively.

Information on video documentation of the 2011 Lethbridge Fire and is given in Appendix 3. Appendix 4 provides a brief overview of Chinook winds, while Appendix 5 provides the specific synoptic weather conditions on November 27, 2011. Appendix 6 briefly documents two additional regional fires on September 12, 2012 that occurred in close proximity to the 2011 fires.

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[1] A hectare (ha) represents an area 100 by 100 m in dimension. For comparison sake, an ice hockey rink is 0.16 hectare in size whereas a football field is 0.6 ha. The city of Lethbridge covers a total area of 12,700 ha.

2.0 FIRE CHRONOLOGY AND DEVELOPMENT

2.1 Lethbridge Fire

The Lethbridge Fire was initially reported at 3:25 p.m. Mountain Standard Time (MST) on November 27, 2011 (Figure 2). It appears the ignition source was a fire used to heat rocks for a sweat lodge ceremony on the Blood Indian Reserve (Myers 2011). The Blood Tribe Fire Department's initial assessment completed at 3:57 p.m. MST was that the fire was out-of-control and they in turn requested mutual aid assistance. A residence, located about 1.5 km downwind from the ignition point was quickly burned over and lost. Two residences along the south flank from the point of origin were burned around without being affected in any way. It appears the fire was initially in grassland fuels, but then entered lands under cultivation for cereal crop production. Values-at-risk in the path of the fire as this time included additional homes, scattered agricultural equipment, oil wells and related infrastructure.

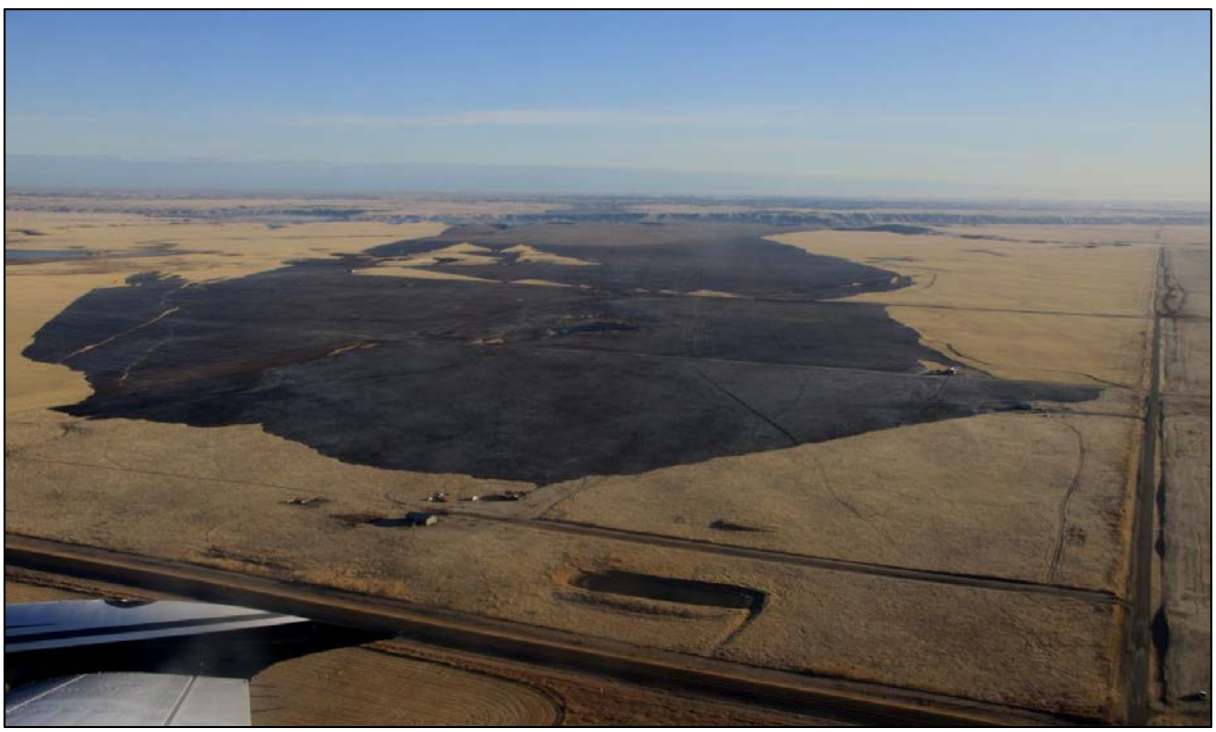

Figure 2. Post-burn aerial oblique view of the Lethbridge Fire of November 27, 2011, looking east-northeast. The fire's suspected point of origin is in the centre foreground. The Oldman River valley is just short of the horizon, with the city of Lethbridge beyond it. This photo was taken on the morning of November 28, 2011. Photo courtesy of the County of Lethbridge.

The fire continued to burn in an east-northeast direction, with the ground gently sloping down towards the Oldman River. Complex terrain, including steep slopes from numerous coulees brought the fire down into the bottom of the Oldman River valley, where a second residence on reserve lands was burned over and subsequently lost. The fire reached a point on the Oldman River at 4:37 p.m. MST.

The fire breached the Oldman River by spotting at around 4:45 p.m. MST and thus entered the County of Lethbridge where it quickly burned upslope from a new point of origin, crossing Range Road 224 at about 4:47 p.m. MST as it spread through agricultural lands. By 5:00 p.m. MST, the fire was approaching 30th Street on the outskirts of the city of Lethbridge (Figure 3).

Figure 3. North flank of the Lethbridge Fire during its major run on November 27, 2011. This photo was taken at 5:04 p.m. MST looking southwest across the Oldman River into the Blood Indian Reserve. Sunset occurred around 6:00 p.m. MST.

After the fire jumped 30th Street, it ran into a recently scraped section of land being prepared for subdivision construction. This allowed firefighters to affect containment of the heading fire.

The fire was declared under control at 7:20 p.m. MST. The Lethbridge Fire spread a total distance of 12.4 km downwind from its point of origin in approximately 1.5 h for an average rate of spread of 138 m/min or 8.3 km/h and burned over an area of about 1568 ha (Figure 4).

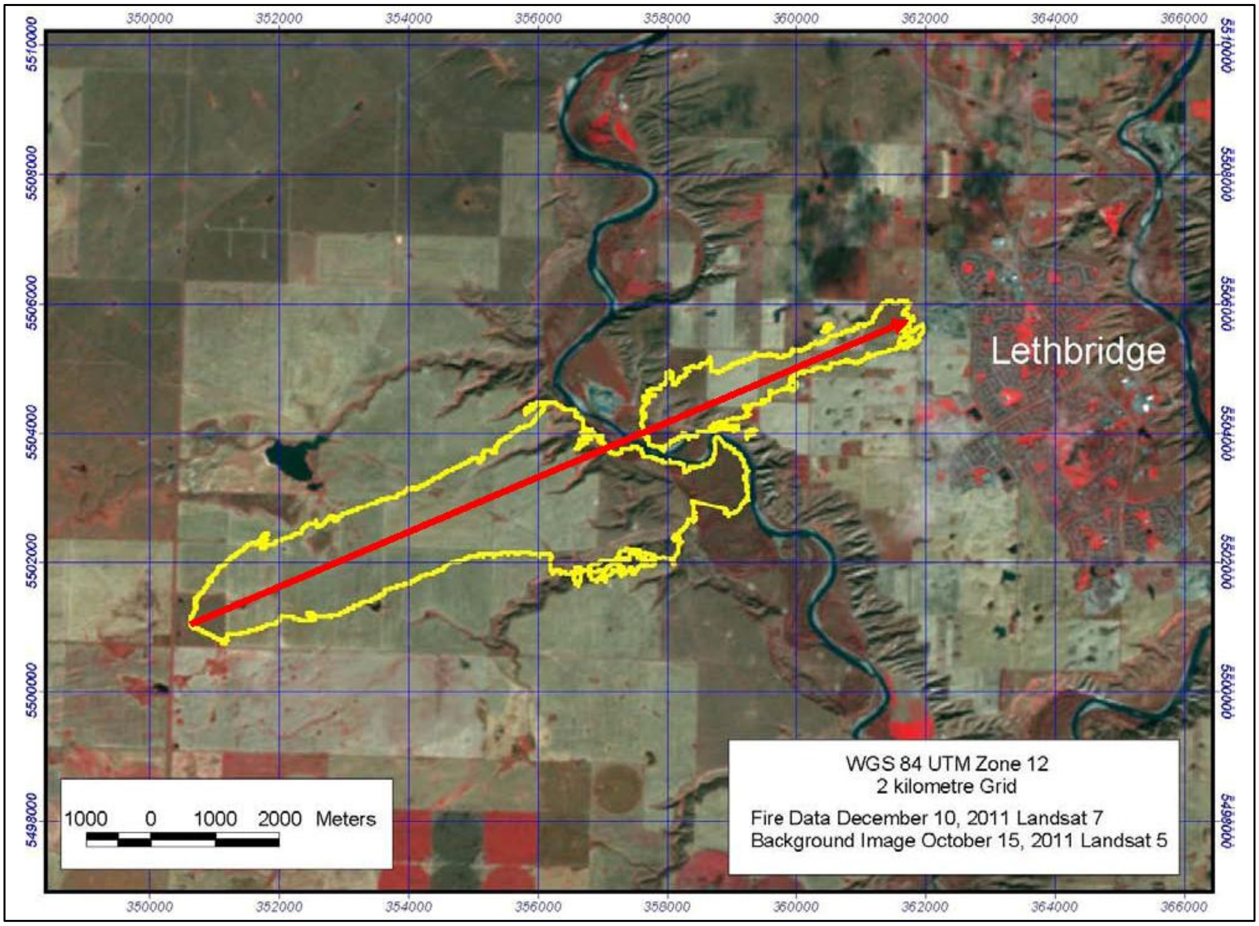

Figure 4. The final perimeter, areal extent, and general spread direction of the Lethbridge Fire of November 27, 2011.

Suppression resources responding to the Lethbridge Fire included fire departments from the Blood Tribe, surrounding rural fire departments, and personnel from the city of Lethbridge. In addition to these firefighting forces, numerous pieces of construction and farm equipment were deployed. Suppression was limited to a flanking action due to the rapid fire growth, head fire intensity and poor visibility. Resources were committed to structural protection in the fire's path. In one instance two engines were trapped while the fire surrounded and burnt around their location.

3.2 Milk River Ridge Fire

The Milk River Ridge Fire was reported at 2:15 p.m. MST on November 27, 2011. The fire was undoubtedly human-caused, with the point of ignition adjacent to an access gate off of a right-of-way on Highway 62 (Figure 5). The Magrath Fire Department was on-scene at 2:30 p.m. MST. The Raymond Fire Department were warned of a large on-coming fire at 2:32 p.m. MST. Suppression actions by Magrath personnel were limited to flanking actions because of again, the high spread rates, intensity and poor visibility in the head fire region. Suppression resources included 4x4 light engines, water tenders and multiple tractors pulling discs. Limited flanking actions continued for a distance of approximately 25 km.

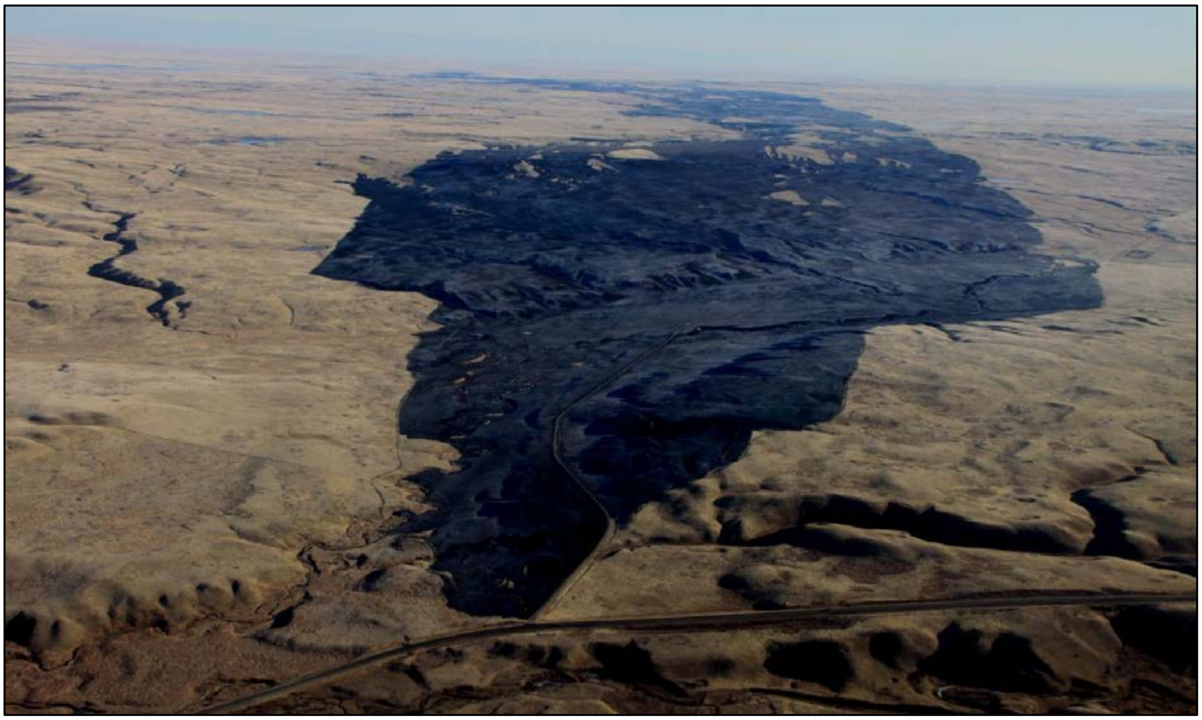

Figure 5. Post-burn aerial oblique view of the Milk River Ridge Fire of November 27, 2011, looking northeast. The fire's point of origin is in the bottom centre of the photo. Photo was taken on November 28, 2011, and is courtesy of the Country of Lethbridge.

Raymond Fire Department personnel prepared mineral earth firebreaks in advance of the approaching fire front. Control wasn't possible until the fire came off the Milk River Ridge onto more easily accessible agricultural lands (C. Holt, Raymond Fire Department Chief, personal communication, 2012). A hastily prepared firebreak was constructed alongside a road running parallel to the direction of fire's path of spread. In an attempt to strengthen the road right-of-way (10-m wide gravel surface and grass ditches), a 5 to 7 m wide firebreak was made with tractor and disc in a stubble field on the upwind side of the right-of way. Another firebreak (5-m wide) was constructed in stubble on the downwind side. These guards were breached as firefighters evacuated the location.

A second attempt was made to halt the fire by constructing firebreaks alongside Highway 506 (again, 10-m wide gravel plus 10-m wide grass ditches) east of the reservoir. Upwind, a 5-m wide firebreak on pasture land was tilled, with a 30-m firebreak downwind in stubble. The fire spotted across this break but all the spot fires were quickly extinguished, thus halting any further fire spread (Figure 6).

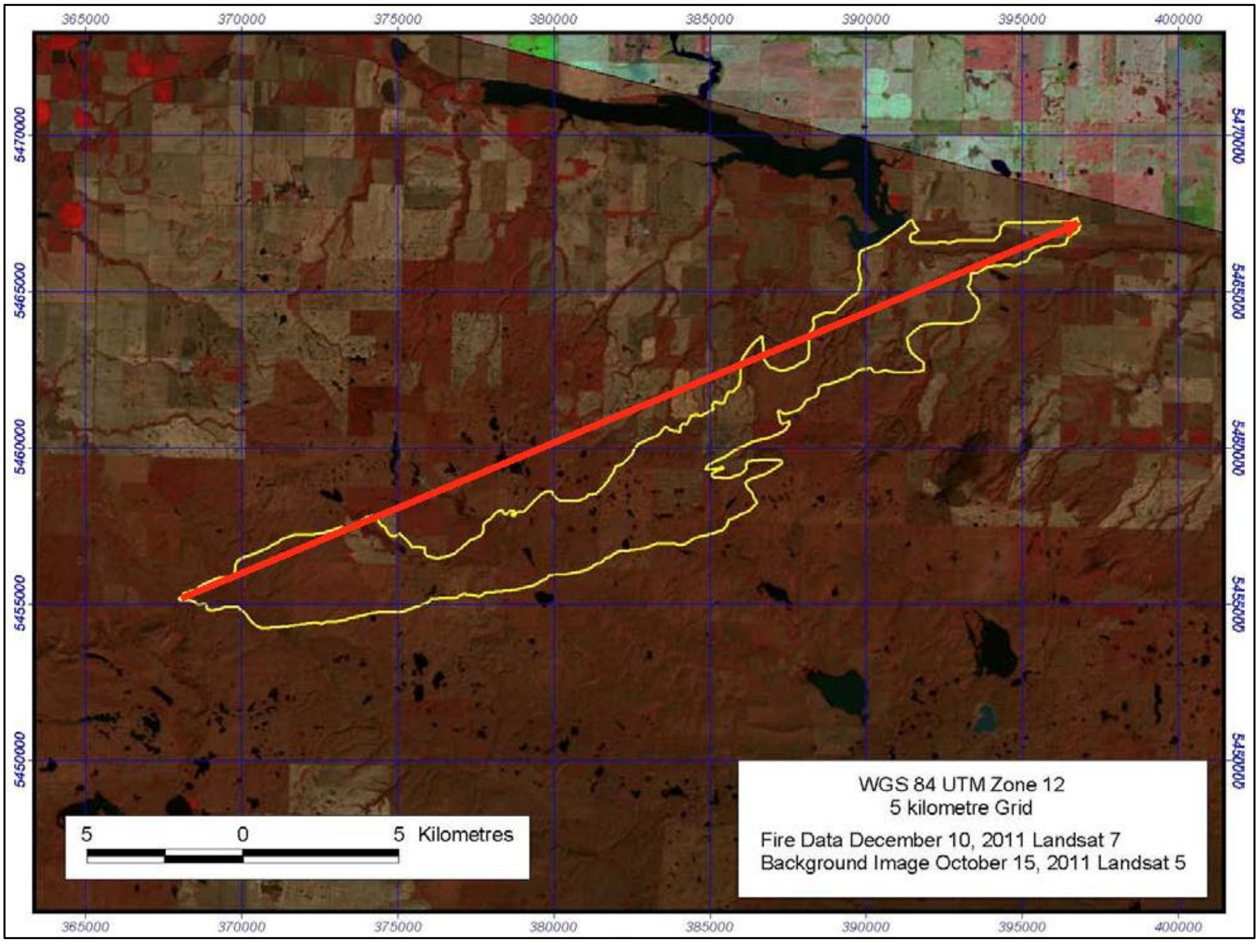

Figure 6. The final perimeter, areal extent, and general spread direction of the Milk Ridge River Fire of November 27, 2011.

The Milk River Ridge Fire was finally declared under control at 11:00 p.m. MST although the main spread event is assumed to have abated sometime earlier in the evening. Unfortunately no times were recorded. The final area burned by the fire was 6950 ha. No structural losses were reported other than fencing. Responding resources included personnel and equipment from eight volunteer fire departments, graders from two counties, and local volunteer resources from farms and Hutterite colonies.

3.0 DESCRIPTION OF THE FIRE ENVIRONMENT

The fire environment is the surrounding conditions, influences, and modifying forces that determine the behaviour of a free-burning wildland or rural fire (Countryman 1972). The fire environment consists of three major components – topography, fuel, and weather. From a wildland fire standpoint, topography does not vary significantly with time but may vary greatly in horizontal space. The fuel component varies in space and also in time. However, except for the moisture content of dead fuels, fuel characteristics change so slowly that they can be considered static for any one fire. Weather is usually the most variable component, changing rapidly in both space and time. Fire behaviour is the result of these environmental components interacting with each other and with the fire itself. It is the current state of each of these influences and their interactions that determine the behaviour of a wildland fire at any moment in time.

3.1 Topography

In cross section, the path taken by the Lethbridge Fire slopes gently downhill about 60 m over 6 km from its point of origin to the rim of the Oldman River valley (Figure 7). From the west rim, the terrain plunges steeply down about 100 m in elevation to the 80-100 m wide river below. Across the river on the east bank, a gently sloping floodplain 500 m wide leads to the foot of steep slopes, which rise about 80 m in elevation to the east rim. The rim to rim distance is about 2 km. The terrain then slopes gently uphill about 30 m over about 4 km to the edge of the city of Lethbridge.

These topographic features affected fire behaviour, especially the abrupt changes occurring due to the steep slopes and variable aspects of the Oldman River valley in the case of the Lethbridge Fire. It was also a significant factor influencing the wind direction on the Milk River Ridge Fire. In most practical guides to predicting fire spread in rolling terrain, "the surging and stalling of a fire as it climbs and descends slopes can be averaged by assuming zero slope" (Rothermel 1991). The path of the Milk River Ridge Fire rises about 150 m over the first 5 km then crosses the top of ridge for another 9 km through rough topography covered with fescue grasslands, wetlands, and small sloughs. The path taken by the fire then drops off the ridge, descending cross-slope about 270 m over the next 17 km through north-draining coulees until reaching the flats east of the reservoir.

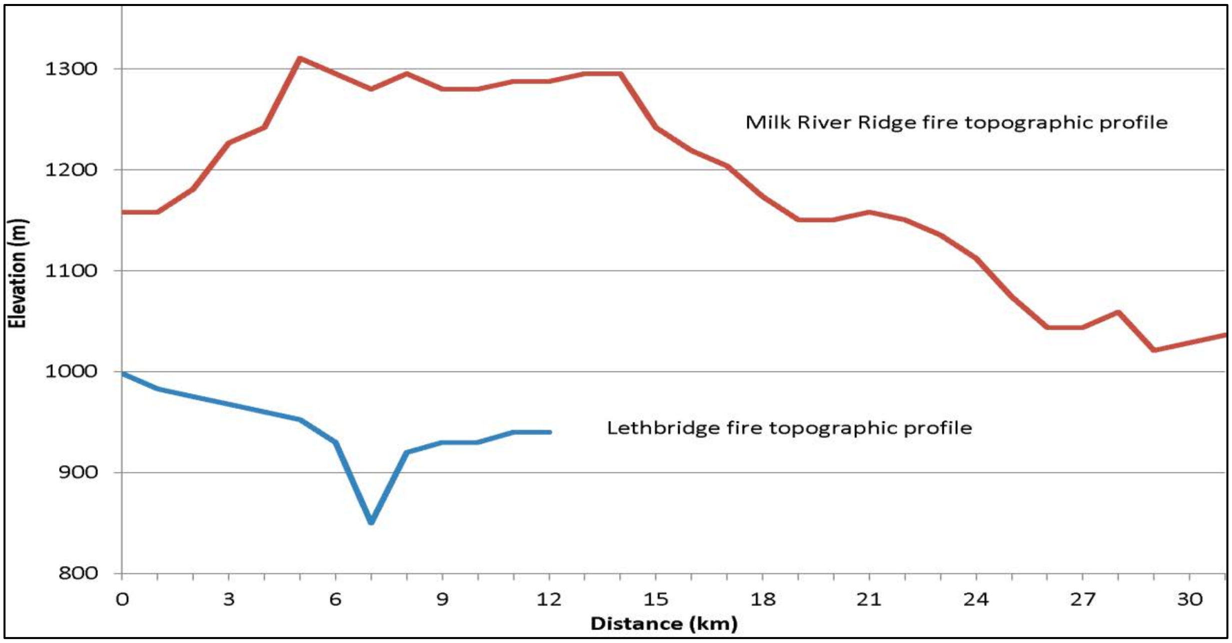

Figure 7. Topographic profiles for the Lethbridge and Milk River Ridge fires of November 27, 2011.

3.2 Fuels

In this region of Alberta, fuels are dominated primarily by either agricultural croplands (e.g., tame grass, wheat, barley, canola) or native grasslands (e.g., fescue), with the coulees and river valleys containing woody fuels along with the grass (Adams *et al.* 2004). These crop and grass fuels cure in the fall after a hard frost, remain dormant over winter and enter spring in a dormant stage before they green-up. At the time of the November 27, 2011 fires it was assume that a 100% degree of curing prevailed. They are largely non-flammable during the summer growing season but become quite fire prone in the spring and fall of the year. Snow-free conditions during the winter can also expose cured grassland and cropland fuels. Weather, climate, and topography interact to produce particular fuel mosaics in terms of vegetation types, amounts, and moisture content.

The Lethbridge Fire burned through cropland, bisected by riverine fuels (Figure 8a) while the Milk River Ridge Fire burned through grasslands and coulees (Figure 8b). Locally on agricultural lands, post-harvest fuel loads vary with crop type, with wheat averaging 3.0 t/ha, barley 2.5 t/ha and canola 2.8 t/ha in Alberta (Bailey-Stamler *et al.* 2007). Fuel sampling in stubble just west of Lethbridge and adjacent to the fire area produced a fuel load of 2.6 t/ha. Fescue grassland fuel loads in the region are estimated to be about 3.5 t/ha (Willms *et al.* 1986; Willms 1988).

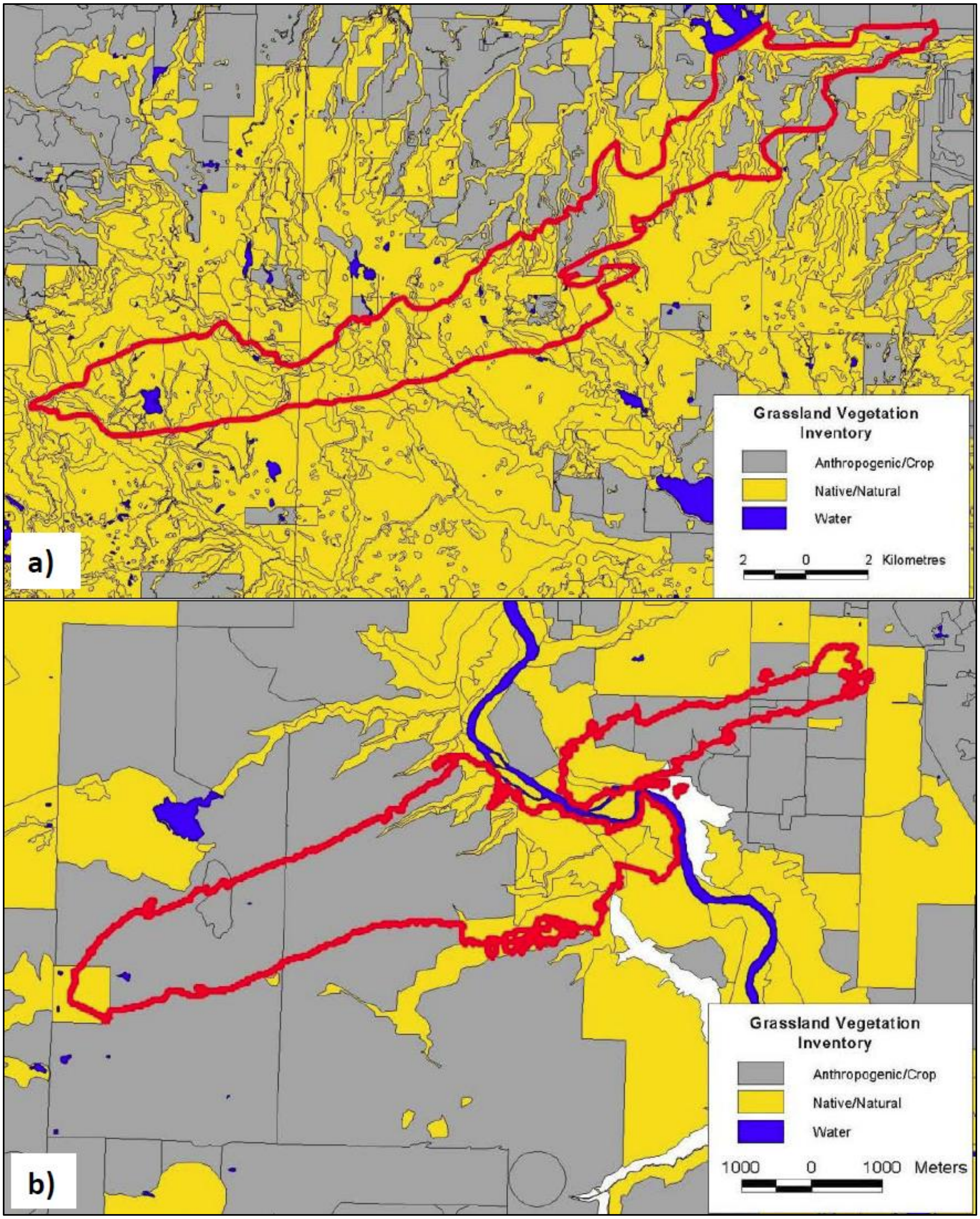

Figure 8. Broad vegetation/fuel typing associated with the (a) Lethbridge Fire and (b) Milk River Ridge Fire of November 27, 2011. The spatial data used to produce the base map is from the Alberta Grassland Inventory (http://www.srd.alberta.ca).

3.3 Weather

3.3.1 Antecedent Climatic Conditions

Following a wet growing season in 2010, a winter drought set in at the end of the year and lasted through to March 2011 (Figure 9). This was followed by four months of above-average moisture during the 2011 growing season. August and September were drier than normal and although October appears significantly wetter than normal, most of the precipitation came in a single event towards the end of the first week of the month. Following this early rain event (~70 mm) in October, drought conditions prevailed until the end of November 2011.

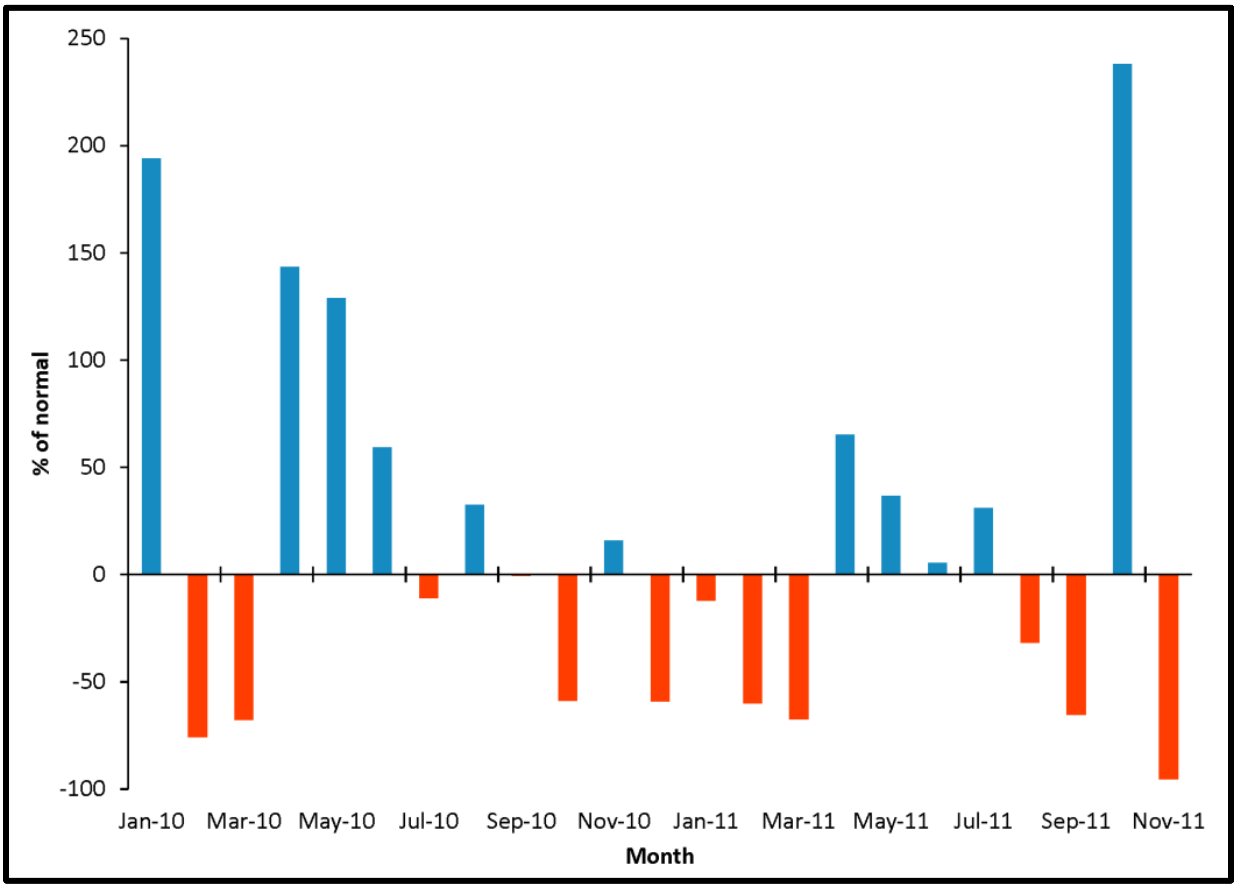

Figure 9. Monthly anomaly graph for precipitation for Lethbridge, Alberta, in the 22 months preceding the Lethbridge and Milk River Ridge fires of November 27, 2011. The anomaly is expressed as a percentage of the monthly value compared to the long-term average (1938 to 2011) as either above or below the average.

Lethbridge experienced its first snowfall of the winter season on November 18 when 2.0 cm of snow was reported; this amounted to just a little more than a trace of water equivalent (Table 1). A covering of snow remained on the ground until November 21 when the accumulation melted as a result of Chinook winds later in the week. The Lethbridge region then remained snow-free for the rest of the month of November.

3.3.2 Surface Weather Observations and Fire Danger Ratings

The 12:00 p.m. MST surface weather observations in the nine days leading up to the occurrence of the Lethbridge and Milk River Ridge fires and the day of the major runs are summarized in Table 1. The two components of the Canadian Forest Fire Weather Index (FWI) System pertinent to grasslands and agricultural crops are also included. The fire danger on November 27 would be by all accounts classed as "extreme" (Alexander 2008).

Table 1. Standard daily 12:00 p.m. MST surface weather and fire danger for the Lethbridge A weather station for November 18-27, 2011.

Date (Nov. 2011)	Dry-bulb temperature (°C)	Relative humidity (%)	Wind speed (km/h)	Cardinal wind direction	24-h precipitation (mm)	Fine Fuel Moisture Code (FFMC)	Initial Spread Index (ISI)
18	-13.6	80	20	North	0.3	-	-
19	-12.5	70	17	South	0.0	-	-
20	-13.2	81	7	Northeast	0.0	-	-
21	3.7	62	24	South	0.0	-	-
22	10.0	44	52	Southwest	0.0	86	25
23	12.1	41	39	Southwest	0.0	87	21
24	4.3	65	6	Southwest	0.0	85	3
25	4.4	42	50	West	0.0	86	24
26	5.6	25	32	Southwest	0.0	89	18
27	14.1	34	48	Southwest	0.0	89	36

Notes: Wind speed represents the 10-m open standard and the 24-h precipitation represents the amount accumulated in the 24-h period between successive daily observation times (Lawson and Armitage 2008). Snow cover prevailed from November 18 to 21 which negated the calculation of the FFMC and ISI.

To better understand the regional fire weather and fire danger situation on November 27, 2011, hourly surface weather observations were compiled along with calculations of fire danger ratings for six local area weather stations (Table 2) for the seven hour period from 12:00 to 7:00 p.m. MST. This included three Agricultural Drought Monitoring (AGDM) weather stations.

Table 2. Hourly weather and fire danger for November 27, 2011.

Station name, location, and elevation	Local time MST (p.m.)	Dry-bulb temperature (°C)	Relative humidity (%)	Wind speed (km/h)	Wind direction (°)	Fine Fuel Moisture Code (FFMC)	Initial Spread Index (ISI)
Lethbridge A	12:00	14.1	34	48	240	86	24
	1:00	14.3	33	61	250	87	31
49°37’49” N	2:00	14.2	32	59	240	88	36
112° 47’59” W	3:00	13.5	33	85	240	89	44
	4:00	11.8	35	67	230	89	43
929 m	5:00	11.0	35	67	240	89	43
	6:00	10.3	39	70	240	88	37
	7:00	8.7	52	56	240	87	30
Lethbridge	12:00	13.9	33	37	250	86	16
CDA	1:00	14.0	34	57	250	87	30
	2:00	14.2	32	54	240	88	34
49°41’42” N	3:00	13.7	32	69	250	89	43
112°46’03” W	4:00	11.9	37	52	250	89	38
	5:00	11.3	35	52	250	89	38
910 m	6:00	10.3	39	54	250	88	34
	7:00	9.3	47	48	250	87	27
Blood Tribe	12:00	14.0	32	69	260	86	28
AGDM	1:00	13.2	34	82	250	87	33
	2:00	13.2	32	91	260	88	38
49°34’ W	3:00	12.1	35	91	260	89	44
113°03’ W	4:00	10.7	38	63	250	89	42
	5:00	10.5	36	72	250	89	43
980 m	6:00	9.4	43	56	240	88	35
	7:00	8.5	53	57	240	87	30
Raymond	12:00	13.6	32	61	240	86	27
AGDM	1:00	13.7	33	43	240	87	24
	2:00	14.1	31	76	240	88	38
49°29’ N	3:00	13.5	32	83	240	89	44
112°41’ W	4:00	12.2	32	82	250	89	44
	5:00	11.6	33	72	240	89	43
937 m	6:00	9.9	44	69	240	88	37
	7:00	9.0	47	56	240	87	30
Del Bonita	12:00	11.2	38	44	240	86	21
AGDM	1:00	11.6	37	48	260	87	27
	2:00	11.7	35	19	280	88	8
49°03’ N	3:00	11.4	36	44	250	89	33
112°49’ W	4:00	9.7	36	74	240	89	44
	5:00	9.7	36	78	240	89	44
1310 m	6:00	7.6	50	65	230	88	37
	7:00	5.7	64	48	230	87	27
Milk River	12:00	12.5	33	22	210	86	7
	1:00	13.3	31	30	230	87	13
49°08’ N	2:00	14.2	30	59	240	88	36
112°03’ W	3:00	13.5	31	57	240	89	40
	4:00	12.7	31	57	250	89	40
1050 m	5:00	11.9	31	52	250	89	38
	6:00	12.4	30	72	260	88	38
	7:00	9.8	44	69	260	87	32

The standard daily Fine Fuel Moisture Code (FFMC) for all six of the stations given in Table 1 on November 27, 2011, was 89. While the 12:00 p.m. MST surface weather observations are used to calculate the standard daily FFMC, that value is not deemed applicable until approximately 4:00 p.m. MST (Van Wagner 1987). The similarities in weather observations and fire danger ratings between the stations as presented in Table 2 are indicative of a large air mass over the region during the afternoon of November 27, 2011.

The hourly FFMC values given in Table 2 were determined based on the diurnal FFMC table given in Lawson *et al.* (1996) and the standard daily FFMC of 89 on November 27 (Table 1). The hourly Initial Spread Index (ISI) values presented in Table 2 were calculated on the basis of the diurnal FFMC values and the hourly wind speeds. In cases where the 10-m open wind speeds exceeded 40 km/h, a special wind speed function contained in the Canadian Forest Fire Behavior Prediction (FBP) System was applied (Forestry Canada Fire Danger Group 1992).

4.0 ANALYSIS OF FIRE BEHAVIOUR

4.1 The Events of November 27, 2011

The standard daily FFMC was 89 at all six weather stations in the region on November 27 (Table 2). On the basis of the observations at the Lethbridge A, Lethbridge CDA, and Blood Tribe AGDM weather stations between 3:00 and 5:00 p.m. MST, the estimated ISI was 42 and the 10-m open wind speeds averaged 69 km/h during the run of the Lethbridge Fire (Table 2).

The predicted head fire rate of spread (HFROS) on level ground for FBP System fuel type O1-b (standing grass) at 100% degree of curing for an ISI of 42 is about 145 m/min or 8.7 km/h. The length-to-breadth (L:B) ratio of an elliptical shaped fire was in turn predicted to be 7.8:1. The predictions of HFROS and L:B compare favourably to the Lethbridge Fire's observed progress (average HFROS 138 m/min or 8.3 km/h) and shape (Figure 10), although admittedly there a slight overestimation, possibility due to fire suppression and/or fuel discontinues. However, as Cheney (1981) has noted: “The reality of fire behaviour predictions is that overestimates can be easily readjusted without serious consequences; underestimates of behaviour can be disastrous both to the operations of the fire controller and the credibility of the person making the predictions”.

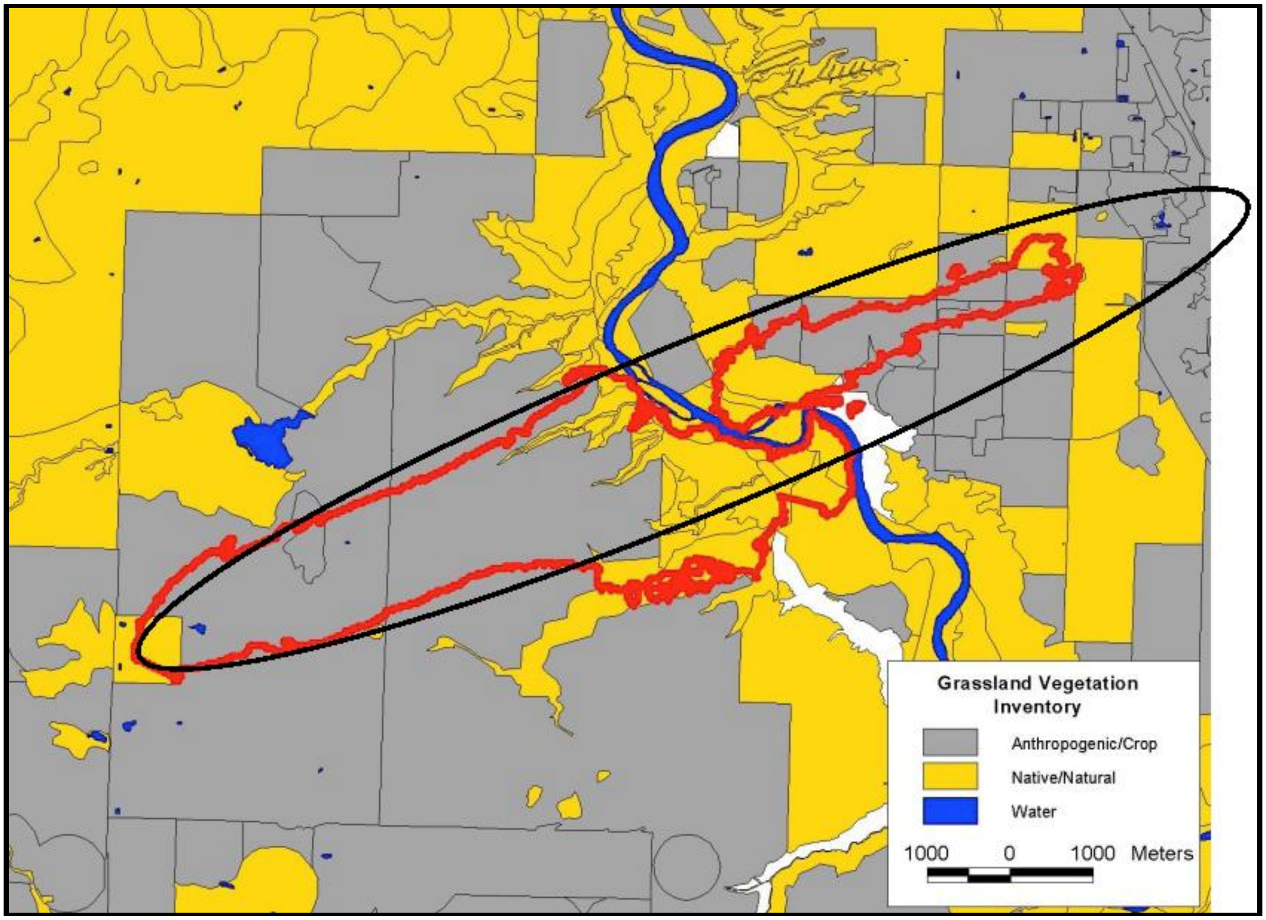

Figure 10. Hindsight projection of the growth of the Lethbridge Fire run of November 27, 2011, using the FBP System compared to the final mapped perimeter and the documented information on the head fire rate of spread.

On the basis of the observations at the Raymond AGDM, Del Bonita AGDM, and Milk River weather stations between 2:00 and 6:00 p.m. MST, the estimated ISI was 38 and the 10-m open wind speeds averaged 64 km/h during the run of the Milk River Ridge Fire.

The predicted HFROS on level ground for FBP System fuel type O1-b (standing grass) at 100% degree of curing for an ISI of 38 is about 135 m/min or 8.1 km/h. The L:B of an elliptical shaped fire was in turn predicted to be 7.6:1. The predictions of HFROS and L:B approximate the fire's observed progress (Figure 11) although not quite as well as the Lethbridge Fire due to the alignment of the ridge in relation to the prevailing winds.

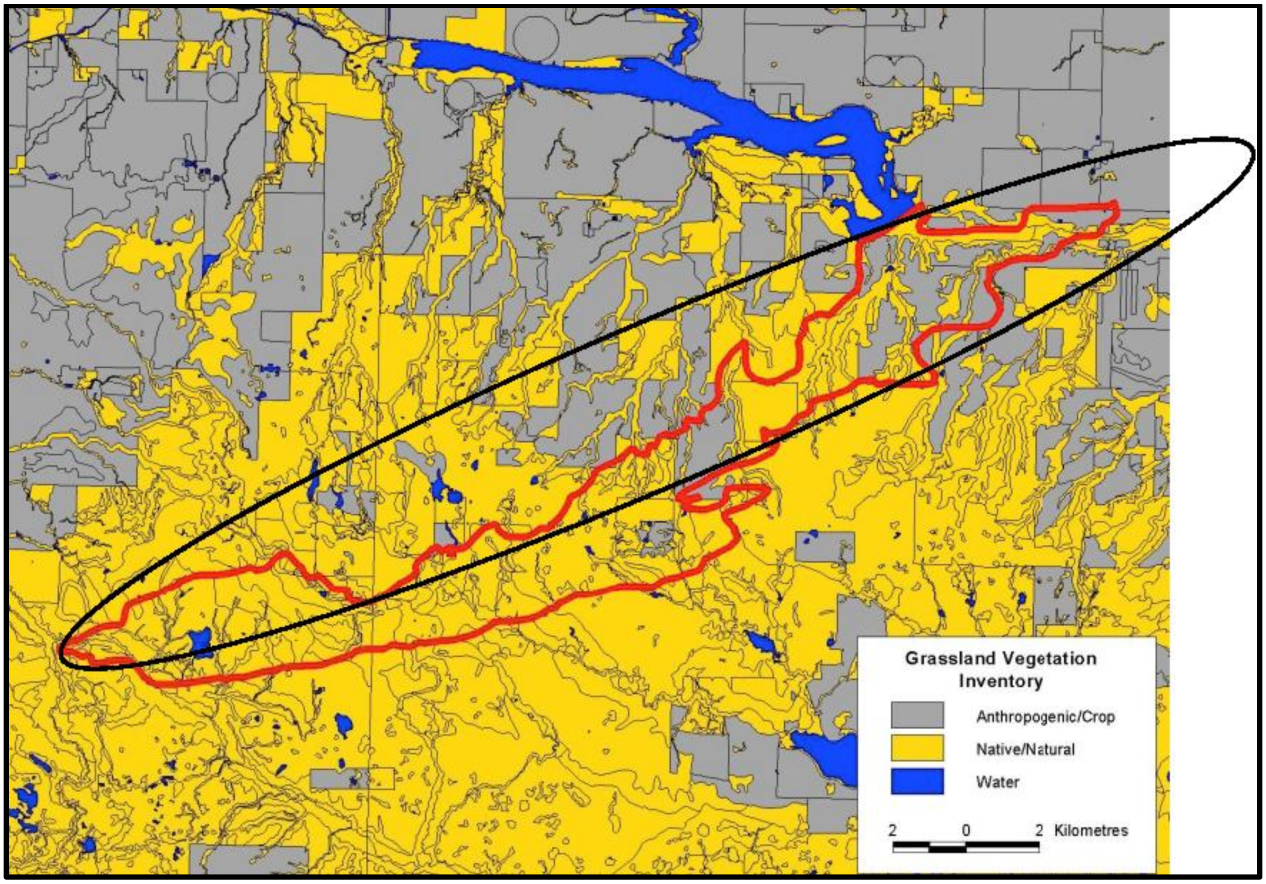

Figure 11. Hindsight projection of the growth of the Milk River Ridge Fire run of November 27, 2011, using the FBP System compared to the final mapped perimeter and assuming the spread event lasted four hours on the basis of the hourly weather.

4.2. Climatological Perspective

In order to develop a long-term climatic view of the grassland fire behaviour potential in the region during the winter months (i.e., November to March), a climatological database was first assembled. The daily 12:00 p.m. MST observations of dry-bulb temperature, relative humidity, 10-m open wind speed, the 24-h total precipitation for the weather stations in the Lethbridge area were downloaded from the Meteorological Service of Canada's National Climate and Information Archive for the period from January 1953 through to August 2007 (http://www.climate.weatheroffice.gc.ca/). The Lethbridge A weather station served as the main source of these observations except for the daily precipitation amounts, where observations were inconsistent or absent after August 2007. The Lethbridge AWOS A weather station became the predominate source of daily precipitation observations from August 2007 through December 2010. Occasional gaps in the daily precipitation record were filled with observations from Lethbridge CDA 2. Daily precipitation since January 2011 comes predominately from Lethbridge A. This amalgamation of weather observations allows the calculation of daily fire danger from 1953 through 2011.

Most of Canada is covered by snow during the winter months (Potter 1965), negating the need for assessing fire danger. Determination of the FFMC and ISI components of the FWI System during the winter months in Chinook country can be problematic (see http://cwfis.cfs.nrcan.gc.ca). The system requires for regions normally covered by snow during the winter, that fire danger calculations begin in the spring on the third day after snow melt (Canadian Forestry Service 1984). For regions where snow cover is not a significant feature, calculation of fire danger begins on third successive day when noon temperatures reach 12°C. In the fall, fire danger calculations should continue until snow covers the ground. Lawson and Armitage (2008) recommend continuing calculations until snow covers the ground or until noon temperatures drop below 12°C for three consecutive days. To examine the occurrence of these specifications, a long-term temperature and snow cover record was created using observations from the Lethbridge A weather station supplemented by data from area weather stations. Missing observations were replaced with observations recorded from nearby stations (i.e., Lethbridge A CR10, Lethbridge CDA, Lethbridge CDA 2, Monarch, Picture Butte), or estimated using temperature and precipitation observations. Snow on ground (cm) and temperature (≥ 12°C) observations were then summarized on an annual basis for the entire period of record (Figure 12).

The periodic lack of snow cover in this region as shown in Figure 12 requires special consideration due to the prevalence of Chinooks. Snow-free conditions can occur quickly during these warm, dry and windy events through sublimation. The exposed and fully cured, fine dead grass or crop fuels dry quickly and become readily available for ignition and fire spread. For the purpose of the analysis reported here, fire danger rating calculations were first run year-round. The calculated FFMC and ISI values for the days during the winter months that recorded snow on the ground were then simply removed from the fire danger record. They are included again within the continuously calculated fire danger record when the region is snow free. This method includes days considered to have potential for ignition and fire spread not included when using conventional start-up and closing procedures (Lawson and Armitage 2008).

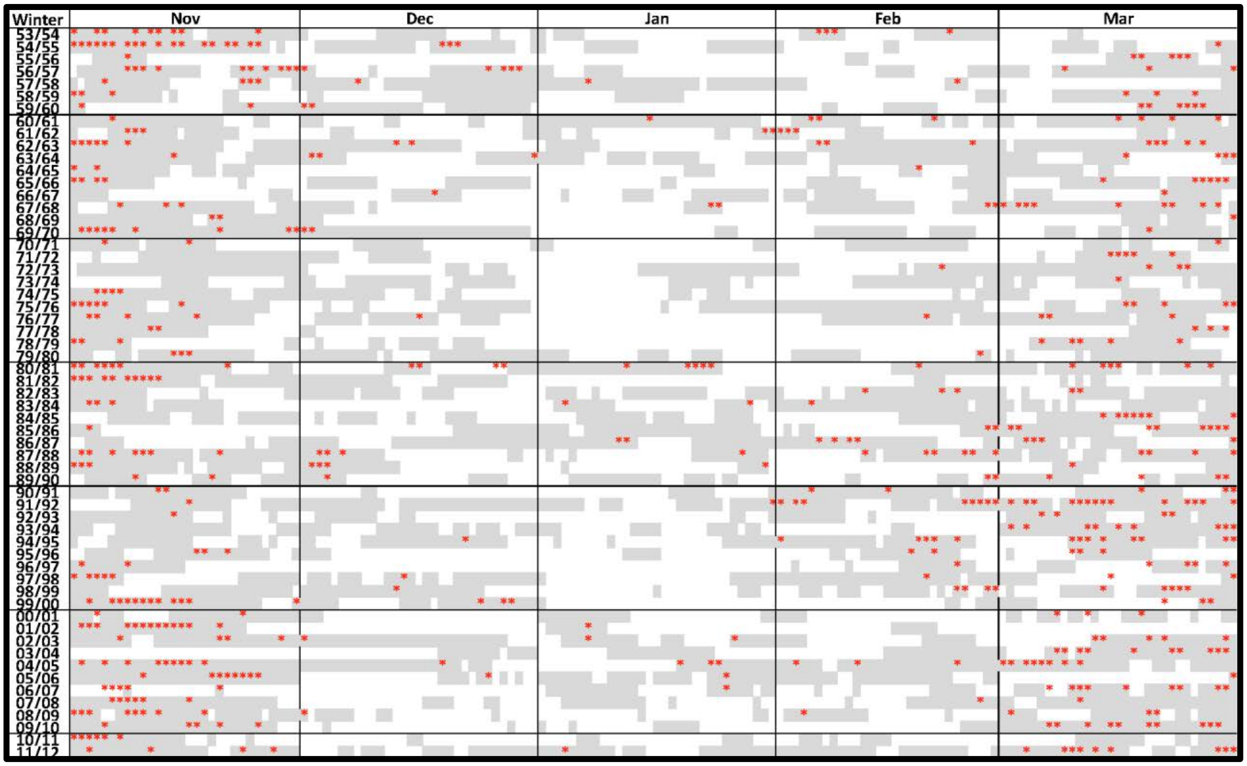

Figure 12. A 59-year (1953-54 to 2011-2012) climatological record of daily snow cover and noon-time temperatures during the winter months in the Lethbridge area. Periods of snow-free cover are shown as **grey**. White constitutes a period of snow on the ground. Days with 12:00 p.m. MST temperatures greater than or equal to 12°C are denoted with a red asterisk (*).

A 59-year fire behaviour climatological record for the winters of 1953-54 to 2011-2012 was created using the fire danger record as discussed previously. Daily calculations of HFROS on level ground for FBP System fuel type O1-b (standing grass) at 100% degree of curing were performed (Figure 13), as were computations for fireline intensity assuming an available fuel load of 3.5 t/ha. These estimates are based on the 12:00 p.m. MST weather observations and thus represent the peak burning conditions during late afternoon. The three HFROS classes selected for use rely on the relative suppression ease by ground forces equipped with a wildland fire engine: (i) easy suppression (HFROS < 1.0 km/h); (ii) challenging suppression (1-4.9 km/h); and (iii) beyond control (≥ 5.0 km/h). Generally speaking, engine attack requires a nozzleman to walk alongside or behind the engine as it progresses down along the flank of a spreading fire. The production rate is thus limited to the walking speed of the nozzleman. Fires spreading faster than the walking speed of a nozzleman are considered “beyond control”.

Figure 13. A 59-year (1953-54 to 2011-2012) climatological record of daily potential head fire rate of spread (HFROS, km/h) based on the Canadian Forest Fire Danger Rating System during the winter months in the Lethbridge area. **Green** represents an HFROS of < 1.0 km/h, **yellow** 1-4.9 km/h, and **red** ≥ 5.0 km/h. White denotes snow-cover days and thus no ignition or fire spread potential.

Less than half the days in an average winter have the potential for ignition and fire spread (Figure 14). The worst burning days (i.e., top 1%) are associated with predicted HFROS values greater than 10 km/h. Days in the winter considered "beyond control" (i.e., HFROS ≥ 5.0 km/h) occurred about 9% of the time. During an average winter, there are 14 days when HFROS exceeds 5.0 km/h with a single winter maximum of 43 days during the winter of 2011-2012 and minimum of zero days in 1973-1974.

Throughout an average winter season, ignition and fire spread potential is greatest in the months of November and March, with early January showing the lowest potential. The November 27, 2011 fires burned with a predicted spread rate of ≈8.5 km/h, which is within the worst 3% of all winter days. Overall, it appears that the winter of 2011-2012 had the greatest fire potential in the entire record.

The fireline intensity values in the climatological record were converted into a probability or possibility of a grass fire breaching a firebreak of a given width, and thus the potential for large fire growth, based on the model developed by Wilson (1988) as discussed in Appendix A. For the purpose of the analysis reported here, the firebreak width was assumed to be 10 m, which is the approximate width of local rural roads. It was further assumed that some woody material from shrubs or scattered trees was within 20 m of the firebreak (the presence of woody materials such as small twigs serves to act firebrand and thus increases the probability of firebreak breaching).

Three probability classes of firebreak breaching were recognized: < 50%; 50-94%; and ≥ 95%. The results are displayed in Figure 14. The wildfires of November 27, 2001, occurred on day when there was a 95% probability of breaching rural roads.

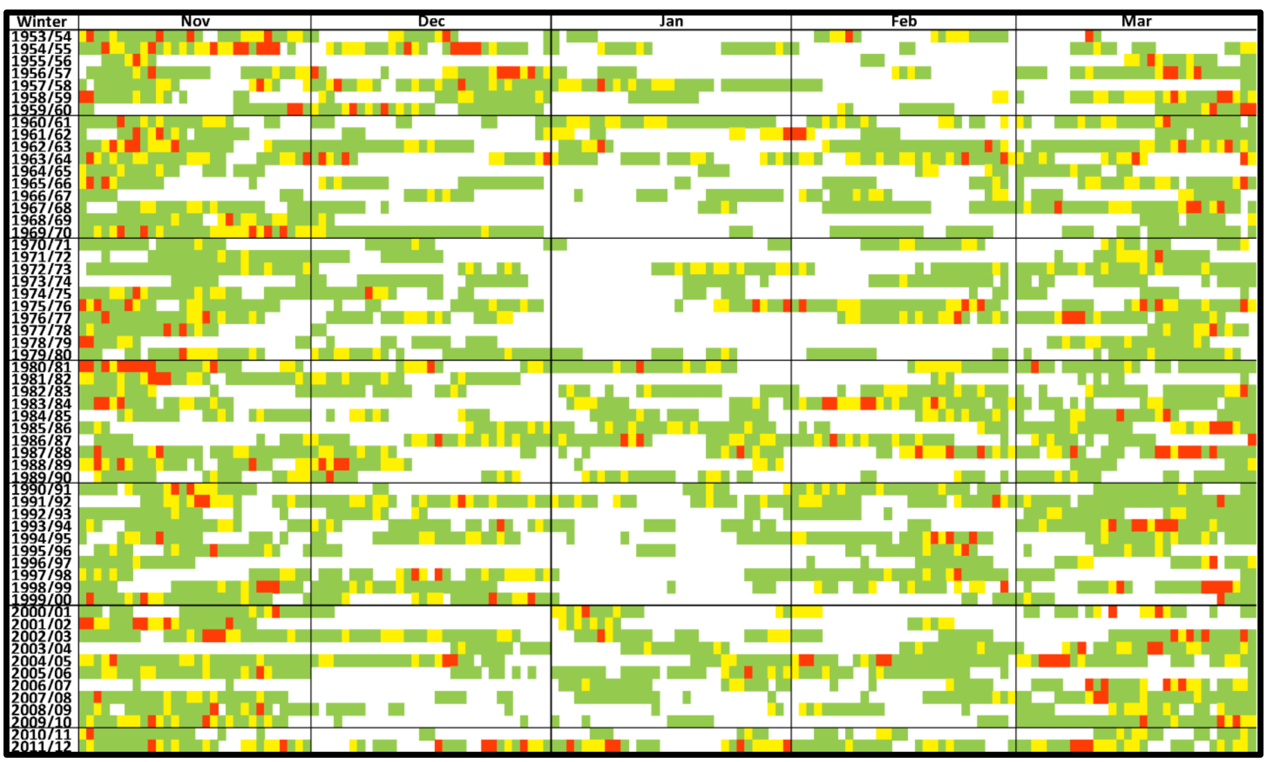

Figure 14. The daily probability of a grass fire breaching rural roads in the Lethbridge area based on a 59-year record of weather data (1953-54 to 2011-2012), the Canadian Forest Fire Danger Rating System, and Wilson's (1988) grassland firebreak breaching model. Green represents < 50%, **yellow** 50-94%, and **red** ≥ 95%. White denotes days of snow cover.

5.0 CONCLUSIONS

This report constitutes another example that can be added to the growing list of grass wildfire case studies globally (e.g., Olsen 1941; Douglas 1966; McArthur *et al.* 1982; Country Fire Authority 1983; Keeves and Douglas 1983; NFPA 1991; Noble 1991; Rasmussen and Fogarty 1997; Anderson 2003). While there are many similarities between grass fires, such as their responsiveness to wind speeds and direction[2], there are also several distinct differences.

The observed fire behaviour of both the Lethbridge and Milk River Ridge fires of November 27, 2011, closely conforms to the predicted fire behaviour using the CFFDRS. The fire danger conditions responsible for the behaviour of these two wildfires was not unique but instead frighteningly common. Firefighters responding to similar wildfires in the future need to be able to rapidly assess fire spread potential enroute and/or on arrival at the fire scene, and then react accordingly. This is especially important in fire environments characterized by an abundance of fine, dead dry fuels and strong winds.

Wildland fire behaviour research in Canada and elsewhere such as Australia (Cheney and Sullivan 2008) has provided the means to make quick estimates of fire spread potential in grasslands. This ranges from simple look-up tables (Taylor *et al.* 1997) to advanced fire growth models running on computer platforms (Tymstra *et al.* 2010). However, these kinds of fire behaviour guides and fire behaviour modelling systems require the continuous monitoring of actual and forecasted weather conditions (i.e., temperature, relative humidity, wind speed and direction, and 24-h accumulated precipitation) during the fire season.

This monitoring of actual and forecast weather conditions, and the computation of fire danger ratings and predictions of fire behaviour is a problem for small rural or municipal fire departments, as it requires a 24/7 commitment to systems operation during the fire season, which in the Lethbridge area, amounts to a year-round proposition. Weather station automation and digitization has allowed computerized solutions to this requirement in many regions of Canada (Lee *et al.* 2002). Unfortunately, the automated wildland fire information systems of both

[2] See, for example, the video entitled "Close Call With A Wildfire" posted on YouTube: http://www.youtube.com/watch?v=X61S-hWV054

the provincial and federal wildland fire management agencies (see (http://srd.alberta.ca/Wildfire and http://cwfis.cfs.nrcan.gc.ca, respectively) and either do not provide adequate coverage and timing or are poorly understood by most rural municipal fire departments active in Canada. This all constitutes a dilemma that needs to be resolved sooner than later.

All firefighters require a sound understanding of wildland fire behaviour coupled with best practices such as the LACES system (Thorburn and Alexander 2011) for safe and effective fire suppression (Countryman 1972). Wildland fire suppression can be an especially dangerous activity. Wildland firefighter fatalities have unfortunately occurred from time to time due to entrapments or burn-overs as well as other causes (Alexander and Buxton-Carr 2011). On October 2, 1993, a rural volunteer near Anerley, Saskatchewan, was overrun by a grass fire and eventually died of the burns he suffered (Fogarty and Alexander 1999).

Firefighting operations require that control actions be based on current and predicted fire behaviour. In the case of rapidly spreading grass fires, which can advance many kilometres during a single daily burning period, rapid fire assessment is essential. The information that is capable of being produced by the CFFDRS needs to be provided to firefighters in a timely fashion so that armed with some simple aids (i.e., ruler, topographic map, compass), they can quickly gauge a fire's probable behaviour and match their response to the fire's spread potential (e.g., Fogarty and Alexander 1999; Alexander and Fogarty 2002).

The general public in southern Alberta would undoubtedly benefit from an increased awareness of grassland fire behaviour and occurrence potential as well as from a safety standpoint (Partners in Protection 2003; Alexander *et al.* 2012b), including an advanced warning that "extreme" fire danger conditions are forecasted and that measures should be taken to reduce ignitions (e.g., check recently burned debris piles).

There are many ignition sources associated with unwanted human-caused wildfires (Woodard and Niederleitner 1983). Wildfires initiated by humans can be the result of: (i) accidents or human carelessness (e.g. wind-blown firebrand from a campfire or debris burning, discarded cigarette, fireworks celebration, arcing power-lines) and (ii) arson (i.e. the malicious setting of a fire with matches, incendiaries such as flares, etc.). Technically, all human-caused wildfires are preventable (Doolittle *et al.* 1976) and thus each wildfire constitutes a fire prevention failure.

While this report has focused on grass fires during the winter months in southern Alberta, many of the principles are also relevant to grass fire hazard during the spring fire season in Alberta and Canada as a whole. A reminder of the general need for action occurred less than 10 months after the fires of November 27, 2011. On Monday, September 10, 2012, two major wildfires, as briefly described in Appendix 6, again occurred southwest of Lethbridge and on the Milk River Ridge (Figure 1). A fire starting on the Blood Indian Reserve spread in a northeasterly direction through grassland and agricultural fields at a rate comparable to the fires of November 27, 2011. The Lethbridge area fire burned over some 5336 ha and forced the evacuation of people from the communities of Coalhurst and Lethbridge. The Milk River Ridge Fire of 2012 near the U.S. border swept over 6390 ha. Normally you don't get too many second chances when it comes to large wildfires.

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Appendix 1. A Primer on Grassland Fire Behaviour in Relation to Fire Suppression

Fire behaviour is defined as "the manner in which fuel ignites, flame develops, and fire spreads and exhibits other related phenomena" (Merrill and Alexander 1987). Three basic elements in proper combination are necessary for combustion and flame production to occur – fuel to burn, heat to ignite it and oxygen (i.e., air) to support the process as illustrated in the fire triangle (Figure A1.1).

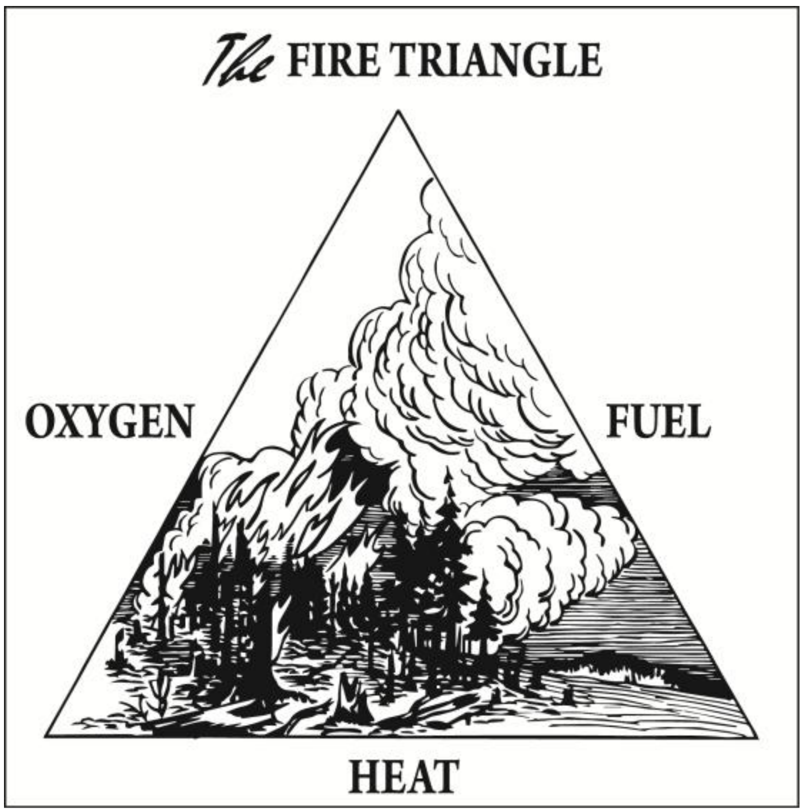

Figure A1.1. The fire triangle or combustion triangle (from Barrows 1951).

There are certain universal principles applicable to all wildland fires regardless of whether they are spreading through live and/or dead fuels:

- There must be sufficient fuel of appropriate size and arrangement for the fire to burn in and through.
- This fuel must be sufficiently dry to support a spreading combustion reaction.
- There must be an agent of ignition.

Fire spread in wildland fuels like grass is governed by fuel moistures (live and dead), fuel characteristics (e.g., condition), wind strength, and slope steepness. The functions are typically non-linear in nature (Alexander and Cruz 2013).

The source of ignition may be natural or anthropogenic (i.e., caused by humans). Lightning-ignited grass fires have been reported in the Canadian prairies (Rowe 1969). The sources of human-caused fires are numerous (NWCG Fire Investigation Working Team 2005).

Grasslands generally present sufficient fuel to support spreading combustion late in the growing season although there are fuel quantity limits (Clark 1983). Fuel quantities do, however, vary depending on variations in seasonal conditions (e.g., rainfall patterns, drought intensity), site fertility, and type and degree of land use (Davis 1949). Grass fires have been observed spreading across very heavily grazed pastures with extremely low fuel loads late in the fire season under severe fire weather conditions (McArthur 1966; Luke and McArthur 1978; Cheney and Sullivan 2008; Sullivan 2010).

Seasonal changes in living vegetation can have a major effect on the condition of both live and dead fuels with respect to moisture content and, in turn, wildland fire behaviour. The most pronounced and readily observable example is the degree of curing that occurs in annual and perennial grasslands (Garvey and Millie 1999; NWS 2010) during the fire season (Figure A1.2) – i.e., the proportion of cured and/or dead plant material in a grassland fuel complex expressed as percentage of the total fuel mass (Cheney and Sullivan 2008).

Grasses constitute very fine fuels with high surface area-to-volume ratios. They become highly combustible when they become fully cured. This occurs as a result of the low moisture contents exhibited by these fuels in response to their exposure to solar radiation and the full force of the wind in the open (McArthur 1966; Luke and McArthur 1978).

Green grass on the other hand is not as flammable due to the high moisture contents it exhibits (Wittich 2011) upon emergence in the spring (Figure A1.2). The trends shown in Figure A1.2 would typically occur from April to August in southern Alberta. As Wright (1932) notes, even in mid summer "there is generally sufficient dead bottom material among the green grass to carry fire well."

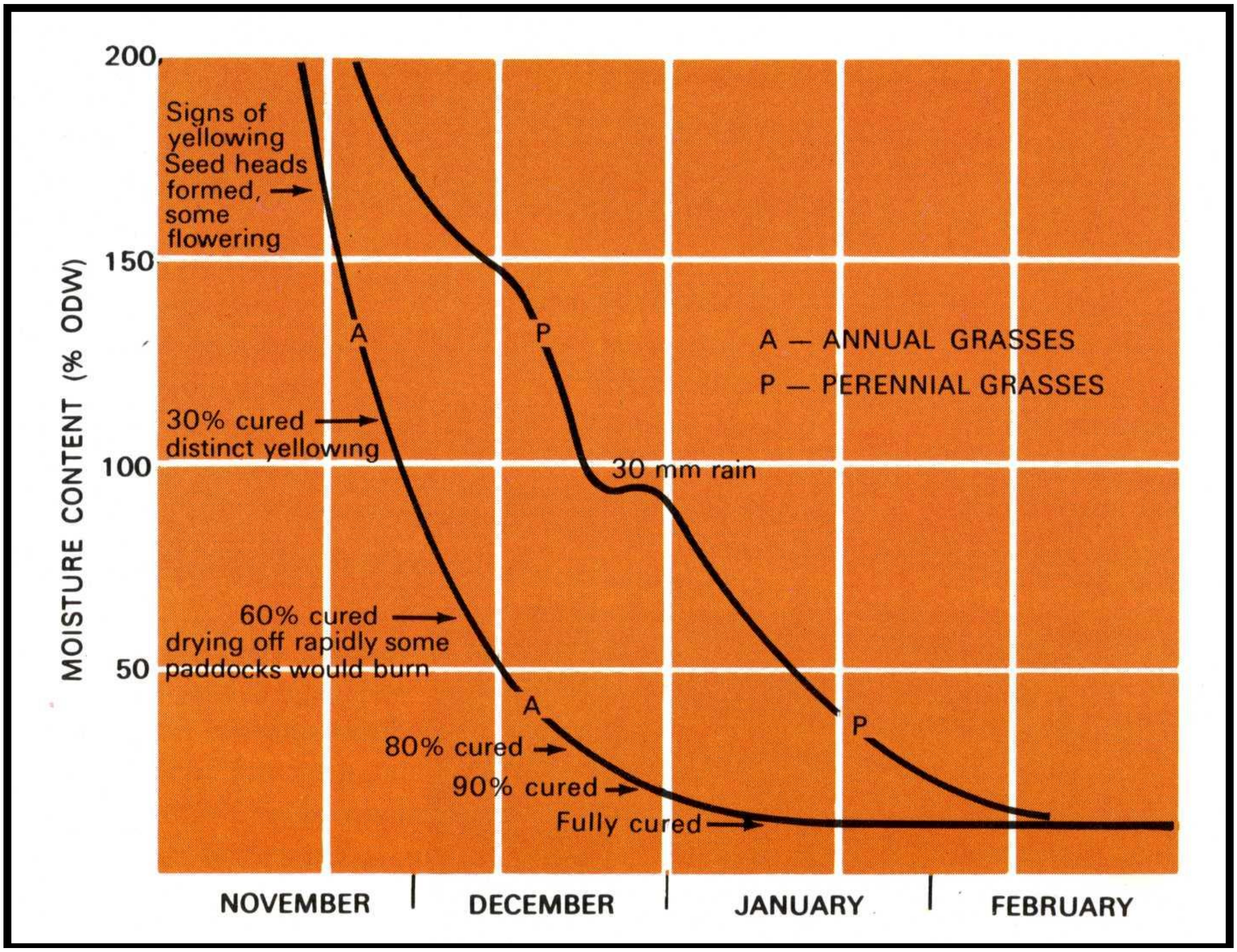

Figure A1.2. Seasonal pattern in moisture content and degree of curing in annual and perennial grasslands in the Australian Capital Territory during the 1964-65 fire season (from Luke and McArthur 1978).

Once grasses become fully cured their moisture content is mainly controlled by air temperature and relative humidity (Figure A1.3), and more so by the latter than the former. The probability of sustained flaming steadily increases as the relative humidity of the air decreases (Figure A1.4).

Fires will not spread in grass under "light" winds (i.e., ≤ 10 km/h) when the dead fuel moisture content exceeds about 20%, but may do so up to 24% fuel moisture content if winds exceed 10 km/h (Cheney and Sullivan 2008).

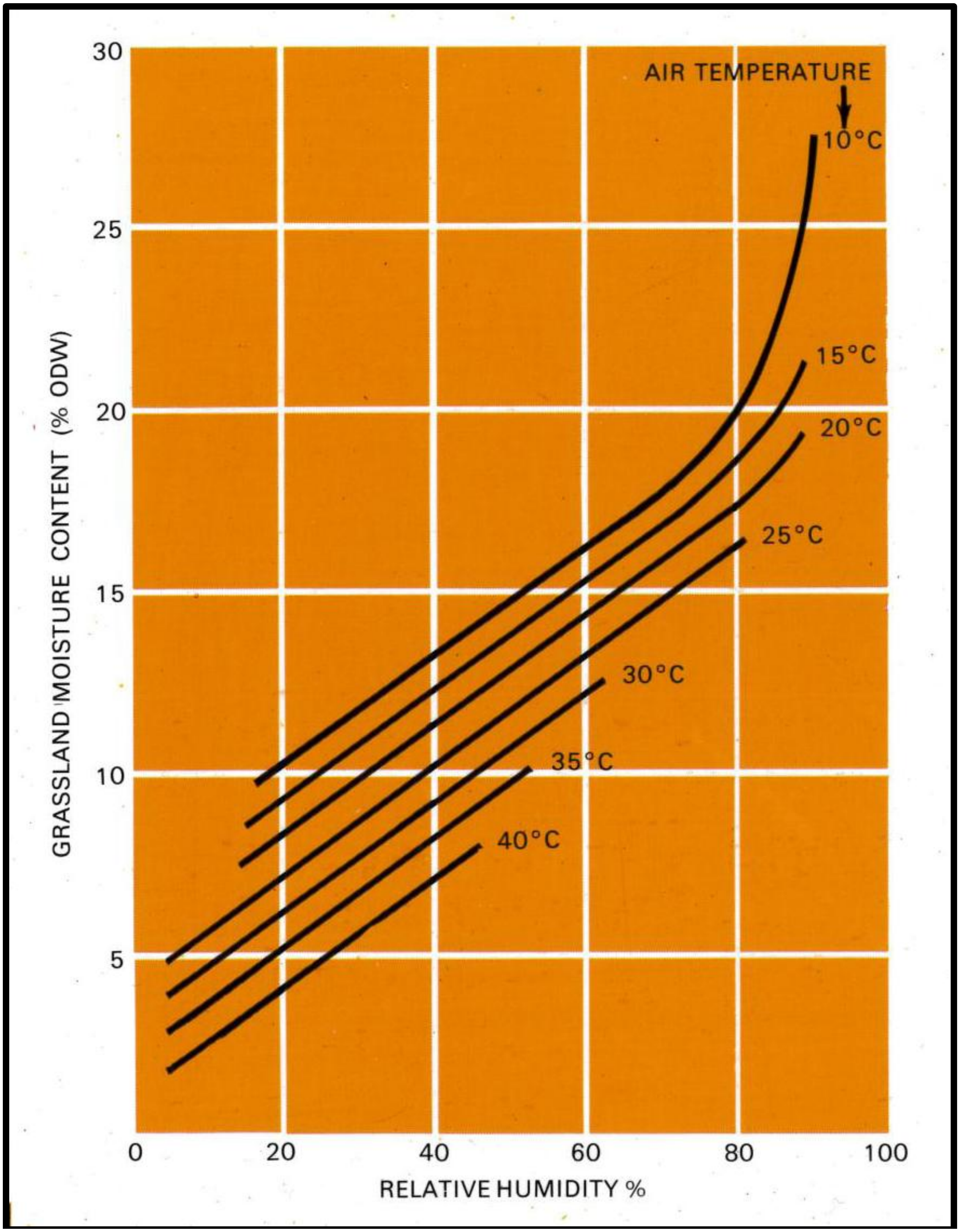

Figure A1.3. Fuel moisture content expressed on a % oven-dry weight (ODW) basis in fully cured standing grasslands related to relative humidity and air temperature (from Luke and McArthur 1978).

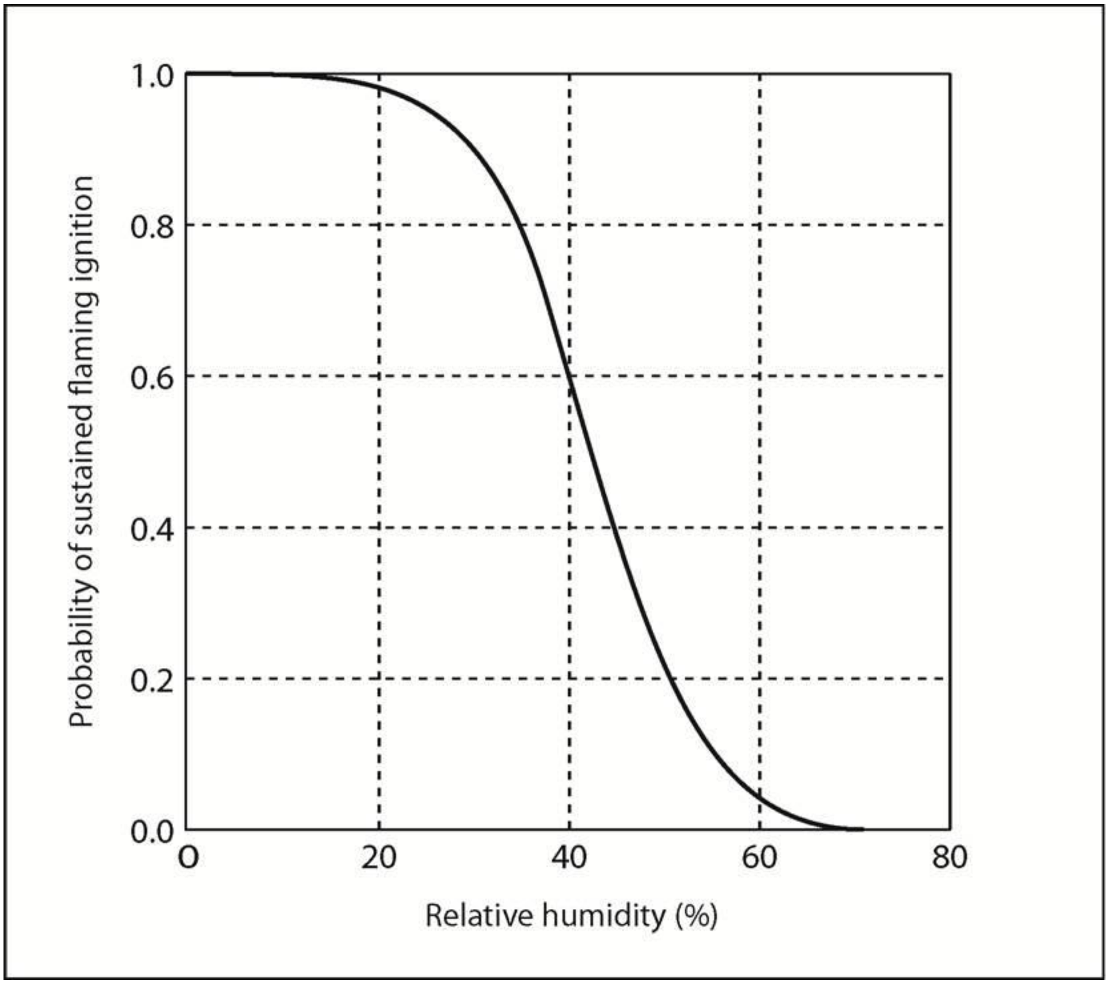

Figure A1.4. Probability of sustained flaming ignition of cured grass fuels during spring conditions as a function of relative humidity based on match ignition tests (adapted from Beverly and Wotton 2007).

A wildfire originating from a single point source ignition (e.g., burn pile, abandoned campfire) will steadily increase its forward rate of advance with elapsed time since ignition, eventually reaching something like an equilibrium state for the prevailing environmental conditions. The period of time required for a fire to attain this level of fire behaviour is highly variable. Experimental grass fires carried out in Australia (Cheney and Sullivan, 2008) took 30 minutes to reach their maximum rate of advance (Cheney and Sullivan 2008). However, they could take from as little as 12 minutes to more than an hour. As McArthur (1968) so aptly states, it is "during the first 30 minutes or so of a fire's life history, suppression forces have their greatest chance of success purely because the fire is still accelerating and has not reached its maximum rate of spread".

In discussing the parts or geography of a wildfire, it is common to talk about the head and front, flanks (e.g., right/left, east/west), and rear or back of the fire (Figure A1.5a). There may also be wind-blown spot fires out ahead of the main advancing fire front. The fire perimeter represents the entire edge or boundary around the fire. In turn, the area enclosed by the fire perimeter represents the fire area or burned area. Unburned islands maybe found within the main body of the fire. In a highly irregular perimeter, pockets or bays may also be found along the perimeter in addition to fingers.

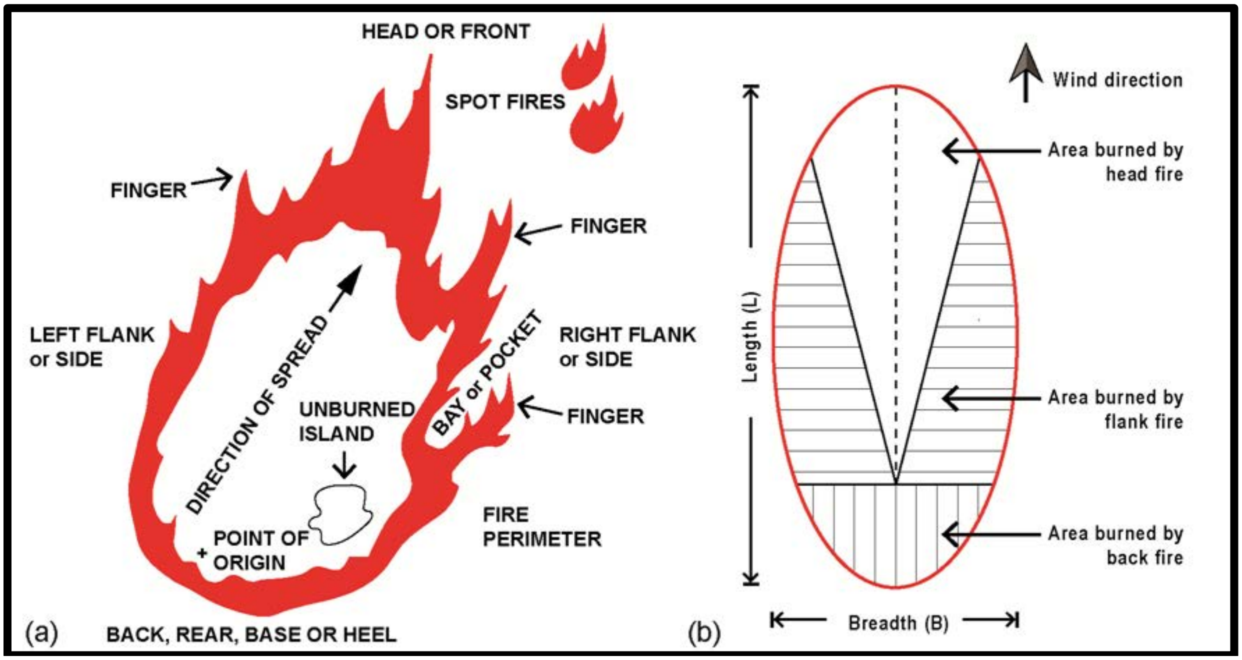

Figure A1.5. Schematic diagrams illustrating (a) the parts of a free-burning, wind-driven wildland fire (after Moberly *et al.* 1979) and (b) a simple elliptical fire growth model with the point of ignition or origin located at the junction of the four area growth zones (after Van Wagner 1969).

The most basic features of any wildland fire are that: (i) it spreads, (ii) it consumes fuel, and (iii) it produces bright light, heat, buoyancy, and smoke. It is therefore useful to think about the behaviour of wildland fire in terms of how fast it travels, where it is headed, what it looks like (e.g. flame dimensions), what it feels and sounds like from some distance, as well as its overall size and shape.

Fireline intensity as originally developed by Byram (1959) represents the rate of heat released from any point around the edge or perimeter of a spreading fire and is calculated as follows (from Alexander 1985a):

$$I = \frac{H \times w \times R}{600}$$

where, I is the fireline intensity expressed in kilowatts per metre (kW/m), ***H*** is the heat yield of the burned fuel in kilojoules per kilogram(kJ/kg) , ***w*** is the quantity of fuel consumed in tonnes per hectare (t/ha), and ***R*** is the linear rate of fire spread in metres per minute (m/min) (Alexander 1982). For practical purposes, ***H*** is generally considered a constant (~18 000 kJ/kg).

In grasslands, most of the potential variation in fireline intensity is largely a result of the possible range in rate of fire spread. Fireline intensity in grassland fuels can vary over an exceedingly wide range, from as low as 10 kW/m, where fires are just barely able to sustain themselves, to upwards of 60 000 kW/m at the head of a very-fast moving grass fire.

Byram's (1959) fireline intensity is directly related to length of the spreading flames (Figure A1.6). The following equation is considered adequate for field use:

$$I = 300 \times L^2$$

where, ***L*** is the flame length in metres (m) and represents the distance between the tip of the flames and the midpoint of the flame depth (Alexander and Cruz 2012). The flame height largely determines the degree of radiant heat received at a given distance from the flame front.

Assuming an elliptical fire shape (Figure A1.5b), a rough estimate of the size of a wildland fire can be made in terms of area and perimeter on the basis of its combined forward and backward spread distances and L:B ratio based on the mathematical formulae for an ellipse (Alexander 1985b). The L:B of an elliptical shaped grass fire is in turn a function of the wind speed (WS, km/h) (Table A1.1):

$$\text{L:B} = 1.1 \times \text{WS}^{0.464}$$

Table A1.1. Length-to-breadth (L:B) ratio for elliptical shaped grass fires on level terrain as a function of the 10-m open wind speed (WS, km/h) (adapted from McArthur 1966; Cheney 1981).

WS	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
L:B	1.0	2.3	3.2	3.5	4.4	4.9	5.3	5.7	6.1	6.4	6.8	7.1	7.4	7.6	7.9

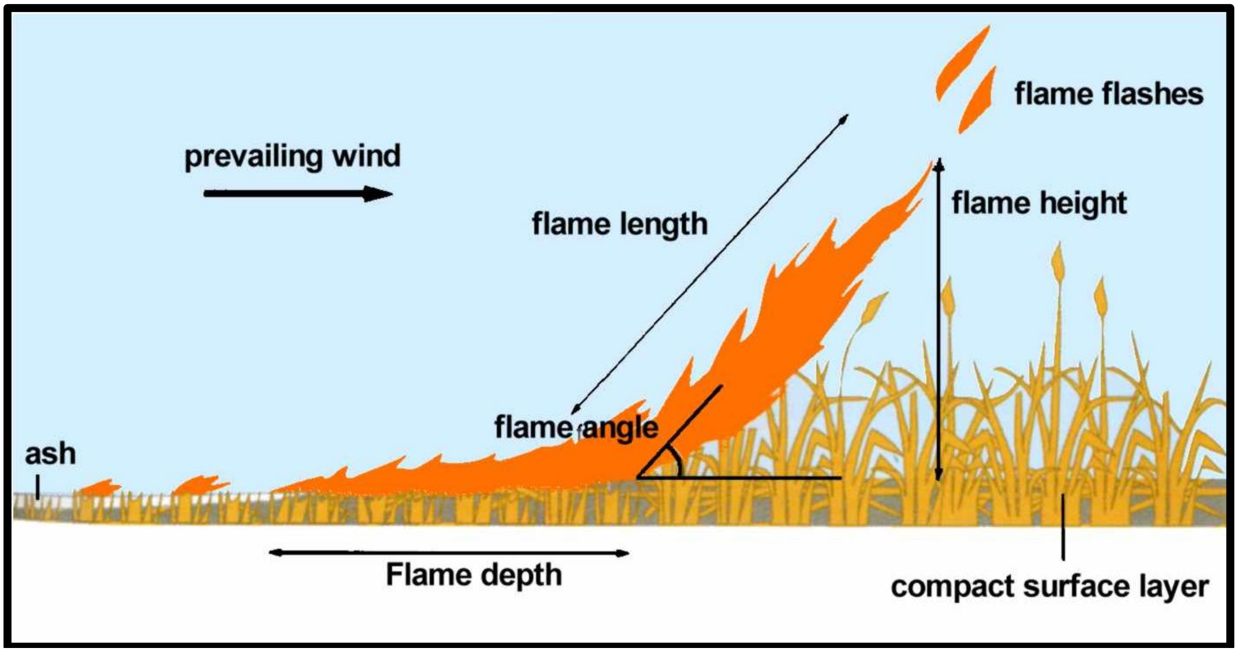

Figure A1.6. Idealized cross-section of a wind-driven surface head fire flame front in grass fuels on level terrain (from Cheney and Sullivan 2008).

The fire triangle is commonly used to illustrate the basic principles of fire suppression (Figure A1.1). To stop a free-burning fire you must either:

1. Remove the fuels ahead of the spreading combustion zone;
2. Reduce the temperature of the burning fuels; or
3. Exclude oxygen from reaching the combustion zone by smothering.

In practical terms this means creating a physical barrier in front of the fire: by removing the fuels; cooling/smothering the flames with water; or covering them with mineral soil, suppressants or chemical fire retardants by various means from either the ground or the air (Alexander 2000).

Fireline intensity and in turn flame length is a major determinant of the limit of effectiveness or minimum requirement for the different types of firefighting resources relative to the difficulty of control (Alexander 2000, 2008). Flame length has been related directly to various measures of fire suppression over the years. Byram (1959), for example, recommended that in the absence of severe spotting, the minimum width of a constructed fireline or fireguard should be 1.5 times the expected flame length.

The probability of containment will depend on sending enough resources of the right type relative to the expected fire behaviour at the time of initial attack (Figure A1.7). In order to achieve successful fire containment, the rate of extinguishment of the fire's perimeter by suppression resources must eventually exceed the rate of perimeter growth of the fire (Alexander 2000).

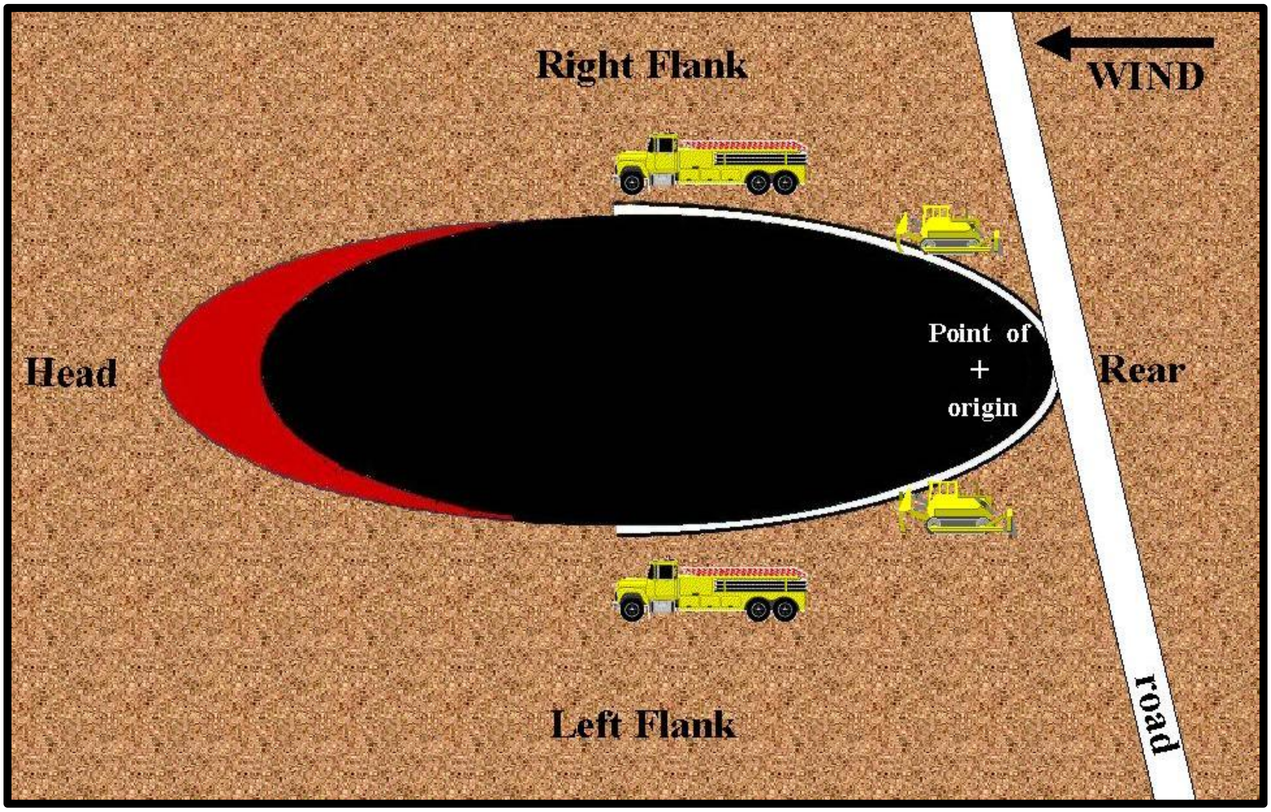

Figure A1.7. Schematic diagram illustrating the direct attack method of fire suppression that involves attacking the fire immediately adjacent to the burning fuel and by progressively moving up along both flanks towards the fire's head.

Douglas (1966) provides an excellent accounting of just such a case (Figure A1.8). Figure A1.8 includes a fire progress map and the general tactics used to suppress the fire. The graph of area burned plotted against elapsed time since ignition indicates that not until at least 9 fire truck units were working on the fire did the rate of increase in area burned begin to decline. Generally the rate of progress of knocking down and holding the fire perimeter with 10 units proceeded at the rate of 3.2 to 6.4 km/h.

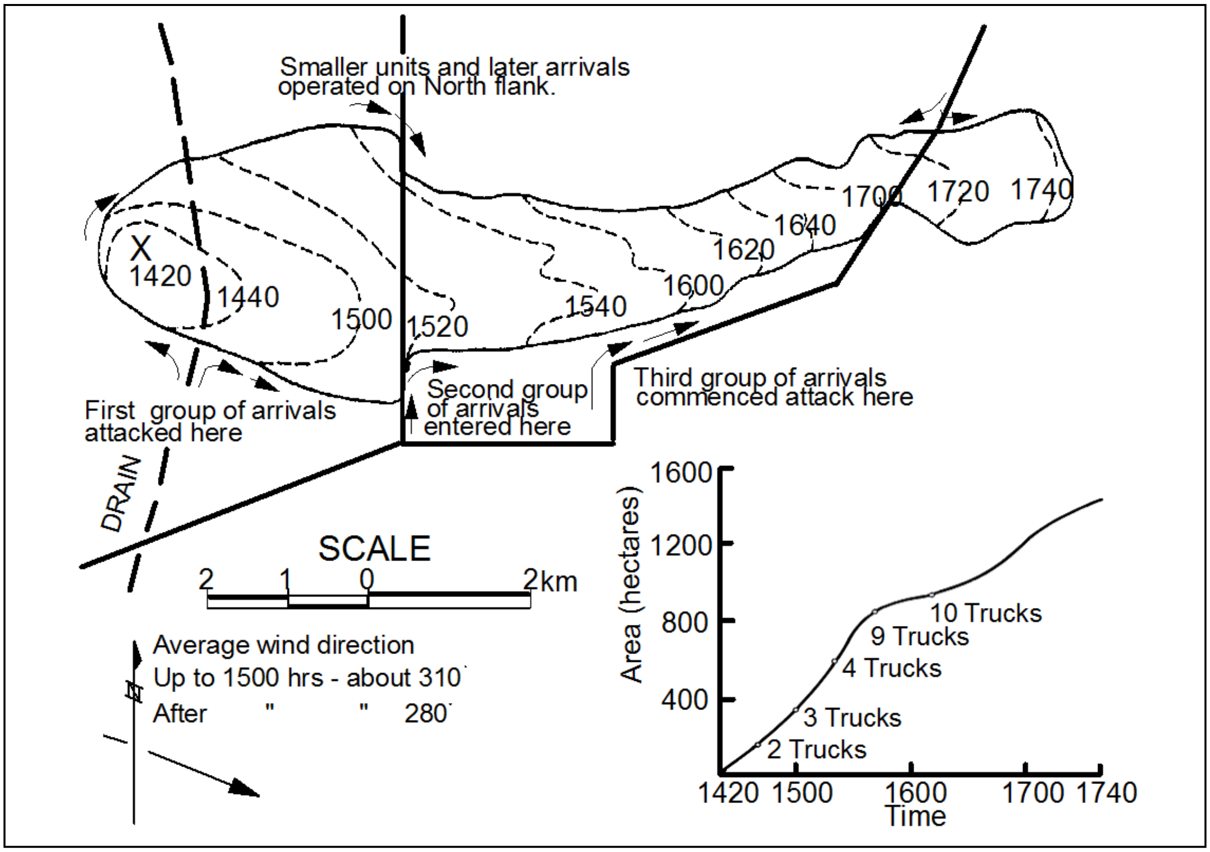

Figure A1.8. Progress map with suppression details and a graph of the cumulative area burned in relation to elapsed time since ignition and arrival of various firefighting water trucks involved in the containment of the 1966 Monbulla Fire in South Australia pasture lands (adapted from Douglas 1966).

Wilson (1988) developed two models for predicting the probability of grass fires breaching constructed firebreaks or other man-made (e.g., gravel or paved road) and natural barriers to fire spread (e.g., creek or river). One model was designed for use with trees/shrubs absent within 20 m of the firebreak and the other where trees/shrubs are present within 20 m of the firebreak (Figure A1.9). In the latter case, woody debris from vegetation serves as a firebrand source for spotting.

The Wilson (1988) models were built upon 113 experimental fires as carried out in the Northern Territory of Australia (Cheney *et al.* 1993; Cheney and Sullivan 2008). The first author of this report (MEA) visited the study area in September 1991 and found the grass fuel structure very similar to Canadian conditions. It is worth noting that flame height in grass fires has been related to the HFROS based on this same set of experimental fires (Figure A1.10).

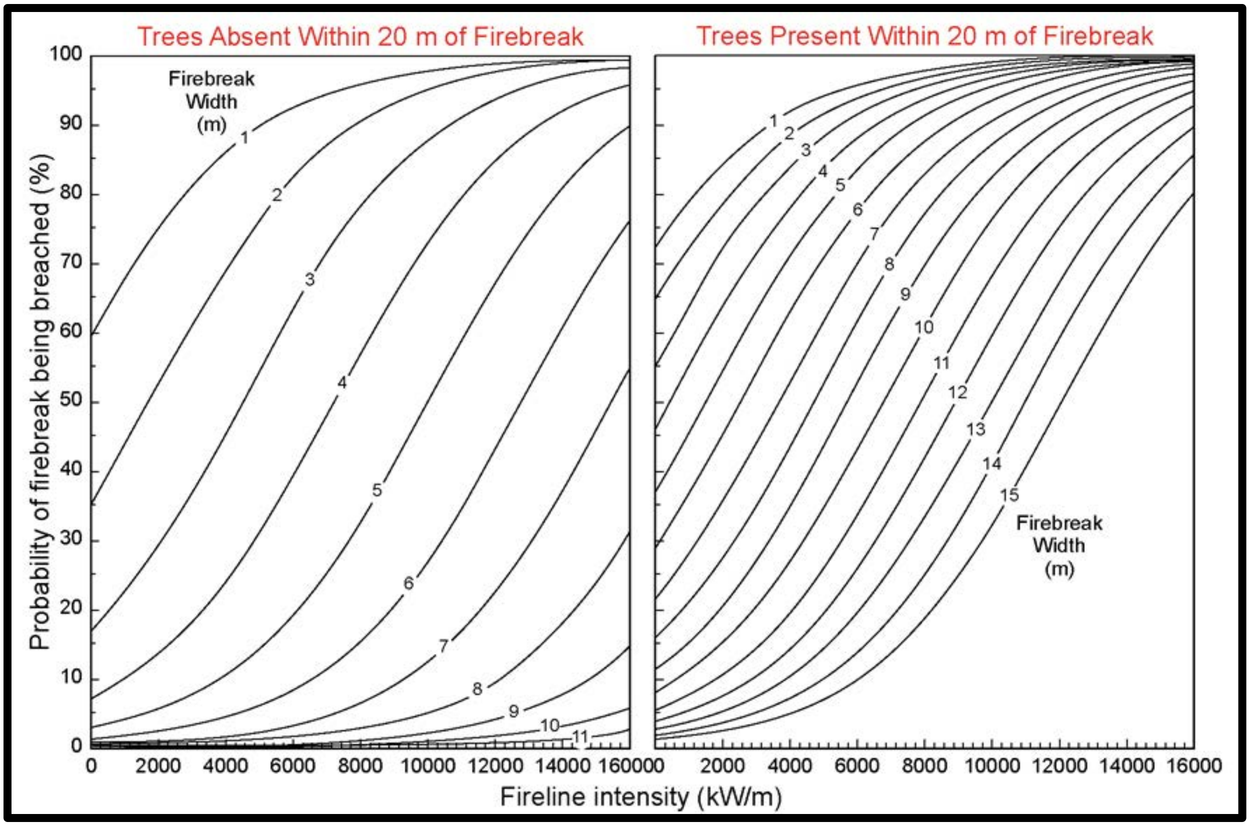

Figure A1.9. Probability of firebreak breaching models for grass fires as a function of fireline intensity and firebreak width (adapted from Wilson 1988).

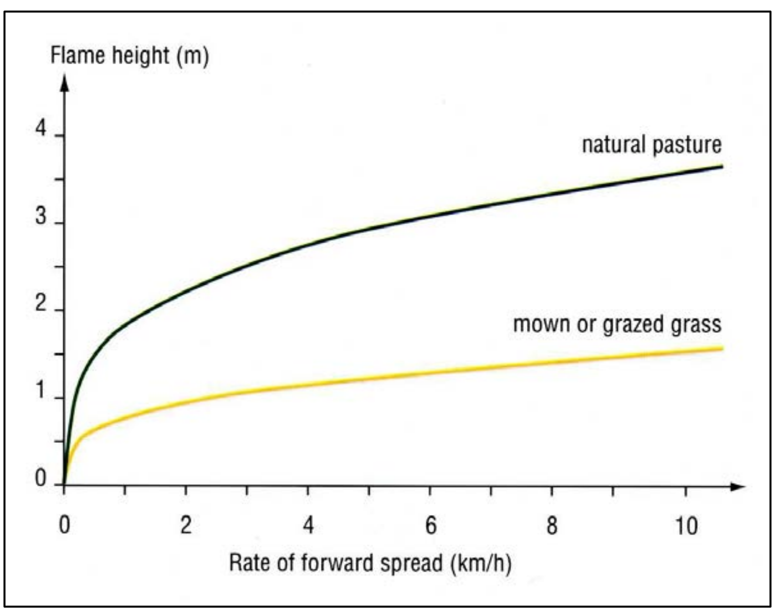

Figure A1.10. Relationship between flame height and rate of fire spread in natural or ungrazed pastures (50-80 cm in height) and mown or grazed grasslands (<25 cm in height) (from Cheney and Sullivan 2008).

Appendix 2. Overview of the Canadian Forest Fire Danger Rating System

The Canadian Forest Fire Danger Rating System (CFFDRS) is comprised of two major subsystems or modules (Stocks *et al.* 1989; Taylor and Alexander 2006):

- the Canadian Forest Fire Weather Index (FWI) System (Van Wagner 1987)
- the Canadian Forest Fire Behavior Prediction (FBP) System (Forestry Canada Fire Danger Group 1992; Wotton *et al.* 2009)

The FWI System is in turn comprised of six standard components that provide relative numerical ratings of wildland fire potential for a standard fuel type (mature pine) on level terrain based on continuous daily noon local standard (1:00 p.m. daylight) observations of four weather measurements (Figure A2.1): dry-bulb temperature, relative humidity, 10-m open wind speed, and 24-h accumulated precipitation. The FWI System is thus dependent entirely on weather and does not consider differences in ignition risk, fuel types or topography.

The first three components of the FWI System are fuel moisture codes that follow the daily changes in the moisture contents of three classes of forest fuel with different drying rates (i.e., litter, duff, and deep organic). For each, there are two phases – one for wetting by rain and one for drying – arranged so that the higher values represent lower moisture contents and hence greater flammability. The Fine Fuel Moisture Code (FFMC) has a maximum theoretical value of 101, but the Duff Moisture Code (DMC) and Drought Code (DC) are “open ended” (i.e., a higher value is always possible in the absence of a precipitation event). The final three components are fire behaviour indexes, namely the Initial Spread Index (ISI), the Buildup Index (BUI) and Fire Weather Index (FWI) itself, representing, on relative basis, the rate of fire spread, amount of fuel available for combustion, and fireline intensity, respectively (Figure A2.1). Their values increase as fire weather severity worsens (i.e., they too are also “open ended”).

Definitions of the six FWI System components are given in Table A2.1. Because calculation of the FWI System components depends solely on weather readings, they can just as easily be calculated from forecast weather to yield a fire danger forecast. Each component of the FWI System conveys direct information about certain aspects of wildland fire potential. Because the FWI System is dependent solely on weather, the actual fire behaviour can in turn be expected to vary from one fuel type to another at the same code or index value.

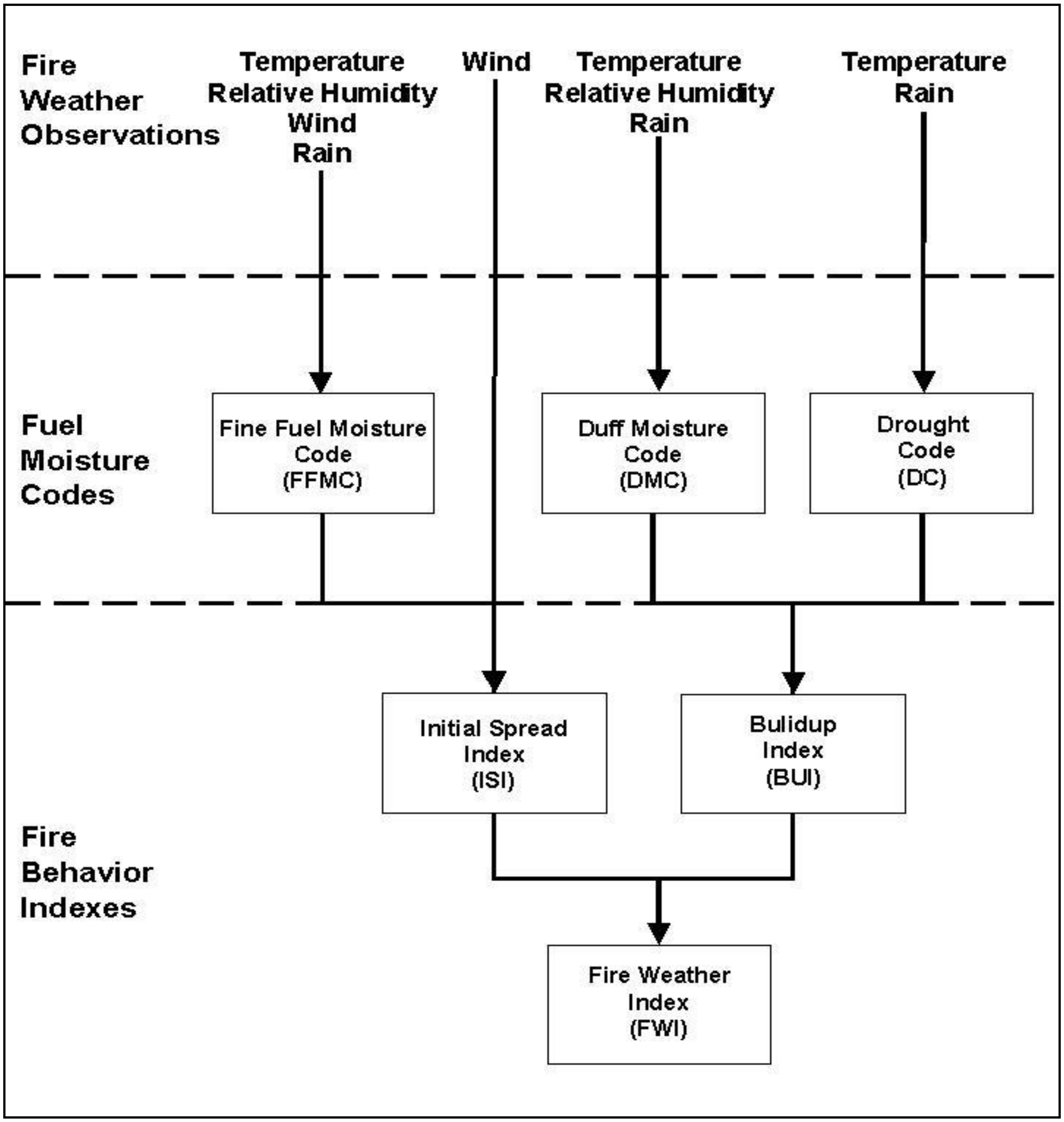

Figure A2.1. Structure diagram for the Canadian Forest Fire Weather Index System (from Canadian Forestry Service 1984). Technically, the calculations of the fuel moisture codes for the day depend not only on the current weather conditions, but also on yesterday's value as well as the month which takes into account the seasonal variation in day length (Lawson and Armitage 2008). The six components are intended to apply to peak burning conditions around 4:00 pm local standard time (Van Wagner 1987; Lawson *et al.* 1996).

Table A2.1. Definitions of the six standard components of the Canadian Forest Fire Weather Index System (from Canadian Forestry Service 1984).

Component	Abbreviation	Definition
Fine Fuel Moisture Code	FFMC	A numerical rating of the moisture content of litter and other cured fine fuels. This code is an indicator of the relative ease of ignition and flammability of fine fuel.
Duff Moisture Code	DMC	A numerical rating of the average moisture content of loosely compacted organic layers of moderate depth. This code gives an indication of fuel consumption in moderate duff layers and medium-size woody material.
Drought Code	DC	A numerical rating of average moisture content of deep, compact, organic layers. This code is a useful indicator of seasonal drought effects on forest fuels, and amount of smouldering in deep duff layers and large logs.
Initial Spread Index	ISI	A numerical rating of the expected rate of fire spread without the influence of variable quantities of fuel.
Buildup Index	BUI	A numerical rating of the total amount of fuel available for combustion that combines DMC and DC. The BUI was constructed so that when the DMC is near zero the DC would not affect daily fire danger (except for smouldering potential) no matter what the level of DC (i.e., when the DMC is near zero, so is the BUI, no matter what the DC value).
Fire Weather Index	FWI	A numerical rating of fire intensity, that combines ISI and BUI. It is suitable as a general index of fire danger in forested areas of Canada.

In contrast to the FWI System, the FBP System provides for quantitative estimates of head fire spread rate, fuel consumption, and fireline intensity in addition to a description of the type of fire (Figure A2.2). With the aid of an elliptical fire growth model, the system also provides estimates of fire size and shape (Figure A2.2). The FBP System is dependent in part on certain inputs from the FWI System. For example, head fire rate of spread is largely determined by the ISI component.

The FBP System takes into account the mechanical effects of slope steepness in increasing rate of fire spread (Table A2.2). Seventeen discrete fuel types are presently recognized in the system, including two variants of the open grass fuel type (Table A2.3); see De Groot (1993) or Taylor *et al.* (1997) for photographic examples of each of the FBP System fuel types.

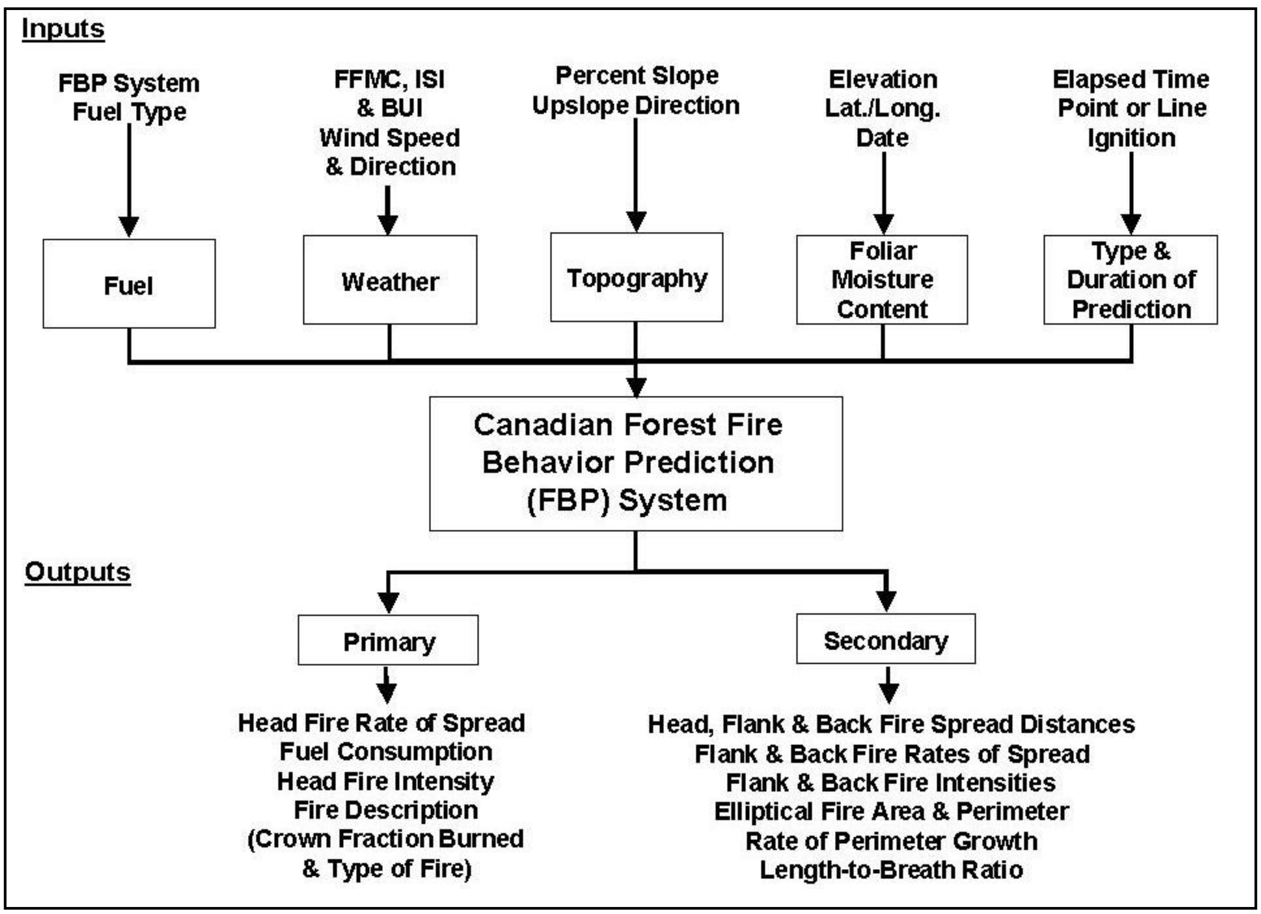

Figure A2.2. Structure diagram for the Canadian Forest Fire Behavior Prediction System (from Wotton *et al.* 2009).

Table A2.2. Relative spread factors (SF) by percent slope (PS) for fires spreading upslope (after Van Wagner 1977). For example, a fire on a 10 percent slope would spread 25% faster than on level ground, all other factors being equal.

PS	0	10	20	30	40	50	60	70
SF	1.0	1.25	1.67	2.30	3.24	4.65	6.78	10.0

Table A2.3. List of fuel types presently recognized in the Canadian Forest Fire Behavior Prediction System (after Wotton *et al.* 2009).

Fuel type group	Fuel type identifier	Fuel type descriptive name	Fuel type modifiers
Coniferous	C-1	Spruce-lichen woodland	-
	C-2	Boreal spruce	-
	C-3	Mature jack or lodgepole pine	-
	C-4	Immature jack or lodgepole pine	-
	C-5	Red and white pine	-
	C-6	Coniferous plantation	Can vary canopy base height
	C-7	Ponderosa pine/Douglas-fir	-
Deciduous	D-1	Leafless aspen	-
	D-2	Green aspen[1]	-
Mixedwood	M-1	Boreal mixedwood-leafless	Must specify % conifer composition
	M-2	Boreal mixedwood-green	Must specify % conifer composition
	M-3	Dead balsam fir mixedwood-leafless	Must specify % dead fir
	M-4	Dead balsam fir mixedwood-green	Must specify % dead fir
Slash	S-1	Jack or lodgepole pine slash	-
	S-2	White spruce-balsam slash	-
	S-3	Coast cedar/hemlock/Douglas-fir slash	-
Open	O-1a	Matted grass	Must specify degree of curing; can
	O-1b	Standing grass	vary fuel load from standard value

[1]See Alexander (2010).

In grasslands and agricultural croplands, the DMC and DC have very little meaning as the component of the forest floor layer they are designed to represent does not exist. In turn, the BUI and FWI are not directly applicable either. In such cases, the rate of fire spread is estimated from (i) the ISI which is based on the FFMC and the 10-m open wind speed, (ii) the degree of curing, and (iii) slope steepness.

Tables 4.25 and 4.26 in the FBP System "Red Book" (Taylor *et al.* 1997) are a quick means of determining the rate of fire spread and a fireline intensity class in the O-1a (matted) and O-1b grass fuel types, respectively. Figures A2.3 and A2.4 represent an updating of these tables based on a grass fuel load of 3.5 t/ha (Wotton *et al.* 2009) instead of 3.0 t/ha (Forestry Canada Fire Danger Group 1992).

Figure A2.3. Updated version of the equilibrium rate of spread and fire intensity class table for Canadian Forest Fire Behavior Prediction System (FBP) fuel type O-1a (matted or cut grass) as contained in the FBP System "Red Book" (Taylor *et al.* (1997). This table is based on the update to the FBP System (Wotton *et al*. 2009) which assumes a grass fuel load of 3.5 t/ha.

Equilibrium rate of spread (m/min) & fire intensity class
O-1a matted grass

Grass Fuel Load 3.5 t/ha

Intensity Class	
1	< 10 kW/m
2	10-500
3	500-2000
4	2000-4000
5	4000-10000
6	> 10000

	Degree of Curing (%)										
ISI	50	55	60	65	70	75	80	85	90	95	100
1	0	0	0	0	1	1	1	1	1	1	1
2	0	1	1	1	1	2	2	3	3	3	4
3	1	1	1	2	3	3	4	4	5	6	6
4	1	1	2	3	4	5	6	7	8	8	9
5	1	2	3	4	5	6	8	9	10	11	13
6	2	2	3	5	6	8	10	11	13	14	16
7	2	3	4	6	8	10	12	13	15	17	19
8	2	3	5	7	9	11	14	16	18	20	23
9	3	4	5	8	11	13	16	18	21	24	26
10	3	4	6	9	12	15	18	21	24	27	30
11	3	5	7	10	13	17	20	23	27	30	33
12	4	5	7	11	15	18	22	26	30	33	37
13	4	6	8	12	16	20	24	28	32	36	41
14	4	6	9	13	18	22	26	31	35	40	44
15	5	7	10	14	19	24	29	33	38	43	48
16	5	7	10	15	20	26	31	36	41	46	51
17	5	8	11	16	22	27	33	38	44	49	54
18	6	8	12	17	23	29	35	40	46	52	58
19	6	8	12	18	24	31	37	43	49	55	61
20	6	9	13	19	26	32	39	45	52	58	64
25	8	11	16	24	32	40	48	56	64	72	80
30	9	13	19	28	38	47	56	66	75	85	94
35	11	15	21	32	43	53	64	75	85	96	107
40	12	16	24	35	47	59	71	82	94	106	118
45	13	18	26	38	51	64	77	89	102	115	128
50	14	19	27	41	54	68	82	95	109	122	136
55	14	20	29	43	57	72	86	100	115	129	143
60	15	21	30	45	60	75	90	105	120	135	150
65	16	21	31	47	62	78	93	109	124	140	156
70	16	22	32	48	64	80	96	112	128	144	160

Figure A2.4. Updated version of the equilibrium rate of spread and fire intensity class table for Canadian Forest Fire Behavior Prediction System (FBP) fuel type O-1b (standing grass) as contained in the FBP System "Red Book" (Taylor *et al.* (1997). This table is based on the update to the FBP System (Wotton *et al*. 2009) which assumes a grass fuel load of 3.5 t/ha.

Equilibrium rate of spread (m/min) & fire intensity class
O-1b standing grass

Grass Fuel Load 3.5 t/ha

Intensity Class	
1	< 10 kW/m
2	10-500
3	500-2000
4	2000-4000
5	4000-10000
6	> 10000

Degree of Curing (%)

ISI	50	55	60	65	70	75	80	85	90	95	100
1	0	0	0	0	0	0	0	1	1	1	1
2	0	0	1	1	1	1	2	2	2	2	3
3	0	1	1	1	2	2	3	3	4	4	5
4	1	1	2	2	3	4	5	6	6	7	8
5	1	2	2	3	4	6	7	8	9	10	11
6	1	2	3	4	6	7	9	10	12	13	15
7	2	3	4	6	7	9	11	13	15	17	19
8	2	3	5	7	9	11	14	16	18	20	23
9	3	4	5	8	11	14	16	19	22	24	27
10	3	4	6	9	13	16	19	22	25	28	31
11	4	5	7	11	14	18	22	25	29	32	36
12	4	6	8	12	16	20	24	28	32	36	41
13	5	6	9	14	18	23	27	32	36	41	45
14	5	7	10	15	20	25	30	35	40	45	50
15	5	8	11	16	22	27	33	38	44	49	55
16	6	8	12	18	24	30	36	41	47	53	59
17	6	9	13	19	26	32	38	45	51	58	64
18	7	9	14	21	27	34	41	48	55	62	69
19	7	10	15	22	29	37	44	51	59	66	73
20	8	11	16	23	31	39	47	54	62	70	78
25	10	14	20	30	40	50	60	70	80	90	100
30	12	17	24	36	48	60	72	84	96	108	120
35	14	19	28	42	55	69	83	97	111	125	138
40	16	21	31	46	62	77	93	108	124	139	154
45	17	23	34	51	67	84	101	118	135	152	169
50	18	25	36	54	72	90	108	127	145	163	181
55	19	26	38	57	76	96	115	134	153	172	191
60	20	28	40	60	80	100	120	140	160	180	200
65	21	29	42	62	83	104	125	146	166	187	208
70	22	30	43	64	86	107	129	150	172	193	214

A grassland fire behaviour pocket card based on the FBP System has also been devised for use in New Zealand based on a FFMC of 93.2, 100% degree of curing, and a fuel load of 3.5 t/ha (Fogarty and Alexander 1999; Alexander and Fogarty 2002). A similar card could be developed for Chinook conditions during the winter months in southern Alberta. For example, using an FFMC of 89 (Table 1).

Various software applications of the FBP System presently exist (e.g., Tymstra *et al.* 2010). Others are under development.[3]

Specific predictions of fireline intensity as opposed to the determination of a fireline intensity class as given in the Red Book can be made on the basis of the equation given in Appendix A and the projected rate of fire spread (Table A2.4) – either for fuel type O-1a (matted grass) or fuel type O-1b (standing grass) and the available grass fuel load; currently, the standard value for the latter quantity has been set at 0.35 kg/m^2 or 3.5 t/ha (Wotton *et al.* 2009).

Table A2.4. Equivalencies of rate of fire spread in metres/minute (m/min) to kilometres per hour (km/h).

m/min	17	33	50	67	83	100	117	133	150	167	183	200
km/h	1	2	3	4	5	6	7	8	9	10	11	12

The prediction of fireline intensity would in turn, in the context of the CFFDRS, permit calculation of the probability of a grassland fire breaching a firebreak of a given width and whether or not trees or shrubs are present with 20 m of the firebreak as discussed previously in Appendix A (Figure A2.5). In this regard, Hsieh *et al.* (2006) has prepared a software tool to undertake such calculations.

Because the FWI System depends solely on weather observations, it can just as easily calculated from forecast weather to yield a fire danger forecast (Lawson and Armitage 2008). In turn, for a given FBP System fuel type, it is also possible for the CFFDRS to provide a forecast of potential fire behaviour (Taylor *et al.* 1992).

[3] See http://redapp.org/ and for further information on the CFFDRS visit: http://www.frames.gov/partner-sites/applied-fire-behavior/canadian-forest-fire-danger-rating-system

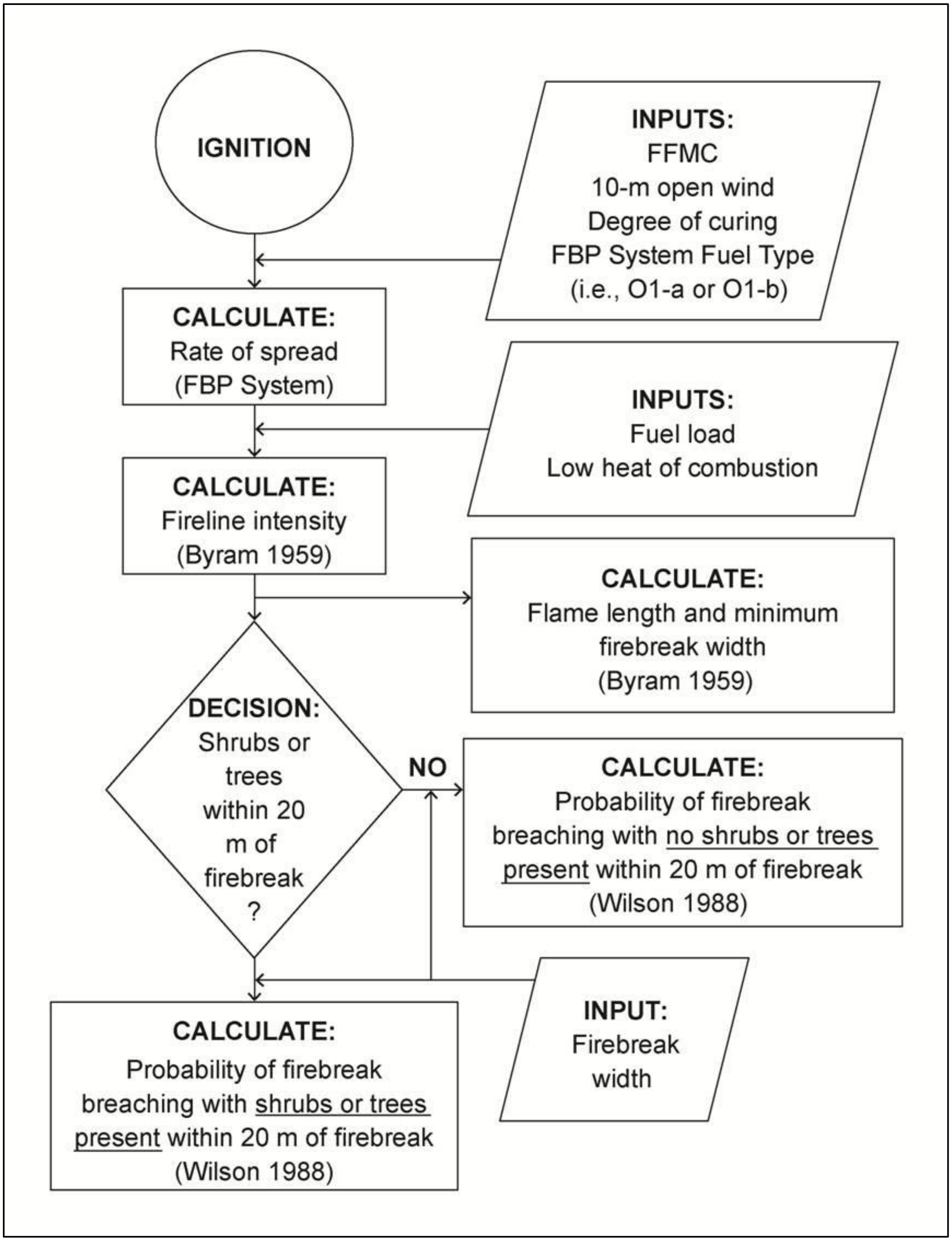

Figure A2.5. Flow diagram for calculating Byram's (1959) fireline intensity and flame length and the probability of grassland firebreak breaching using Wilson's (1988) models in the context of the Canadian Forest Fire Danger Rating System.

Appendix 3. Video Documentation

A number of video clips were posted on *YouTube* by members of the public following the fires of November 27, 2011. Three are worthy of note:

- Southern Alberta Wild Fire near Lethbridge November 27, 2011[4] (http://www.youtube.com/watch?v=eY72fqquyjg, uploaded November 28, 2011 by bigsky780). A 4:59 minute video showing fire spread along a fence line running parallel to a rural road). Good quality fire behaviour documentation of fire spread in fully cured grassland fuels.

- Southern Alberta Wildfires (http://www.youtube.com/watch?v=vDvn-lZ6bLA, uploaded November 28, 2011 by Lethbridge Herald). A 1:26 minute video showing aerial shots of fires' aftermath, narrated by the City of Lethbridge Fire Chief Brian Cornforth.

- Lethbridge Grass Fire – November 27, 2011 (http://www.youtube.com/watch?v=4-kiVWMYdQI, uploaded November 28, 2011 by shemseger). A 6:55 minute video of a drive around the fire by two members of the public.

[4] Over the course of approximately 15 seconds, a portion of the 2011 Lethbridge Fire is seen spreading perpendicular to a rural road in which fence posts immediately adjacent to the road are clearly visible in the footage. During this time interval, the fire spreads pass six fence posts. Assuming a 5-m distance between posts, this amounts to 25 m. The rate of fire spread would in turn be: 25 ÷ 0.25 min = 100 m/min or 6 km/h (Table A2.4).

Appendix 4. Brief Summary of the Chinook Wind.[5]

Foehn winds are warm, dry downslope winds that occur on the lee side of a mountain range. A "chinook" is the name given to the strong and gusty foehn type of wind that occurs on the east side of the Rocky Mountains (Huschke 1959). The warmth and dryness of a chinook wind is due to the adiabatic compression that causes the air temperatures to increase at 9.8 °C per km upon descending the mountain slopes (Figure A4.1).

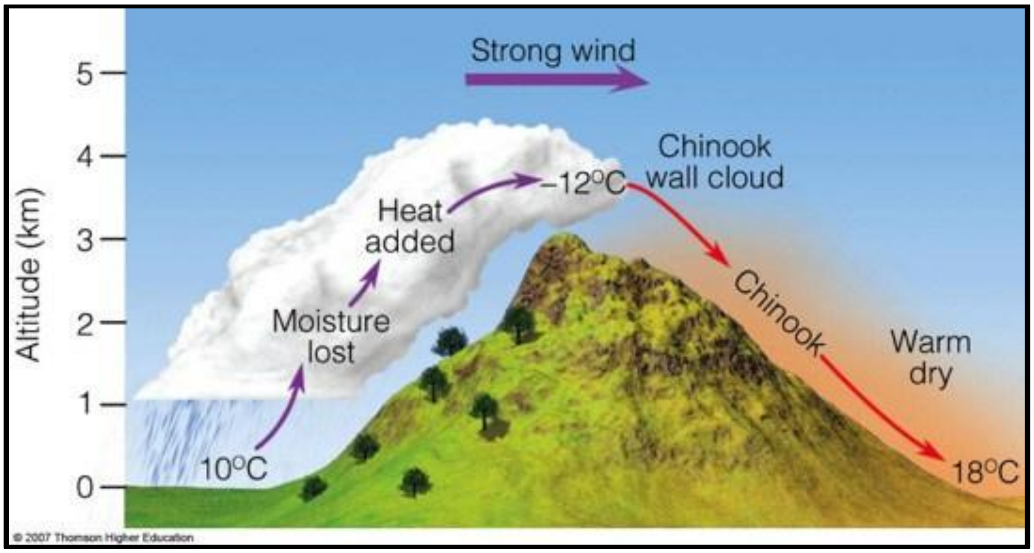

Figure A4.1. Adiabatic warming of downward moving air produces the warm, dry downslope Chinook wind on the east side of the Rocky Mountains (from Ahrens 2007).

The chinook generally blows from the west or southwest but its direction may be modified by the topography. They blow most frequently from November through March. Chinooks are most prevalent over southern Alberta in a belt from Pincher Creek and Crowsnest Pass through to Lethbridge, which gets 30 to 35 chinook days per year on average.

The chinook brings relief from the cold of winter, but it's most important effect is to blow, melt and sublimate snow cover rapidly (perhaps 30 cm in a few hours) in wintertime, earning it the name "snoweater" (Whiteman 2000). Chinooks have been observed to raise temperature from below -20 °C to as high as 10 to 20 °C for a few hours or days and then temperatures plummet to their base levels.

[5] From https://en.wikipedia.org/wiki/Chinook_wind unless otherwise indicated.

Appendix 5. Synoptic Weather Pattern Characteristics and Flow Patterns of the Chinook Event in Southern Alberta on November 27, 2011[6]

The surface flow pattern on November 27, 2011 indicated there was a lee trough developing over southern Alberta with a sharp ridge building over the windward side of the Rocky Mountains (Figure A5.1). The upper flow was showing a strong ridge tilting northeast from the California coast into the Prairies followed by a fast approaching deep trough (Figures A5.2 and A5.3).

Early in the day, rapid falling pressure due to the developing lee trough significantly intensified the surface pressure gradients in the foothill areas ahead of the mountain ridge – a typical Chinook pattern. Meanwhile, the upper atmosphere carried a very strong jet stream in a southwest to northeast orientation extending from the lower atmosphere near 1.5 km into the higher atmosphere beyond 10 km (Figure A5.4).

The above flow pattern created a very strong and gusty downslope flow out of the southwest in southern Alberta during the morning into the mid afternoon, particularly in areas south of Calgary, giving southwest winds of 50 to 70 km/h with gusts of 80 to 130 km/h. Wind directions in the lower atmosphere were from the southwest (220° to 240°) and wind speeds were higher than 80 km/h at a height of 1.5 km that eventually surged down to the surface (Figure A5.4).

Strong subsidence warming resulted in Chinook conditions for the southern foothills and plains of Alberta with minimum relative humidity (RH) values in the lower 30% range in between 6:00 a.m. and 3:00 pm MST. The vertical temperature (T) and dewpoint (Td) profiles presented in Figure A5.5 illustrate the dryness of the atmosphere on the lee slopes of the Rocky Mountains; the spread between temperature and dewpoint was about 20°C, indicating a RH value of near 25%.

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[6] This section of the report was prepared by Alice Ou, a Fire Weather Meteorologist with Alberta Environment and Sustainable Resource Development located at the Provincial Forest Fire Centre in Edmonton. Alice obtained her B.Sc. (1990) and M.Sc. (2005) degrees in meteorology from the Nanjing Institute of Meteorology in P. R. China and University of Alberta in Edmonton, respectively. She has 20 years of operational weather forecasting experience in Alberta, Saskatchewan, Newfoundland, and in P. R. China.

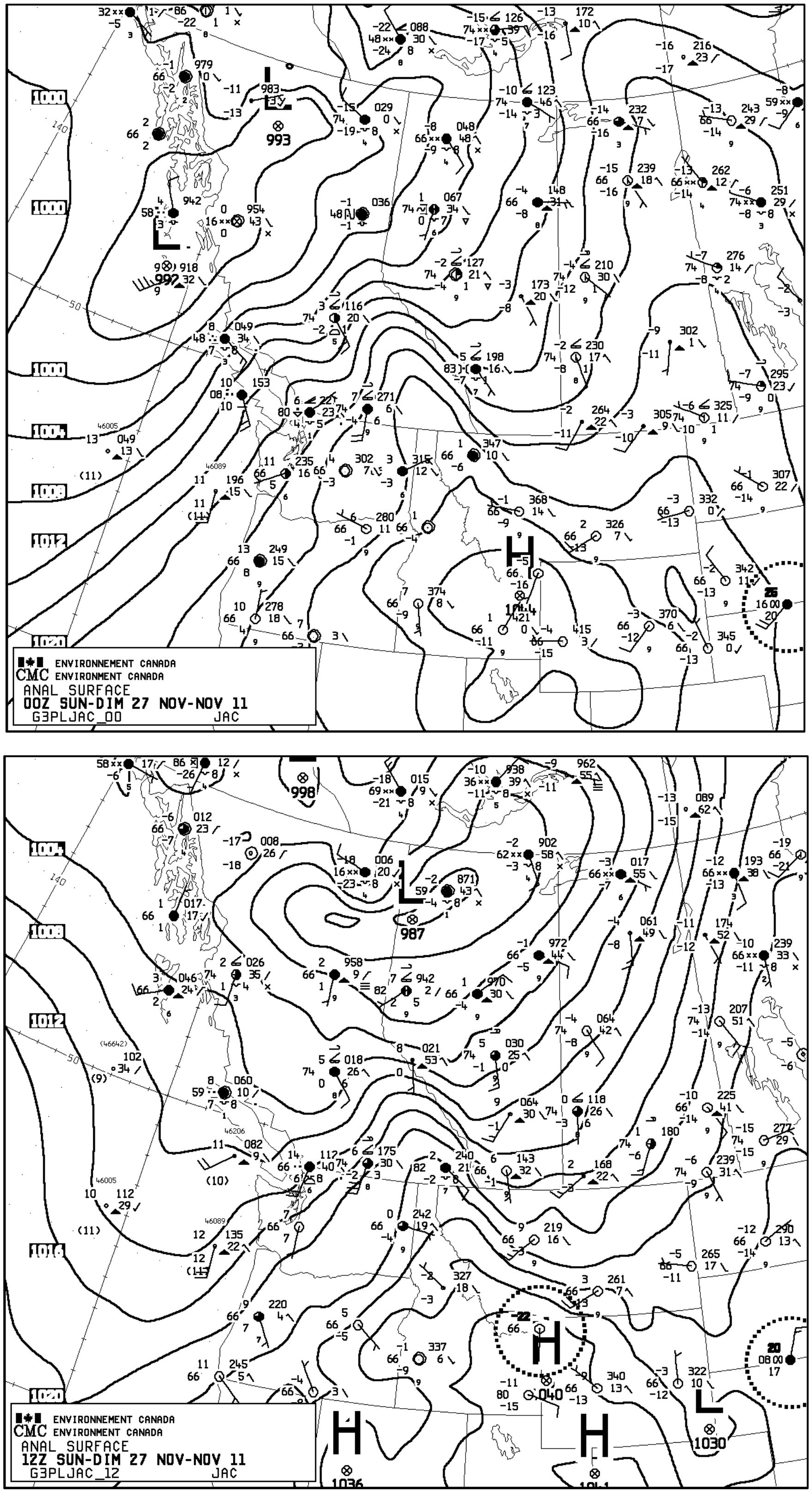

Figure A5.1. Surface weather maps for 5:00 p.m. MST, November 26, 2011 (top), and 5:00 a.m. MST, November 27, 2011 (bottom).

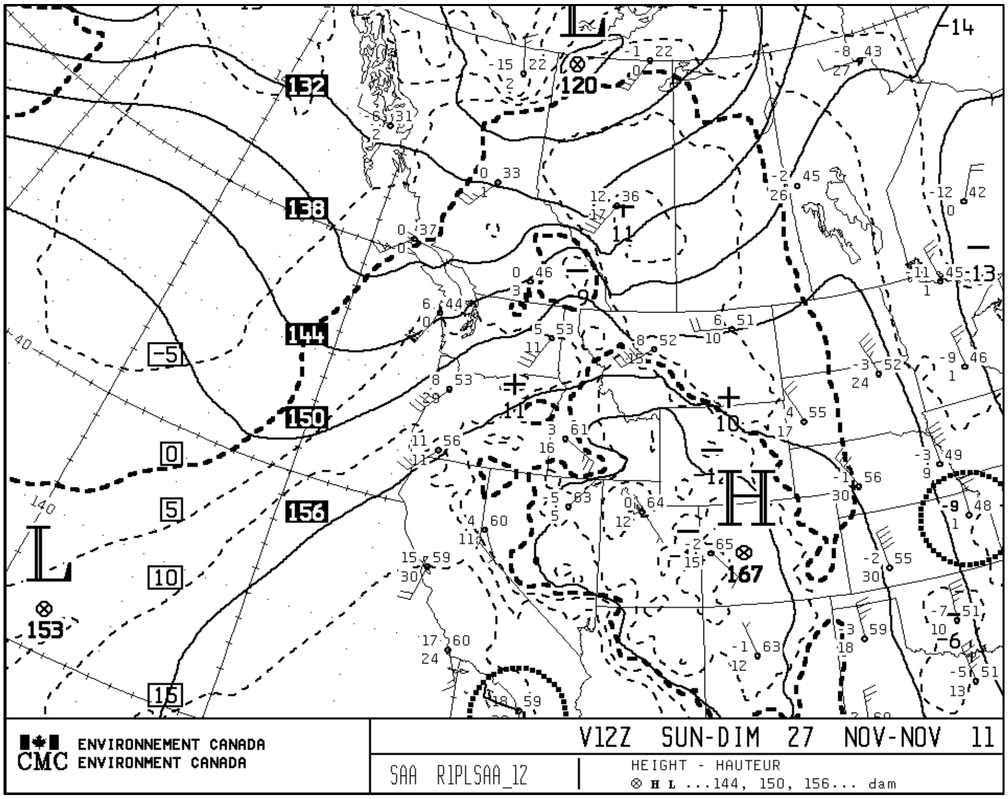

Figure A5.2. 850 mb chart analyses for 5:00 a.m. MST, November 27, 2011.

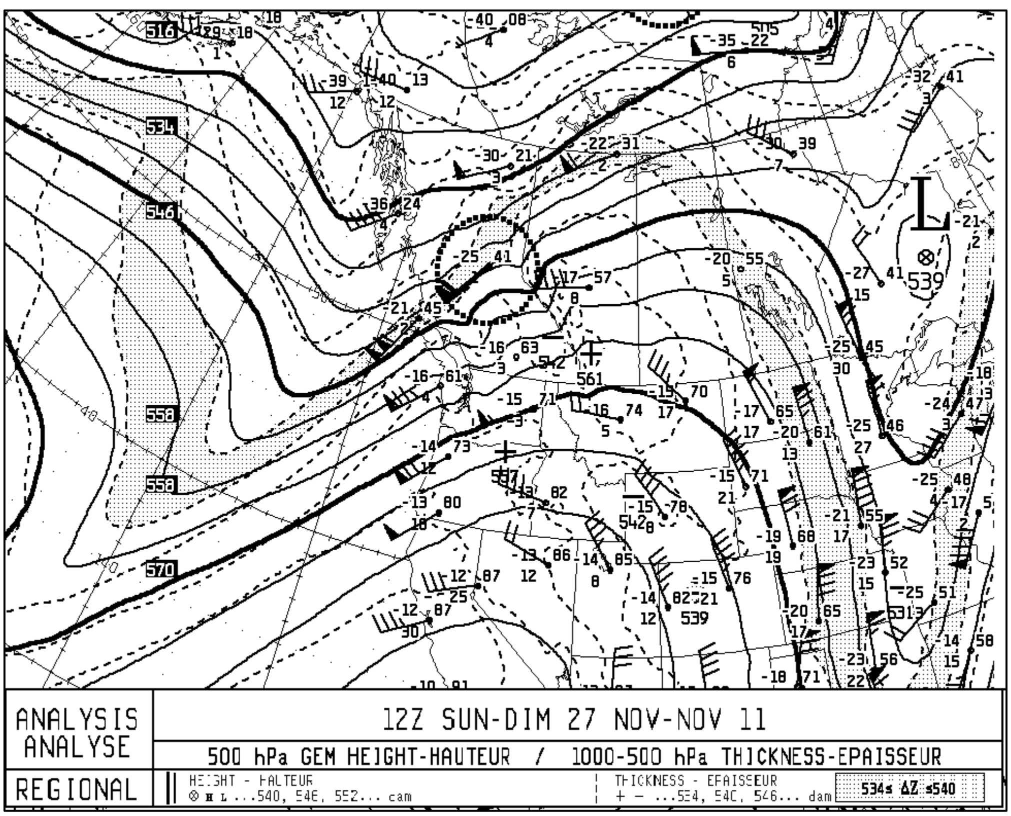

Figure A5.3. 500 mb chart analyses for 5:00 a.m. MST, November 27, 2011.

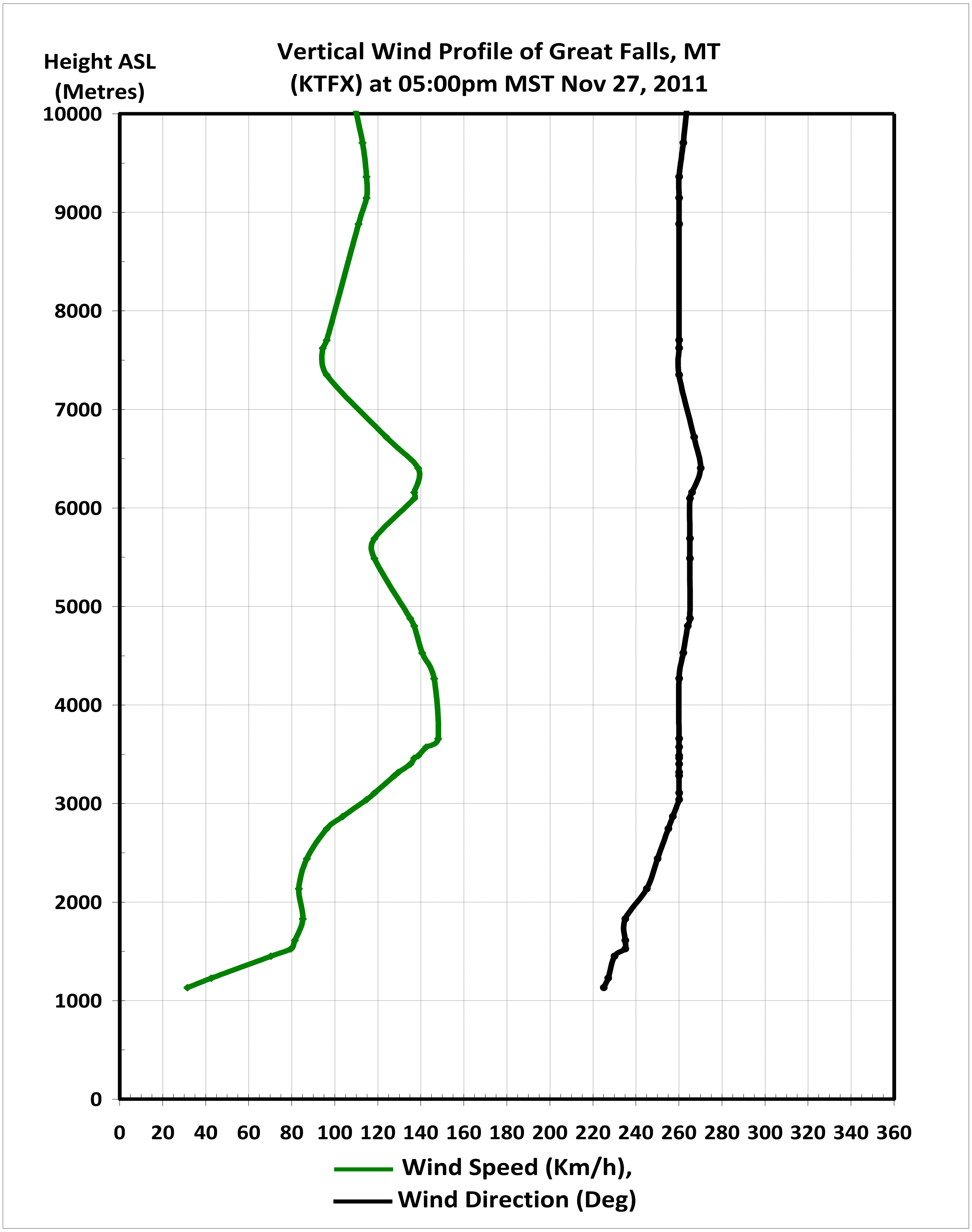

Figure A5.4. Vertical wind speed and direction profile above Great Falls, Montana, at 5:00 p.m. MST, November 27, 2011.

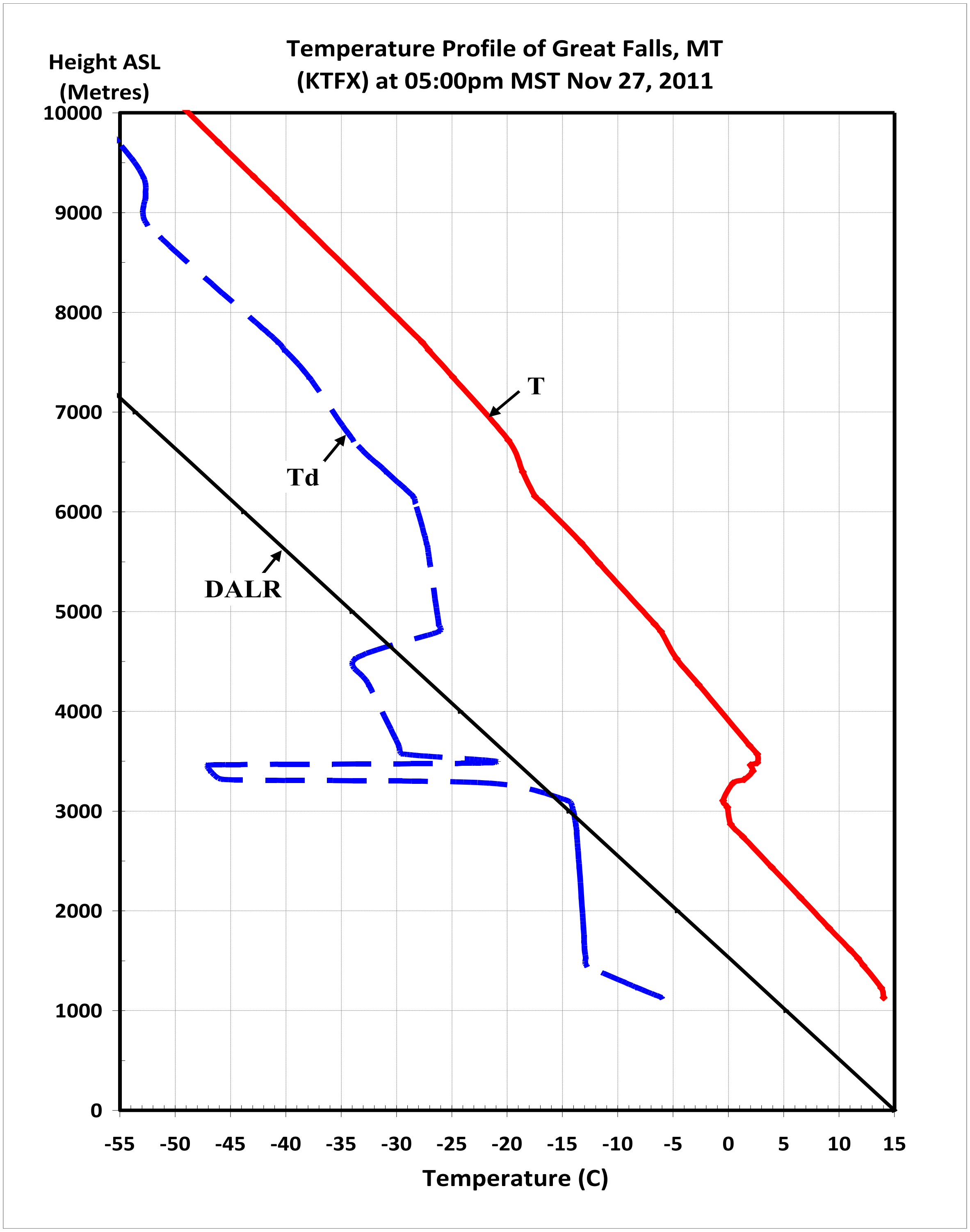

Figure A5.5. Vertical temperature (T) and dew-point temperature (Td) profile above Great Falls, Montana, at 5 p.m. MST, November 27, 2011. DALR = Dry adiabatic lapse rate (9.8 °C/km).

Appendix 6. Major Southern Alberta Grassland Fires of September 10, 2012

The Lethbridge and Milk River Ridge fires of September 10, 2012, occurred earlier in the year (Figure A6.1) under much warmer/drier and windier conditions than the fires of November 27, 2011 as evident by the information contained in Tables A6.1 and A6.2. However, the grass fuels were not fully cured at the time.

Figure A6.1. Grass fire spreads across the Blood Indian Reserve west of Lethbridge, Alberta, on September 20, 2012. Photo by Jaime Vedres.

Table A6.1. Standard daily 1:00 p.m. MDT surface weather and fire danger for the Lethbridge A weather station for September 1-10, 2012.

Date (Sep. 2012)	Dry-bulb temperature (°C)	Relative humidity (%)	Wind speed (km/h)	Cardinal wind direction	24-h precipitation (mm)	Fine Fuel Moisture Code (FFMC)	Initial Spread Index (ISI)
1	21.9	35	9	East	0.0	93	10
2	22.0	22	24	West	0.0	93	22
3	21.1	22	28	West	0.0	93	27
4	16.0	46	6	Northwest	1.6	81	2
5	21.3	29	23	North	0.3	90	14
6	15.5	55	8	Northwest	0.0	88	5
7	23.3	25	4	West	0.0	92	7
8	26.6	17	14	Southwest	0.0	95	17
9	25.0	21	10	South	0.0	95	14
10	20.5	27	53	Southwest	0.0	94	79

Notes: Wind speed represents the 10-m open standard and the 24-h precipitation represents the amount accumulated in the 24-h period between successive daily observation times (Lawson and Armitage 2008).

Table A6.2. Hourly weather and fire danger for September 10, 2012.

Station name, location, and elevation	Local time MDT (p.m.)	Dry-bulb temperature (°C)	Relative humidity (%)	Wind speed (km/h)	Wind direction (°)	Fine Fuel Moisture Code (FFMC)	Initial Spread Index (ISI)
Lethbridge A	1:00	20.8	24	55	250	93	70
	2:00	20.0	26	63	250	93	74
49°37’49” N	3:00	19.6	26	81	240	94	89
112° 47’59” W	4:00	17.8	33	67	270	94	87
	5:00	14.1	35	59	270	94	83
929 m	6:00	14.0	30	59	260	93	73
	7:00	12.6	33	48	250	92	55
	8:00	11.5	36	35	270	90	25
Lethbridge	1:00	20.4	26	65	250	90	49
CDA	2:00	20.6	27	46	250	91	46
	3:00	19.6	25	63	250	92	64
49°41’42” N	4:00	17.0	34	56	270	92	61
112°46’03” W	5:00	14.7	34	56	270	92	61
	6:00	14.0	32	56	250	91	53
910 m	7:00	12.9	33	39	270	90	31
	8:00	11.6	39	22	280	88	10
Blood Tribe	1:00	19.4	28	69	250	90	50
AGDM	2:00	18.8	29	74	250	91	58
	3:00	18.4	30	63	250	92	64
49°34’ W	4:00	14.8	45	67	270	92	66
113°03’ W	5:00	12.3	41	57	280	92	62
	6:00	13.1	34	57	270	91	54
980 m	7:00	11.6	37	44	260	90	38
	8:00	10.0	44	35	250	88	19
Raymond	1:00	20.1	25	56	240	90	46
AGDM	2:00	19.7	25	67	240	91	57
	3:00	18.8	28	72	250	92	67
49°29’ N	4:00	18.6	23	70	260	92	66
112°41’ W	5:00	14.5	32	70	280	92	66
	6:00	14.0	35	59	270	91	55
937 m	7:00	12.3	40	52	270	90	44
	8:00	11.1	38	37	270	88	21
Del Bonita	1:00	18.1	28	50	240	90	43
AGDM	2:00	17.4	28	70	240	91	57
	3:00	16.3	31	67	250	92	66
49°03’ N	4:00	14.8	38	52	240	92	59
112°49’ W	5:00	14.0	36	57	260	92	62
	6:00	9.9	64	41	250	91	39
1310 m	7:00	8.0	71	37	270	90	28
	8:00	8.3	58	46	280	88	30
Milk River	1:00	19.4	24	54	250	93	69
	2:00	20.7	21	56	230	93	71
49°08’ N	3:00	20.1	22	52	250	94	78
112°03’ W	4:00	18.7	28	52	250	94	78
	5:00	16.4	31	39	270	94	54
1050 m	6:00	14.0	43	33	300	93	35
	7:00	11.6	52	20	280	92	16
	8:00	10.3	48	20	290	90	12

The 2012 Lethbridge Fire is assumed to have started around 2:00 p.m. Mountain Daylight Time (MDT) with the run lasting approximately three hours (Figure A6.2). Assuming an 85% degree of curing and an average ISI of 68 for the period from 2:00 to 5:00 pm MDT at the Lethbridge A, Lethbridge CDA, and Blood Tribe AGDM weather stations (Table A6.2), the predicted head fire rate of spread for FBP System fuel type O1-b was 148 m/min or 8.9 km/h.

The 2012 Lethbridge Fire was thus projected to achieve a forward spread distance of 27 km (Figure A6.2). It in fact spread only about 20 km downwind from its point of origin which translates into an average HFROS of 6.7 km/h. The 10-m open winds in turn averaged 63 km/h. This would translate into a L:B of 7.5:1.

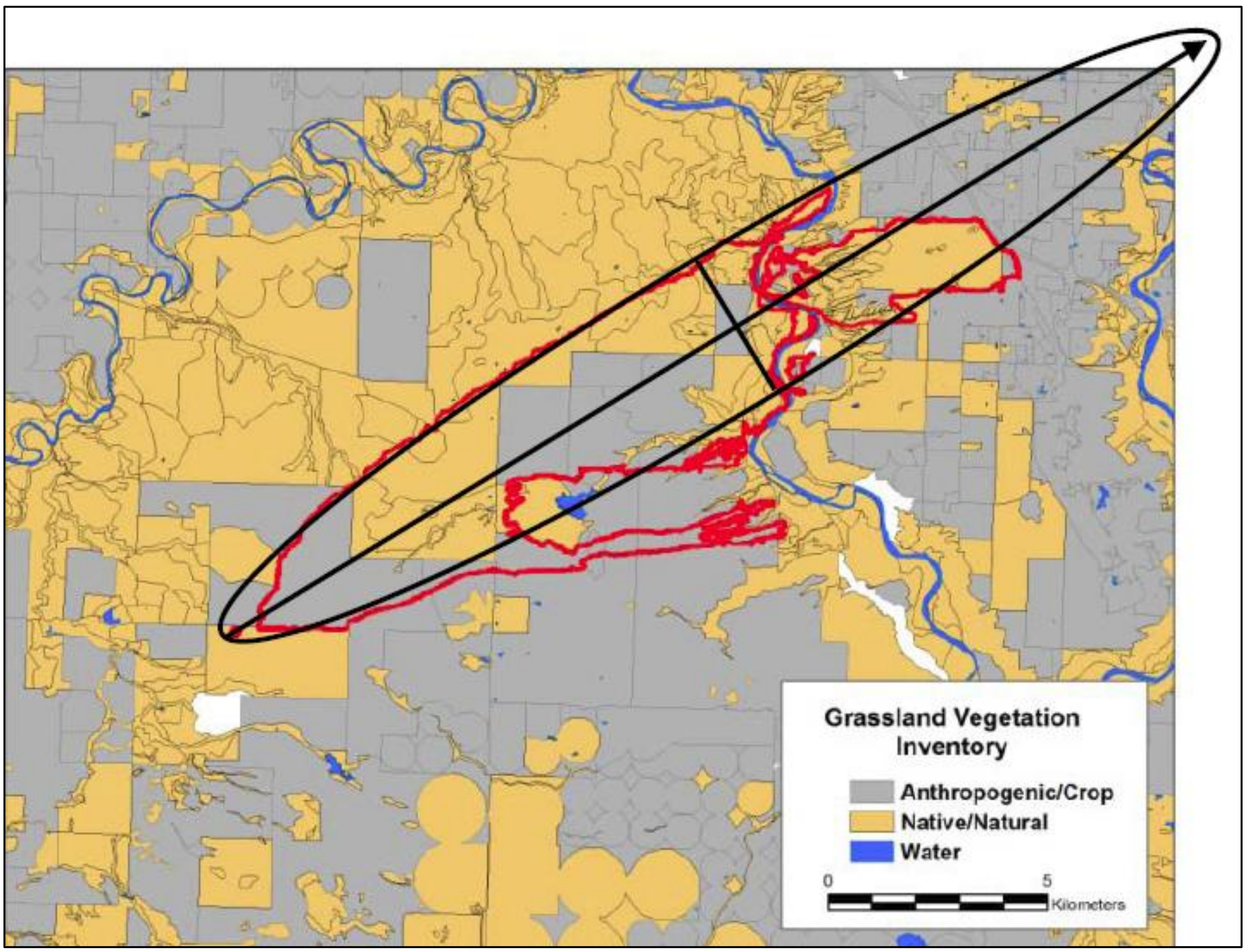

Figure A6.2. Hindsight projection of the growth of the Lethbridge Fire run of September 10, 2012, using the FBP System compared to the final mapped perimeter and assuming the spread event lasted three hours on the basis of the hourly weather.

The Milk River Ridge Fire on September 10, 2012, is presumed to have started about the same time but spread for an hour longer. The average 10-m open wind speed and ISI for the Milk River Ridge Fire based on the Raymond AGDM, Del Bonita AGDM, and Milk River weather stations for the four hour period from 2:00 to 6:00 p.m. MDT were 57 km/h and 61 (Table A6.2).

The predicted rate of spread would for 85% degree of curing thus be 141 m/min or 8.5 km/h and the L:B 7.2:1. This would give a projected forward spread distance of 34.8 km (Figure A6.3) compared to an observed value of 33 km (i.e., a HFROS of 8.25 km/h).

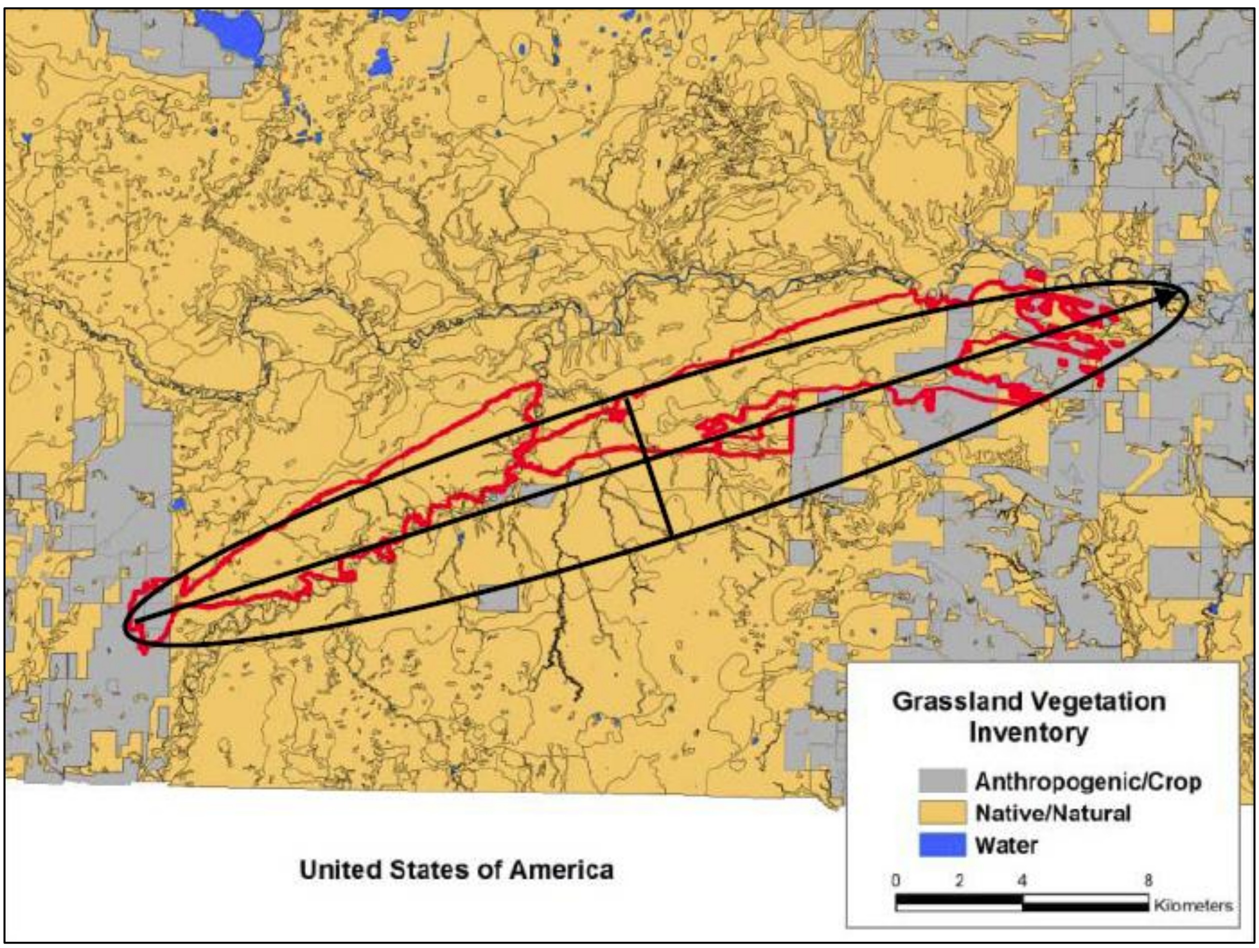

Figure A6.3. Hindsight projection of the growth of the Milk River Ridge Fire run of September 10, 2012, using the FBP System compared to the final mapped perimeter and assuming the spread event lasted four hours on the basis of the hourly weather.

NOTES

"Those who cannot remember the past are condemned to repeat it."
George Santayana

The Winter WILDFIRE Triangle in Southern Alberta

Ignition Sources:

- human caused
- many types
- widespread

Chinook Winds:

- strong
- warm
- dry

Native Grasslands and Agricultural Croplands:

- often snow-free
- fully cured
- continuous

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