WILDFIRE BEHAVIOR ON THE CANADIAN SHIELD:

A CASE STUDY OF THE 1980 CHACHUKEW FIRE, EAST-CENTRAL SASKATCHEWAN[1]

by

William J. De Groot[2] and Martin E. Alexander[3]

INTRODUCTION

Saskatchewan averages about 430 wildfires a year which burn over an area of about 274 000 ha according to provincial records for 1960-85. Many fires occur in the Precambrian Shield region of the province. A small number of these fires have exhibited extreme fire behavior and subsequently developed into 'Class E' (i.e., >200 ha.) or campaign fires. In response to a concern expressed by local fire managers about certain so-called "unique" aspects of rating fire danger in the Shield country, a case study of wildfire behavior was recently completed by the first author, with particular emphasis on the associated climatic and meteorological conditions, and the applicability of the Canadian Forest Fire Danger Rating System (CFFDRS) (Alexander 1982a, 1985b, 1986a). This paper documents the results of the analyses.

The 1980 Chachukew Fire occurred in the east-central region of the province, 6 km north of the town of Pelican Narrows (Fig. 1). This fire was selected for analysis because documentation was readily available from a review, completed shortly after the fire was declared out, by W. E. Dodds at the request of the Saskatchewan Department of Parks and Renewable Resources (SDPRR). The format of the case analysis is similar to that of Alexander et al. (1983).

FIRE CHRONOLOGY

The Chachukew Fire (#116) was first detected on July 8 at 1900 h Central Standard Time (CST) by a commercial aircraft and reported to the SDPRR Resource Office at Pelican Narrows as being 0.1 ha in size. This lightning fire was suspected to have started within the 12 hours prior to detection. Two Grumman S2F Trackers dispatched from La Ronge (150 km west of the fire area) dropped long-term fire retardant at the head of the fire (four sets of paired drops) within an hour of detection, and it was held to approximately 0.2 ha. By 0900 h CST the next morning, the initial attack crew had secured the perimeter of the fire with hand tools and the center of the fire appeared to be gradually

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[1]A presentation made by the first author at the Third Central Region Fire Weather Committee Scientific and Technical Seminar, April 3, 1986, Winnipeg, Man.

[2]Fire Research Officer, Saskatchewan District Office, Canadian Forestry Service, Western and Northern Region, 101 - 15 Street East, Prince Albert, Sask., S6V 1G1.

[3]Fire Research Officer, Northern Forestry Centre, Canadian Forestry Service, Western and Northern Region, 5320 - 122 Street, Edmonton, Alta., T6H 3S5.

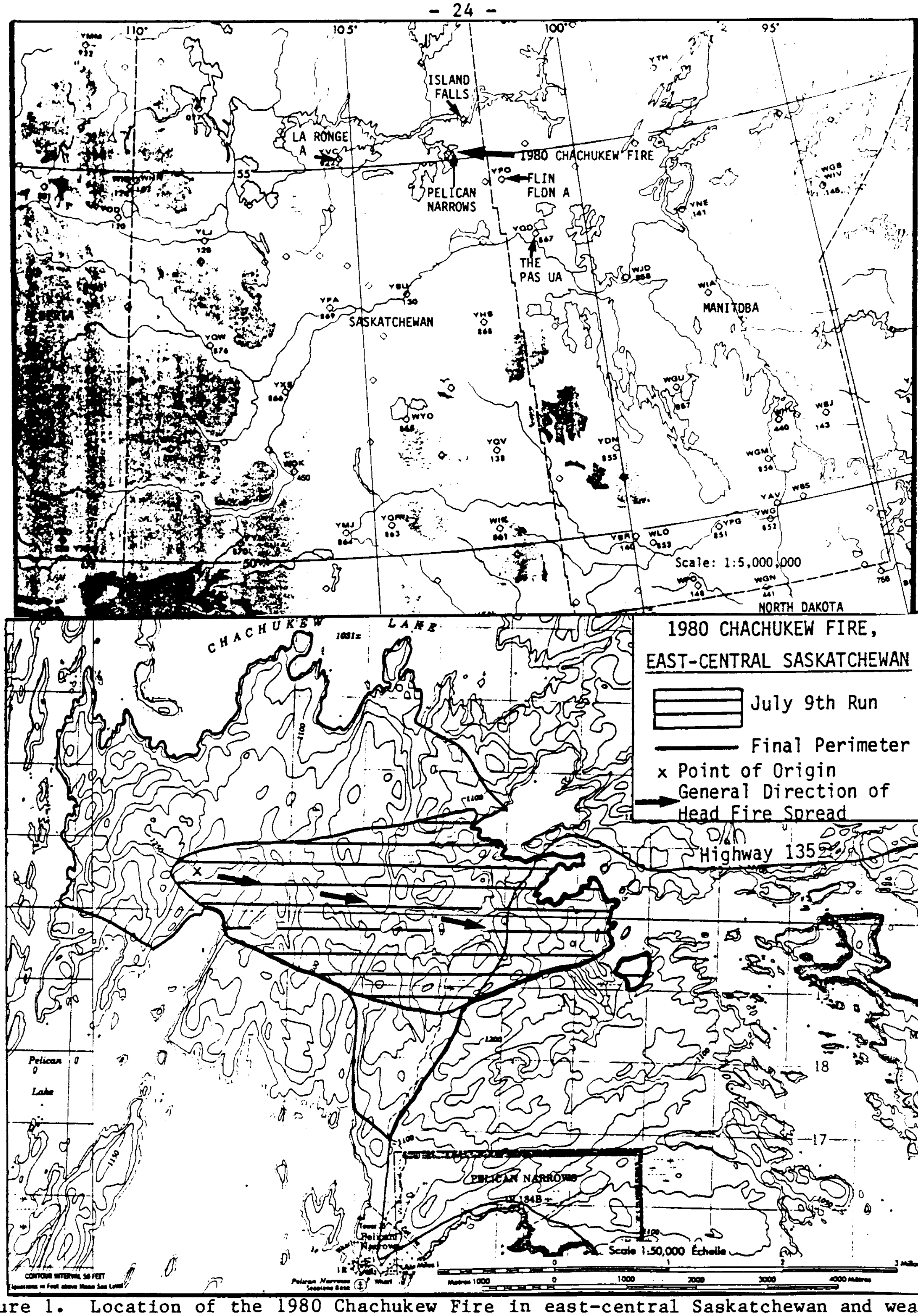


Figure 1. Location of the 1980 Chachukew Fire in east-central Saskatchewan and weather stations utilized in the case study analysis (*top*). The approximate boundary of the major run on July 9 and final perimeter are portrayed on a reduced National Topographic System 1:50 000 scale map of the fire area (*bottom*).

burning itself out. However, at 1100 h CST, the central area of the fire began producing increasing amounts of smoke. Due to a multiple-fire start situation in the province at that time, the airtankers were committed to initial attack action on other unmanned fires. Soon afterwards, torching was experienced at the fire's center. At 1400 h CST the fire jumped the line of held perimeter and quickly became an active crown fire. By 1800 h CST the fire had crossed Highway 135 to the east of the fire's origin, while at the same time cutting power and telephone service to the town of Pelican Narrows (Fig. 1). By 1900 h CST the fire had travelled a total distance of 5.9 km and burned an area approximately 1115 ha in size with an estimated perimeter length of 18.3 km (Figs. 1 and 2). The Chachukew Fire was deemed to be under control on July 20 and was finally declared out on August 15. Final size: 2550 ha.

FUELS AND TOPOGRAPHY

The Chachukew Fire area is located within the Northern Coniferous Forest Section (B.22a) of Canada's Boreal Forest Region according to Rowe (1972) and in the Northern Coniferous Ecodistrict (2b) - Northern Boreal Ecoregion of Saskatchewan as described by Harris and others (1983). The predominant forest cover in the vicinity of the major run on July 9 consisted of black spruce (*Picea mariana* Mill B.S.P.) and jack pine (*Pinus banksiana* Lamb.) stand mixtures on the drier knolls, interspersed with pockets of pure black spruce stands and treed muskeg in the lowland sites (Fig. 2). Tree heights averaged 10-15 m, and crown closure was chiefly in the 60-70% class. A small percentage of the area was comprised of mixedwood stands, hardwood stands, brush and grassland.

Pelican Lake is situated at an elevation of 314 m MSL, and the highest point in the fire area is 381 m MSL (Fig. 1). The majority of the area has less than a 7-8% grade, although there are a few slopes in the 10-20% range. Because of shallow slopes and rolling topography, it was therefore concluded that the effect of ground slope on fire behavior would be minimal.

ANTECEDENT CLIMATIC CONDITIONS

During the three months prior to the fire's occurrence, most of east-central Saskatchewan experienced below-normal precipitation (Fig. 3). Island Falls (elevation: 299 m MSL) is the closest year-round Atmospheric Environment Service (AES) climatological station (Fig. 1) to the fire (55 km northeast) and it recorded 32% of normal precipitation (Anon. 1982). Flin Flon airport (elevation: 304 m MSL), 90 km southeast of the fire (Fig. 1), and La Ronge airport (elevation: 375 m MSL), 150 km west of the fire area (Fig. 1), recorded 59% and 44% of normal precipitation during the same period, respectively. Air temperatures during the four-month period prior to the fire were also consistently higher than the 30-year normals (Anon. 1982).

SYNOPTIC WEATHER PATTERN

During the two days prior to the main run of the Chachukew Fire, a weak arctic front moved back and forth across the fire area. A major incursion of the modified arctic air occured on July 7, as indicated by the sharp dip in the 500 mb anomaly chart (*see* Figure 9). The main characteristic of this modified arctic air mass was the lack of moisture associated with it as indicated by the dew-point temperatures which were generally in the 5-7°C range (Countryman 1971). The front retreated north of the fire area on July 8 alowing maritime

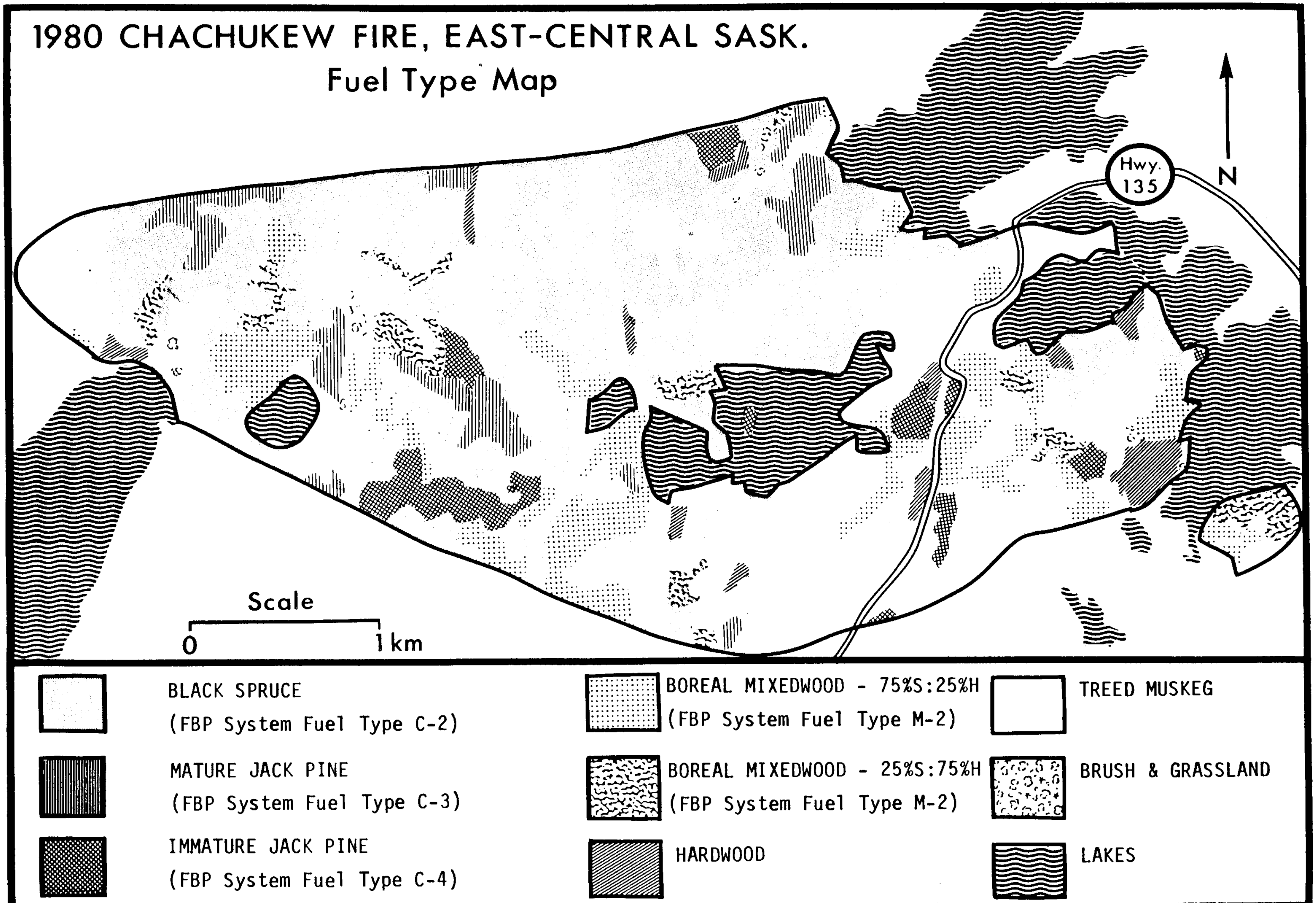
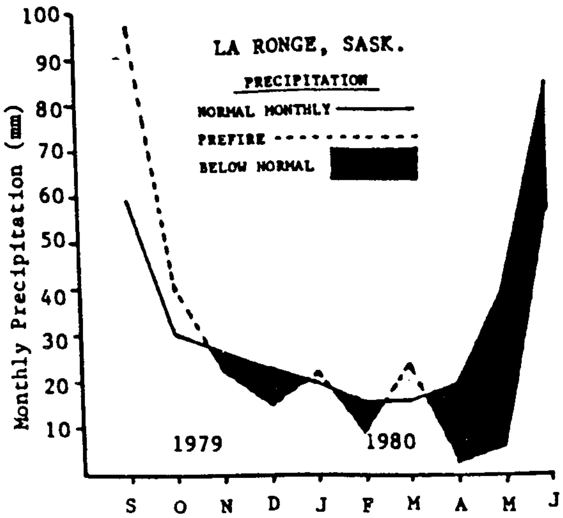


Figure 2. A forest cover map for the area affected by the July 9 run of the 1980 Chachukew Fire based on a 1973 provincial inventory maintenance map (1972 aerial photography). The corresponding fuel types presently recognized in the Canadian Forest Fire Behavior Prediction (FBP) System have also been identified, were applicable.



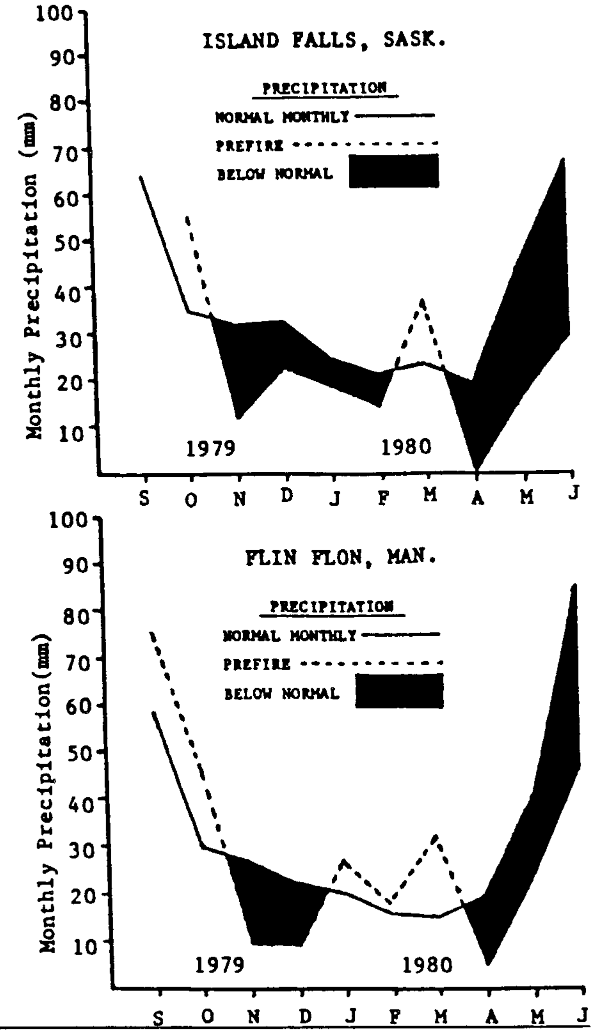


Figure 3. Departure from normal monthly precipitation amount for three year-round climatological stations during the 10-month period preceding the 1980 Chachukew Fire. The normal monthly precipitation (1951-80) is delineated by the broken line, the actual prefire precipitation by the solid line. The dark shaded areas represent periods when precipitation was below normal.

air with typical dew points in the 11-17°C range to return. On July 9 a minor trough at 500 mb moved southeastward through northern Manitoba (Fig. 4). This was accompanied by a southward push of the weak arctic cold front which moved through the fire area around 1200 h CST (Fig. 5). During the morning, dew points in the fire area were typical of the maritime air mass (i.e., ~ 15° C) rising to 19.6°C at Flin Flon around 1300 h CST (Table 1 and Fig. 6). As the arctic air pushed southward the dew point at Flin Flon dropped to below 10°C by 1500 h CST and a further 5+°C by 1700 h CST. Thus, the dew point was a phenomenal 15°C lower at the height of the burning period than it was at 1300 h CST. Another feature of this modified arctic air mass is that it remained quite shallow over the fire area. Thus, it did not have a major influence in lowering surface temperatures. Flin Flon recorded a maximum temperature of 28.7°C (Table 1 and Fig. 6). Combined with the low dew points, this resulted in relative humidities in the low 20s at the height of the burning period. This was undoubtedly the main weather factor contributing to the fire run. However, the timing of the cold frontal passage was also critical. If the cold front had passed through the fire area after the height of the burning period, as it did at The Pas around 2000 h CST, dew points would have remained in the mid teens and relative humidities would have remained in the 30s.

Atmospheric stability and winds aloft often contribute to extreme fire behavior (Byram 1954, 1955, 1959; Schroeder 1961; Taylor 1962; Edie 1969; Schroeder and Buck 1970; Steiner 1975, 1976; Alexander et al. 1983; Feunekes 1983; Simard et al. 1983; Burrows 1984; Street 1985; Street and Birch 1986). The nearest AES upper air station to the fire area is located at The Pas UA, Manitoba, 190 km southeast (elevation: 271 m MSL). The rawinsonde soundings

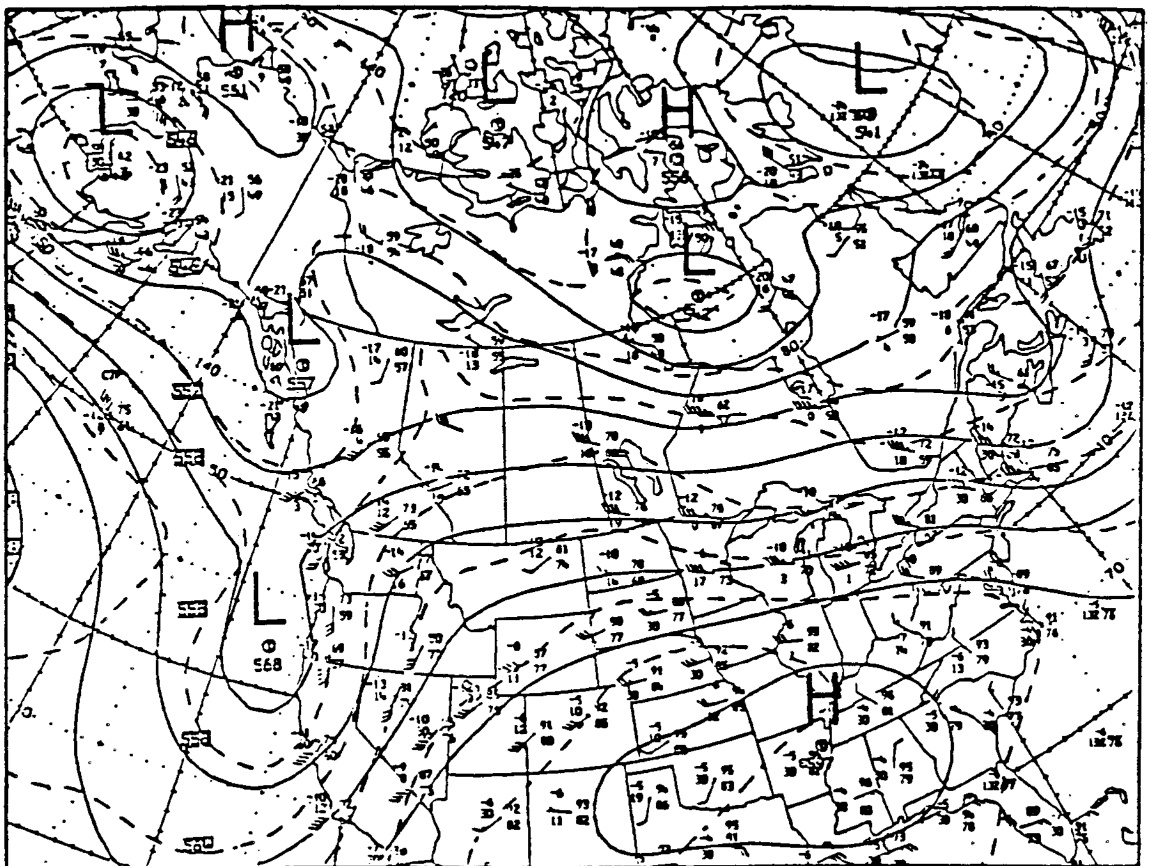


Figure 4. 500 mb chart for 0600 h CST, July 9, 1980.

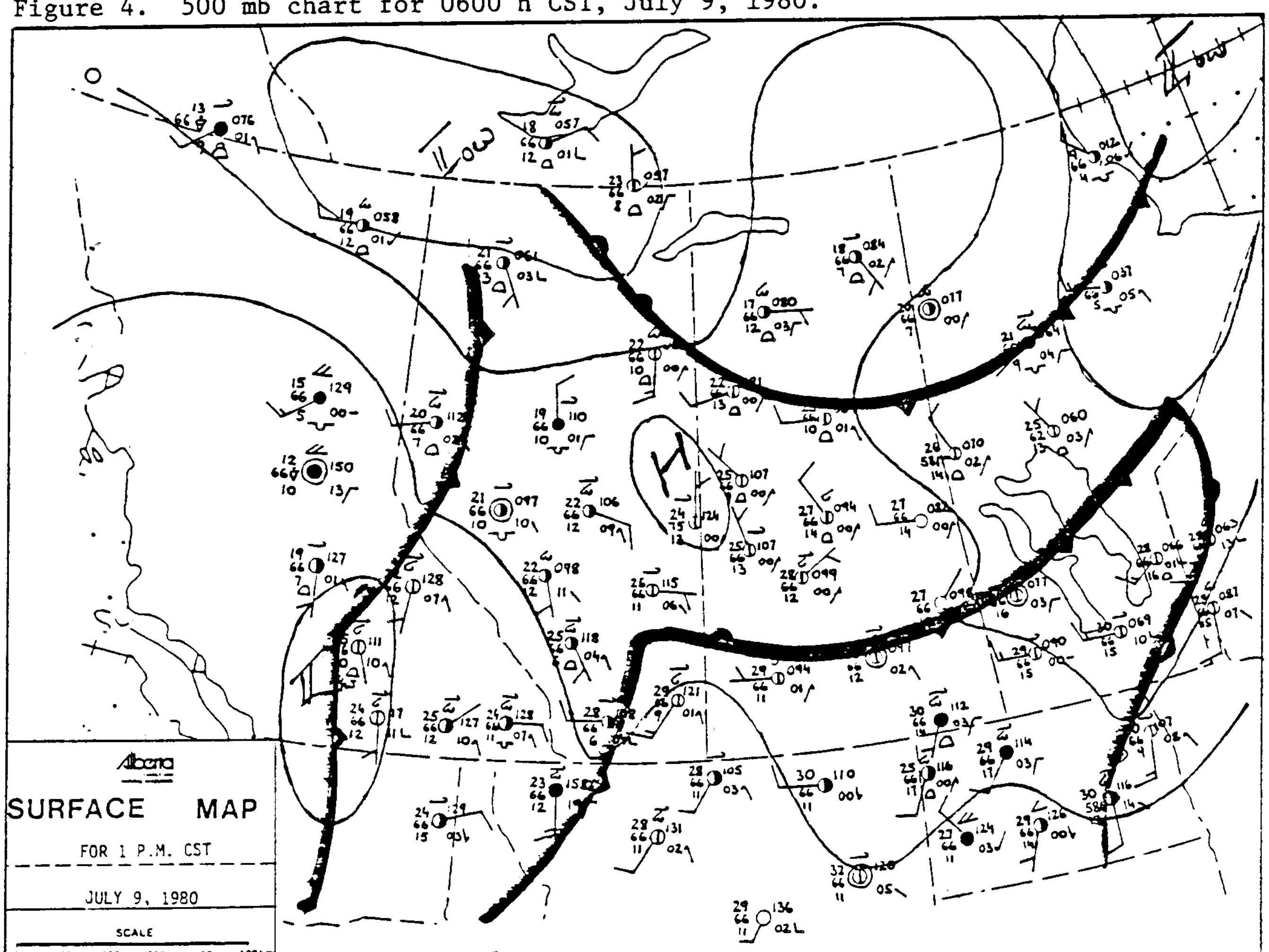


Figure 5. Surface weather map for 1300 h CST, July 9, 1980.

Table 1. Hourly weather observations and fire danger conditions recorded at Flin Flon A, Manitoba, during the major run of the Chachukew Fire on July 9, 1980.

Local time (h CST)	Dry-bulb temperature (°C)	Dew-point temperature (°C)	Relative humidity (%)	10-m open wind Direction (°)	10-m open wind Speed (km/h)	FWI System components[1] FFMC	ISI	FWI
1100	24.5	15.7	58	270	13(24)[2]	82.7	3.0	11
1200	25.4	17.2	61	290	9	83.3	2.6	10
1300	26.6	19.6	66	290	20	83.7	4.8	16
1400	27.0	10.3	35	270	20(33)	85.3	6.0	19
1500	28.3	9.8	32	270	17	86.8	6.3	20
1600	28.7	7.3	26	280	20(33)	88.3	9.2	26
1700	28.6	4.6	22	300	19(33)	89.7	10.6	28
1800	27.8	4.8	23	310	22(37)	90.7	14.3	35
1900	26.8	5.8	26	320	22(39)	91.3	15.5	37
2000	21.3	12.4	57	20	22(33)	90.7	14.3	35
2100	20.2	12.1	60	-	calm	90.5	4.6	16
2200	17.2	13.4	78	-	calm	89.8	4.1	14

[1]Abbreviations of selected Canadian Forest Fire Weather Index (FWI) System components: FFMC - Fine Fuel Moisture Code; ISI - Initial Spread Index; and FWI - Fire Weather Index. Calculations based on the equations for the 1984 version of the FWI System (Van Wagner and Pickett 1985).

[2]Reported gusts in parentheses.

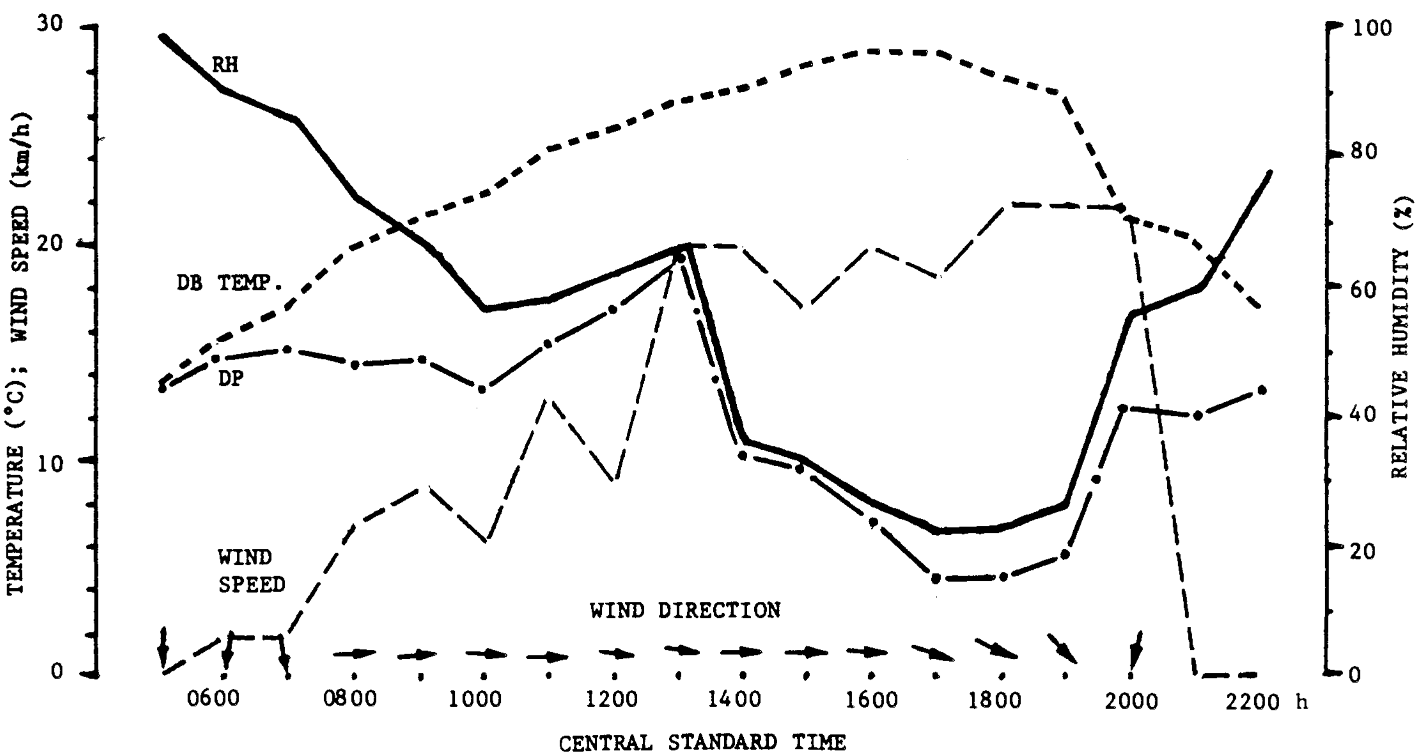


Figure 6. The diurnal trends in dry-bulb temperature, dew-point temperature (DP), relative humidity (RH), wind direction, and wind speed at Flin Flon A, Manitoba, during the major run of the Chachukew Fire on July 9, 1980.

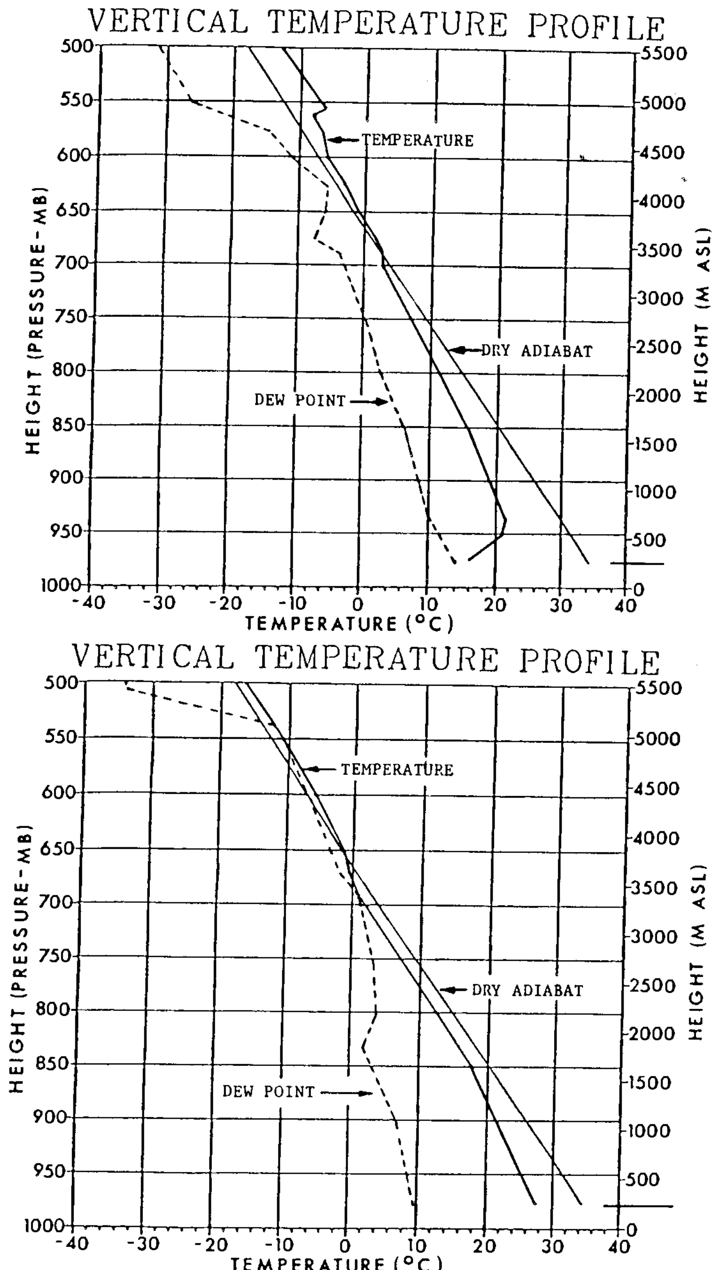


Figure 7. Vertical temperature profile above The Pas UA, Manitoba, at 0600 h CST *(top)* and 1800 h CST *(bottom)*, July 9, 1980. Note the shallow temperatures inversion near the surface. The evening sounding indicates very dry air below 2000 m as evident by the wide separation between temperature and dew point; temperature is very near the dry adiabatic lapse rate, indicating a relatively unstable atmosphere.

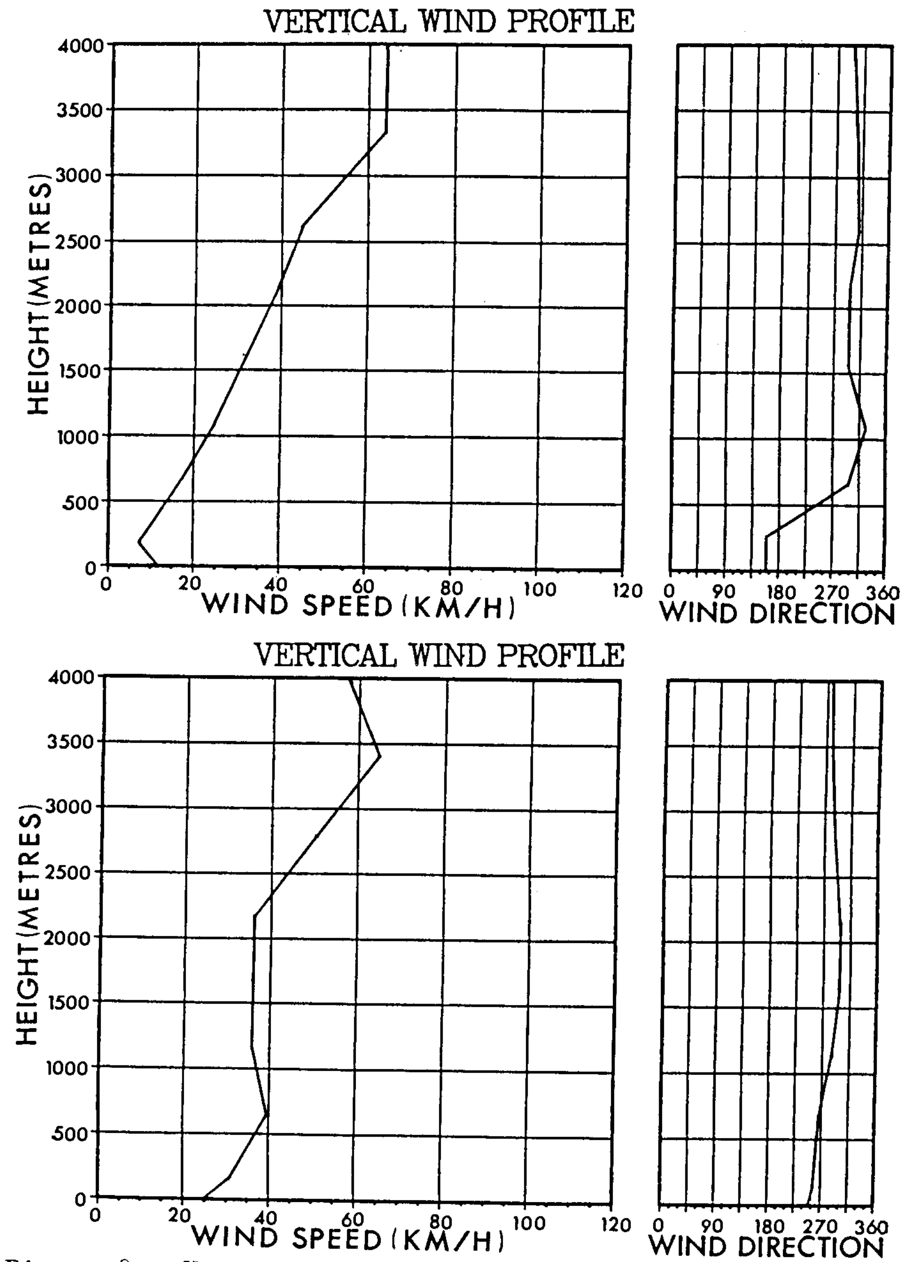


Figure 8. Vertical wind profile above The Pas UA, Manitoba, at 0600 h CST *(top)* and 1800 h CST *(bottom)* July 9, 1980. There is no evidence of a pronounced low-level jet wind (LLJW), which is often associated with extreme fire behavior. However, there may have been a minor LLJW south of the weak, advancing cold front.

for July 9 are presented in Figures 7 and 8. Unfortunately, the winds and lower levels of the temperature profile are probably not representative of the fire area due to the differences in air mass characteristics between the two locations.

The 500 mb anomaly chart (Fig. 9) indicates a slightly above-normal height level above The Pas UA, Manitoba station at the time of the fire run on July 9. However, in this particular case, there was no major breakdown of an upper ridge which can usually be predicted 24 to 48 hours in advance, and which often signals the onset of extreme fire behavior (Nimchuk 1983; Janz 1985; Janz and Nimchuk 1985). A corresponding seasonal display chart of fire danger indexes often show high and/or increasing values during a period of positive anomaly.

The Forestry Area Forecast or "FAF" (Vandervyvere 1985) for Hudson Bay, Saskatchewan issued by the AES's Prairie Weather Centre in Winnipeg for 0700 h CST on July 9 to 0700 h CST on July 10 indicated a maximum dry-bulb temperature of 30°C, a minimum relative humidity of 35%, 5.0 mm rain affecting 20% of the forecast area, and W-SW winds at 15 km/h until 0900 h CST then reaching 30 km/h until 2000 h CST when they would then become light and variable. The public weather forecast (also received at the SDPRR provincial fire control centre) indicated isolated showers in the evening of July 8 and overnight, and that July 9 would be clear with high temperatures.

FIRE DANGER CONDITIONS

The burning conditions during the major run of the 1980 Chachukew Fire are expressed here in terms of the Canadian Forest Fire Weather Index (FWI) System (Van Wagner 1974, 1987; Turner and Lawson 1978; Canadian Forestry Service 1984; Van Wagner and Pickett 1985). The FWI System consists of six standard components. Computations are based on consecutive daily 1200 h LST observations of dry-bulb temperature, relative humidity, 10-m open wind speed, and 24-h accumulated precipitation. The first three components of the FWI System are fuel moisture codes representing the moisture content of fine surface litter (Fine Fuel Moisture Code - FFMC), loosely compacted duff of moderate depth (Duff Moisture Code - DMC) and deep compact organic matter (Drought Code - DC). The other three components are fire behavior indexes representing rate of fire spread (Initial Spread Index - ISI), fuel available for combustion (Buildup Index - BUI) and fire intensity (Fire Weather Index - FWI). More specifically, the ISI represents the combined effect of wind and FFMC on fire spread rate. The BUI is a combination of the DMC and DC which represents the total fuel available to a spreading fire. The FWI is a combination of the ISI and BUI, and represents the energy output rate per unit length of an advancing fire front. In Saskatchewan, the FWI component is currently used as the principal indicator of fire danger. The following fire danger classes, based on the frequency of occurrence (Alexander 1982a), are presently recognized in Saskatchewan:

Fire Danger Class	Fire Weather Index
Low	0-5
Moderate	6-16
High	17-30
Extreme	31+

The July 9 fire weather and danger forecast issued for the SDPRR Pelican Narrows station (elevation: 320 m MSL) by the AES Prairie Weather Centre

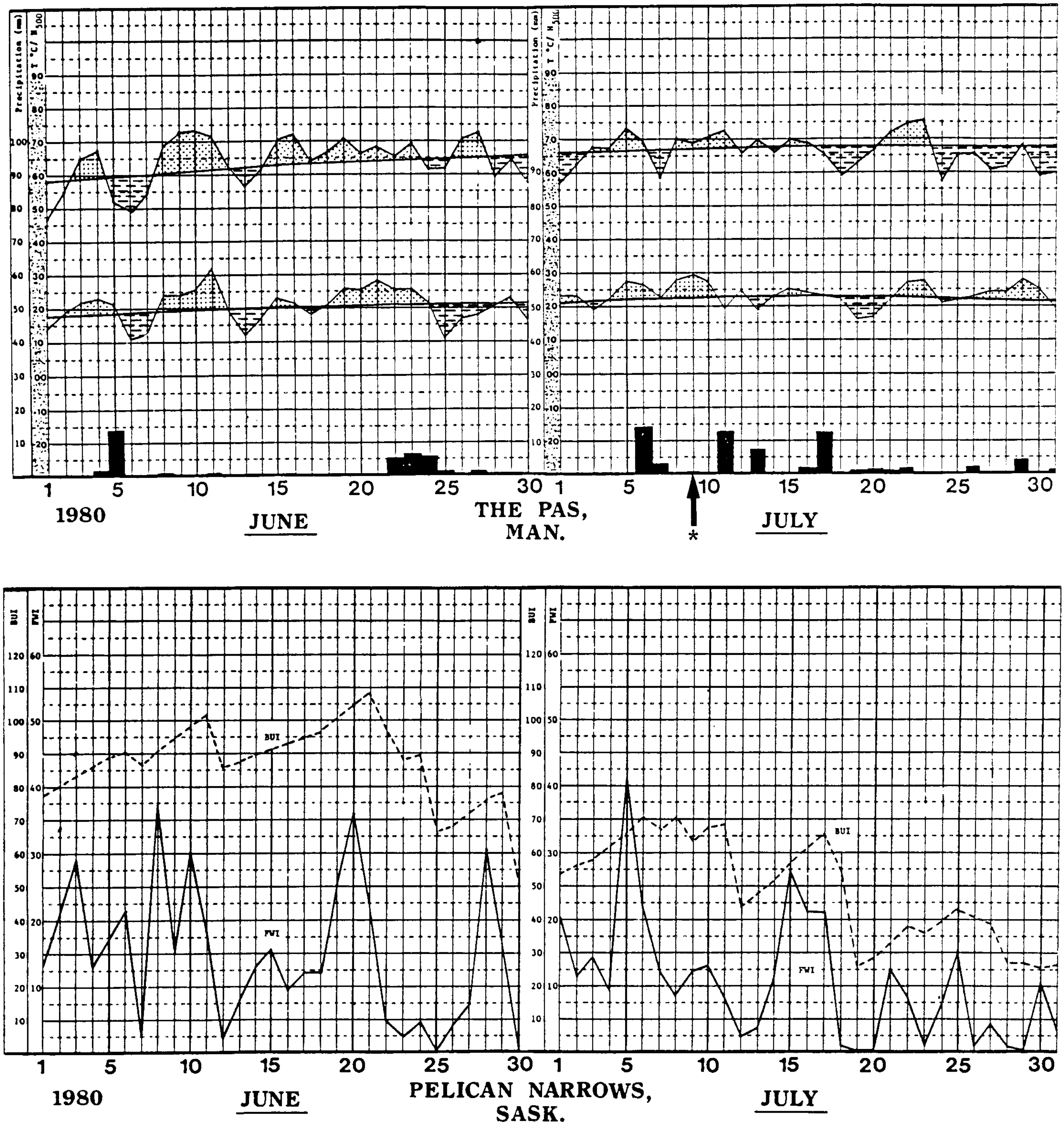


Figure 9. Charts of 500 mb height/maximum surface temperature anomalies with daily precipitation amounts at The Pas, Manitoba (*top*) and fire danger indexes at Pelican Narrows, Saskatchewan (*bottom*) during June and July, 1980. The main run of the Chachukew Fire occurred on July 9, 1980(*). The 500 mb mean height contour curves were constructed from the basic statistical data given in Titus (1973) for The Pas UA, Manitoba station. Alternatively, map data could have been used (e.g. Harley 1980).

(Raddatz and Atkinson 1982) during the afternoon of July 8 indicated slightly moderated conditions from those contained in the FAF:

DB Temp. (°C)	RH (%)	10-m Wind (km/h)	Rain (mm)	FWI System components[4]					
				FFMC	DMC	DC	ISI	BUI	FWI
21.0	56	15	0.0	86	46	426	5	73	16

The 0800 h CST weather observations at Pelican Narrows on July 9 show a dry-bulb temperature of 18°C, relative humidity of 74%, wind speed of 15 km/h, and an 18-h precipitation total of 0.3 mm. On the morning of July 9, a revised forecast was issued for Pelican Narrows, using the 18-h precipitation amount. The increased temperature and considerably decreased humidity was somewhat offset by the lower predicted wind speed which resulted in fairly similar FWI System values to those contained in the previous forecast:

DB Temp. (°C)	RH (%)	10-m Wind (km/h)	Rain (mm)	FWI System components[4]					
				FFMC	DMC	DC	ISI	BUI	FWI
23.0	39	3	0.3	88	47	427	4	74	13

It's worth noting that the FWI System values contained in the forecast are deemed applicable for 1600 h LST by applying the 1200 h LST weather readings to a "normal" diurnal pattern of the measured parameters. For example, the predicted relative humidity for 1200 h CST on July 9 was 39%. However, by mid to late afternoon, the RH could quite possibly reach the low 30s or even the high 20s, especially if the temperature reached 30°C as predicted in the FAF. This would suggest that unsecured fires would undoubtedly experience control problems. The only factor preventing "explosive" burning conditions was the low wind speed prediction. The FAF predicted winds of 30 km/h for most of the day, although the July 9 0800 h CST fire danger forecast was projecting only light winds (i.e., 3 km/h).

The actual fire weather observations and calculated FWI System values for the Pelican Narrows station on July 9, 1980 by the AES Prairie Weather Centre are as follows:

DB Temp. (°C)	RH (%)	10-m Wind (km/h)	Rain (mm)	FWI System components[4]					
				FFMC	DMC	DC	ISI	BUI	FWI
25.0	44	20	3.0	80	38	420	3	62	11

As indicated above, an additional 2.7 mm of rain fell at Pelican Narrows between 0800 and 1200 h CST for a 24-h total of 3.0 mm. A trace of rain was reported by the SDPRR ground suppression crew at the fire scene on the previous evening, although there is no account of any other rain occurring at the fire site on July 9. The Pelican Narrows fire weather network station is located about 6 km south of the fire's origin. Apparently, the isolated thundershower activity predicted in the previous day's forecast did materialize over Pelican Narrows but missed the fire site.

[4]Note: These calculations, which were actually made in 1980, are based on the equations for the 1976 version of the FWI System (Van Wagner and Pickett 1975).

The nearest AES synoptic network weather station is located at Flin Flon A, Manitoba. The hourly records show that relative humidities climbed between 1000 and 1300 h CST and then dropped from 66% at 1300 h CST steadily to 35% at 1400 h CST (Table 1 and Fig. 6). The relative humidity continued to decrease and stayed in the mid to low 20s until 2000 h CST, when it again sharply increased. The temperature at Flin Flon reached a high of almost 29°C around 1600 h CST. Winds near 20 km/h were maintained from 1300 to 2100 h CST. All of these factors contributed to the extreme burning conditions experienced at the fire site.

For this case study analysis, the daily 1200 h CST fire weather observations for the SDPRR network station at Pelican Narrows were acquired and all weather data were then processed by computer using the most current edition (1984) of the FWI System (Van Wagner and Pickett 1985). The results were used in the plotting of the FWI/BUI seasonal display chart. The spring starting values of the DC was also adjusted for overwinter precipitation (Turner and Lawson 1978; Alexander 1982c, 1983a, 1983b; Lee and Alexander 1982). The DC on the last day (September 6) of calculations in the fall of 1979 was 267 at the Pelican Narrows fire weather station. This early closing date was approximately seven weeks prior to a continuous covering of snow. The snow cover is usually gone in the spring around May 1 but as late as May 17 and as early as April 10 (Potter 1965). However, in 1980 complete snowmelt occurred considerably earlier than normal. The total overwinter precipitation for the Pelican Narrows area was judged to be about 212.4 mm (water equivalent) between September 7 and April 12 based on observations at Island Falls and Flin Flon. The initial spring DC starting value was computed to be 39 based on a DC_F = 267, P = 212.4 mm, fall carry-over fraction **a** = 0.75, and a precipitation effectiveness fraction **b** = 0.50. Based on the 1200 h CST weather observations at Flin Flon A, an additional 21 DC units were estimated to have accumulated between April 16 and April 22, the actual spring starting date at Pelican Narrows. Thus, the final result was DC_S = 60. The spring starting value of the DMC was estimated to be 15.

Assuming that the area burned on July 9 did not receive any significant rain (i.e., greater than a trace or 0.1 mm) and that fire weather conditions occurring at Flin Flon are representative of the fire site (this is generally a very reasonable assumption in the boreal forest, particularly for temperature and relative humidity, given the level terrain and minor differences in elevation), a new set of FWI System calculations could have been undertaken. Turner and Lawson (1978) state that when sudden weather changes occur, revised calculations for the day is warranted. In this particular case, the relative humidity didn't follow a normal diurnal pattern and a recalculation for the day could have been undertaken due to the sharp drop in RH around 1400 h CST. Using the 1400 h CST weather observations from burning Flin Flon and a 24-h precipitation of 0.1 mm, the probable burning conditions for the fire site are as follows:

DB Temp. (°C)	RH (%)	10-m Wind (km/h)	Rain (mm)	FWI System components[5]					
				FFMC	DMC	DC	ISI	BUI	FWI
27.0	35	20	0.1	91	49	450	13	77	33

The values given in Table 1 and above are certainly more indicative of the

[5]Note: Calculations based on the FORTRAN program for the 1984 verison of the FWI System (Van Wagner and Pickett 1985).

burning conditions actually experienced at the fire site than the original calculations for Pelican Narrows in 1980, although they can not be considered as strictly representative. However, similar trends in the fluctuations of the parameters probably did occur, but they most likely were not identical. It's worth noting that the location of the Pelican Narrows fire weather station on the shore of Pelican Lake (Fig. 1) in relation to a westerly wind would likely indicate a slightly lower temperature and higher relative humidity. The somewhat abnormally high DC and BUI values for July are undoubtedly a reflection of the below-normal precipitation and above-normal temperatures during the previous three months.

Note that the FWI System values given in Table 1 are based on the assumption that no rain fell at the site of the Chachukew Fire. The required 1100 h CST FFMC starting value is based on the standard daily FFMC at Pelican Narrows on July 8 and the FFMC diurnal adjustment table (Alexander 1982d). Subsequent computations were determined on the basis of the hourly FFMC (Van Wagner 1977a; Alexander et al. 1984).

FIRE BEHAVIOR PREDICTION

A projection of free-burning growth for the 1980 Chachukew Fire run of July 9 using the 1984 interim edition of the Canadian Forest Fire Behavior Prediction (FBP) System (Alexander and others 1984; Lawson et al. 1985) and a simple elliptical model (Alexander 1985a, 1986b; McAlpine 1986) is summarized in Figure 10. The FBP System projection for Fuel Type C-2 underpredicted the forward spread distance, but the area burned prediction was very close. The Fuel Type C-4 projection overestimated the total area burned, but accurately predicted the forward spread distance. Underpredictions of fire perimeter length is a recognized feature of the simple elliptical fire growth model (Alexander and others 1984; Alexander 1985a; Lawson et al. 1985; McAlpine 1986). The lakes on the eastern half of the fire obviously influenced the somewhat irregular shape of the July 9 run (<u>see</u> Figure 1).

The CFFDRS does effectively integrate the influence of moisture conditions on potential fire behavior. Its sensitivity to the occurrence of precipitation as reflected by the isolated rainshowers in the area surrounding the Pelican Narrows fire weather station is illustrated in Figure 11. Note that the chart given in Figure 11 does represent a prototype format for one possible means of presenting, in management-useable form, the frontal fire intensity component of the FBP System which is due for completion in 1987 and could be used for plotting actual or forecast indices for one or several network fire weather stations.

The concepts presented in the 'intensity rank chart' (Fig. 11) can also be used to display the hourly changes in fire behavior and the corresponding fire suppression requirements to achieve control. The diurnal pattern shown in Figure 12 is based on a "no rain" BUI at Pelican Narrows of 77 and the ISI values contained in Table 1. For several hours, the Chachukew Fire exceeded the limits of control by conventional means available to fire management personnel.

The average forward rate of advance of the Chachukew Fire during the afternoon of July 9 was 1.2 km/h or 19.7 m/min. Based on the BUI level and boreal forest fuel types involved, the available fuel consumed (w) probably amounted to about 2.5 kg/m^2 -- i.e., 1.5 kg/m^2 for ground and surface fuels + 1.0 kg/m^2 for crown fuels. Using a head fire rate of spread (r) figure of 0.33 m/sec (i.e., 19.7 m/min ÷ 60) and a net heat of combustion value (H)

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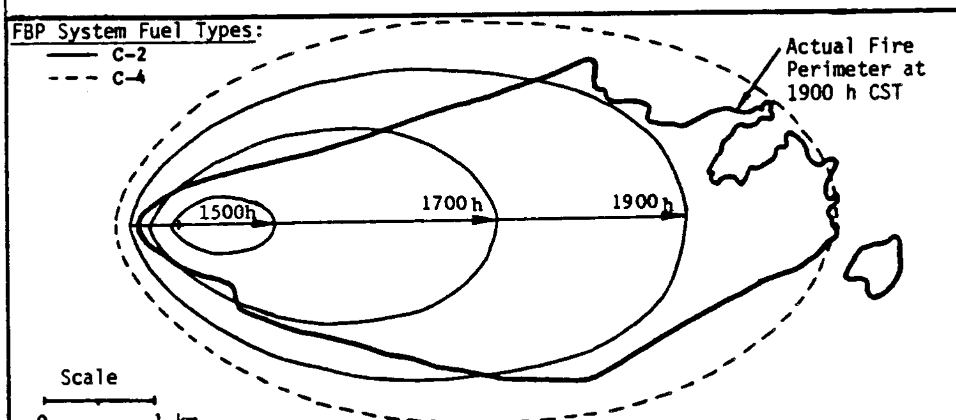
CANADIAN FOREST FIRE BEHAVIOR PREDICTION (FBP) SYSTEM WORKSHEET

Fire Number/Name CHACHUKEW #116 (SASK.) Date & Time 09.07.80 1400 h CST

Prediction Date & Time Interval 09.07.80 from 1400 h to 1900 h CST

		1400-1500h	1500-1700h	1700-1900h		
1	Prediction Point	1 P.I.	1 P.I.	1 P.I.		
	Fuel Type Information					
2	FBP System Fuel Type	C-2	C-2	C-2		
3	Softwood Species Composition (%)	-	-	-		
4	Hardwood Species Composition (%)	-	-	-		
5	Cured/Dead Grass (%)	-	-	-		
6	Grass Fuel Weight (t/ha)	-	-	-		
	Fine Fuel Moisture Code (FFMC) Time & Slope/Aspect Adjustments					
7	Standard Daily FFMC	91	91	91		
8	Time "T"	1400	1600	1800		
9	FFMC at Time "T"	90	91	90		
10	Aspect (N, E, S, or W)	-	-	-		
11	Ground Slope (%)	0	0	0		
12	Adjusted FFMC	90	91	90		
	Rate of Spread (ROS) Calculations					
13	10-m Wind Speed (km/h)	20	20	20		
14	Initial Spread Index (ISI)	12*	14*	12*		
15	Spread Factor (SF)	1.00	1.00	1.00		
16	ROS on Level (m/min or km/h)	14	17	14		
17	ROS[16] x SF[15] (m/min or km/h)	14	17	14		
		* CROWN FIRE				
	Fire Size Calculations					
18	Elapsed Time (min or h)	60	120	120		
19	Spread Distance (m or km)	840 +	2040 +	1680		
20	Area Shape Factor (K_A)	0.54	0.54	0.54		
21	Area Burned (ha)	38	448	1123		
22	Length/Breadth Ratio (L/B)	1.76	1.76	1.76		
23	Perimeter Shape Factor (Kp)	3.54	3.54	3.54		
24	Perimeter Length (m or km)	2974	10195	16142		
	Fire Area Plotting 1:50 000					
25	Map Conversion Factor (cm/km)	2.00	2.00	2.00		
26	Map Distance (cm)	1.8/1.1	6.3/3.6	10.0/5.7		
27	Wind Direction	W	W	W		



NOTES:

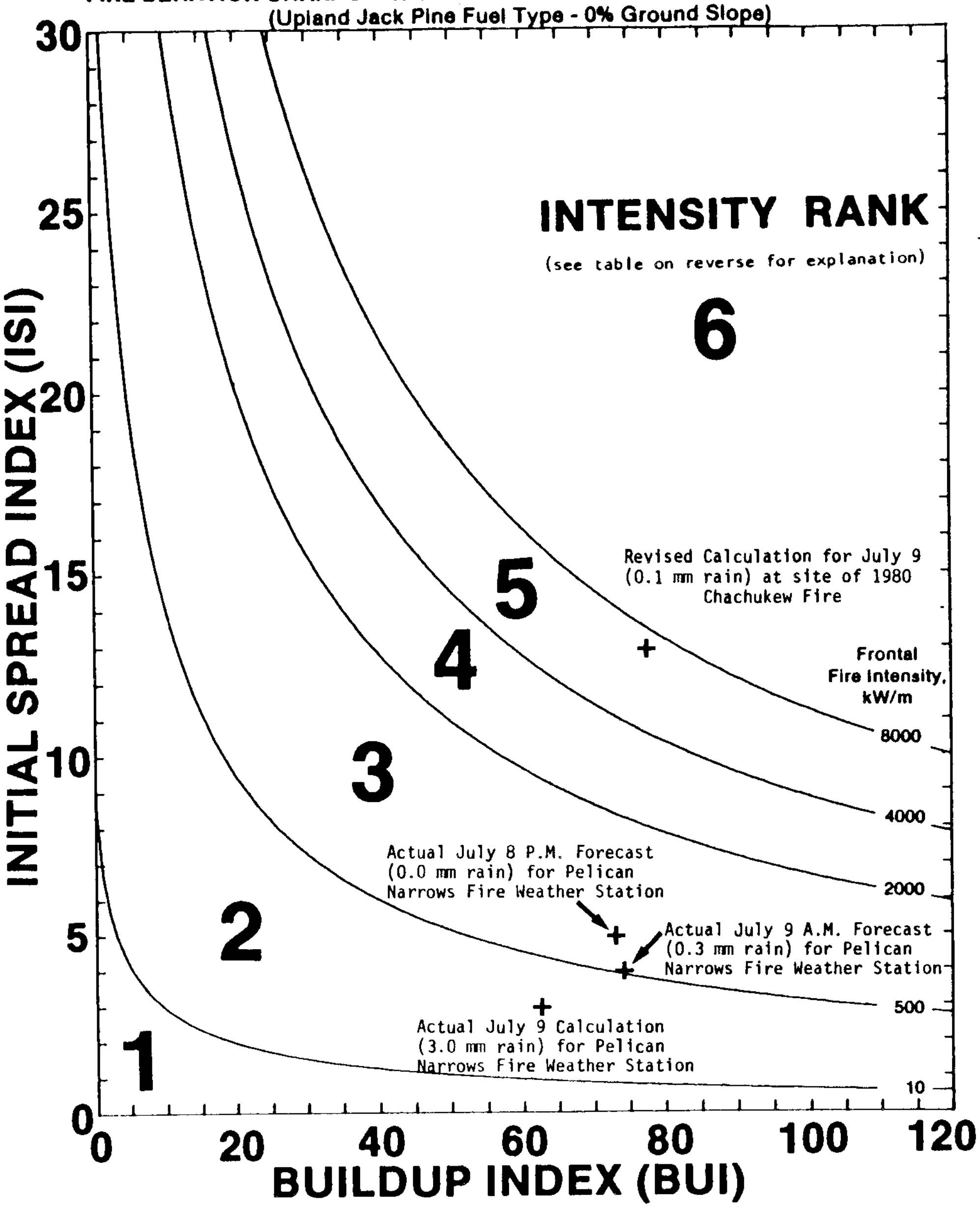
The Area and Perimeter Shape Factors are from Tables 14 and 15, respectively of Alexander (1986a) which indirectly account for backfire spread.

The Area Burned, Perimeter Length, and Map Distance computations for 1500-1700 h and 1700-1900 h CST are based on the cumulative forward Spread Distances (i.e., 2880 m and 4560 m, respectively).

The plotting of the elliptical fire areas displayed at left are based on the procedures described in Alexander (1986a) which take into account the back-fire spread. Map distances refer to the NTS 1:50 000 scale topographic map.

Figure 10. After-the-fact projection for the main run of the 1980 Chachukew Fire utilizing the worksheet and procedures for plotting fire growth from a point ignition contained in the user guide to the 1984 interim edition of the Canadian Forest Fire Behavior Prediction (FBP) System. The 5-h prediction of fire growth is based on the 1400 h CST fire weather observations and fire danger ratings at Flin Flon, Manitoba and FBP System Fuel Type C-2 (Boreal Spruce), assuming that no rain fell at the fire site. An additional prediction for Fuel Type C-4 (Immature Jack Pine) is also given.

FIRE BEHAVIOR CHARACTERISTICS/SUPPRESSION INTERPRETATIONS CHART
(Upland Jack Pine Fuel Type - 0% Ground Slope)



CFS Fire Danger Group, January 1986

Chart Rank	Frontal Fire Intensity (kW/m)	Head Fire[1] Flame Length (m)	Head Fire[1] Flame Height (m)	Description of Fire Behavior Characteristics and Fire Suppression Interpretations	Fire Weather Index[2] (FWI)
1	<10	<0.2	<0.1	Smouldering ground or creeping surface fire. Firebrands and going fires tend to be virtually self-extinguishing unless high Drought Code (DC) and/or Buildup Index (BUI) values[3] pervail, in which case extensive mop-up is generally required.	0-3
2	10-500	0.2-1.4	0.1-1.0	Low vigour surface fire. Direct manual attack at fire's head or flanks by fire-fighters with hand tools and water possible. Constructed fire guard should hold.	4-13
3	500-2000	1.4-2.6	1.0-1.9	Moderately vigorous surface fire. Hand-constructed fire guards likely to be challenged. Heavy equipment (bulldozers, pumpers, retardant air-craft, skimmers, helicopter w/bucket) generally successful in controlling fire.	14-23
4	2000-4000	2.6-3.5	1.9-2.5	Highly vigorous surface fire or passive crown fire (torching). Control efforts at fire's head may fail.	24-28
5	4000-8000	3.5-4.8	2.5-3.4	Extremely vigorous surface fire or active crown fire. Very difficult to control. Suppression action must be restricted to fire's flanks. Indirect attack with aerial ignition (i.e., helitorch and/or AID dispenser) may be effective.	29-33
6	>8000	>4.8	>3.4	"Blow-up" or "conflagration" type fire run; violent physical behavior probable. Suppression actions should not be attempted until burning conditions ameliorate.	>34

[1] Applicable to surface fire only; flame height based on flame length and a 45° flame angle.

[2] Applicable to mature jack pine stands on level ground.

[3] DC >300 and/or BUI >40.

Prepared by: Martin E. Alexander, CFS-NoFC, Edmonton, Alta.

Figure 11. Differences in probable wildfire potential and fire control requirements/difficulty as a result of isolated rain-shower activity in the Pelican Narrows area of east-central Saskatchewan during the afternoon of July 9, 1980.

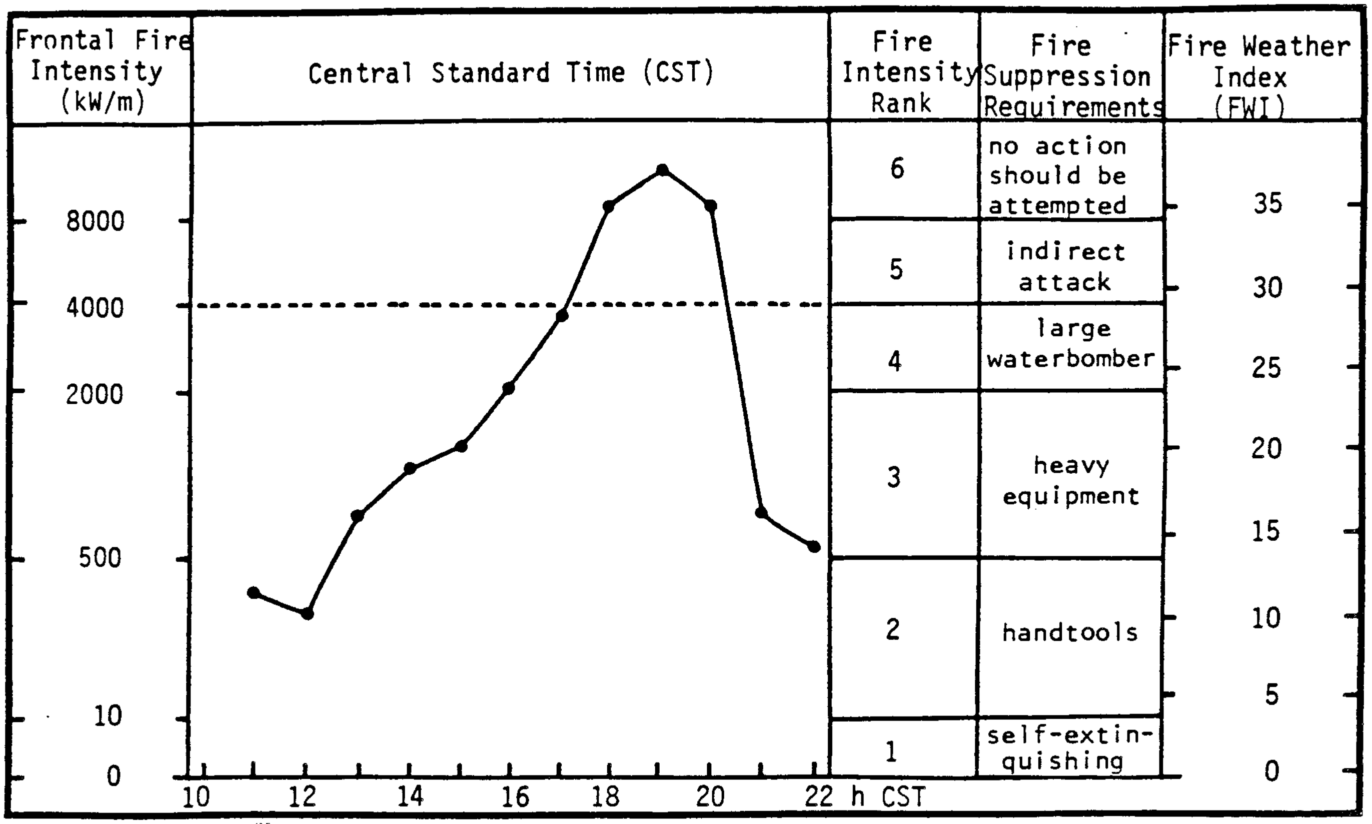
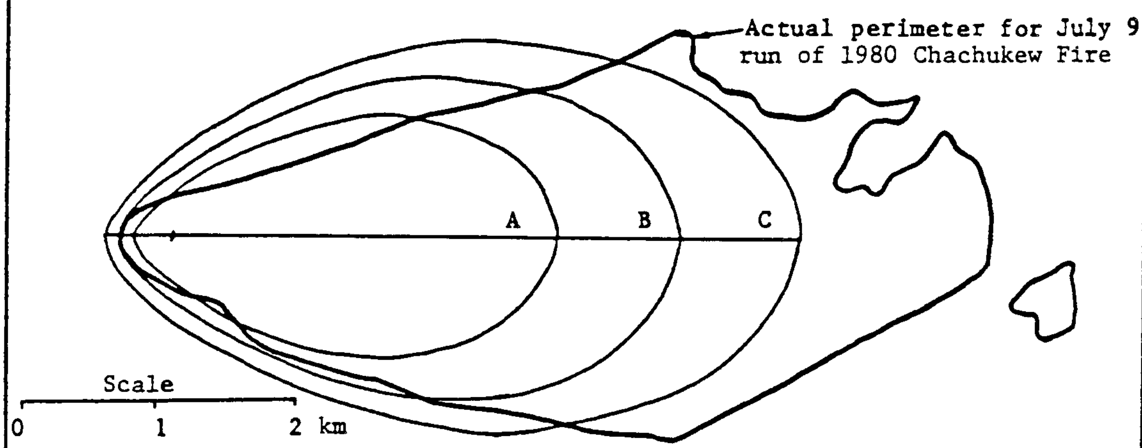


Figure 12. Diurnal pattern in probable fire potential and fire control requirements during the major run of the Chachukew Fire on July 9, 1980.

	Temperature (°C) Dry-bulb	Temperature (°C) Wet-bulb	RH (%)	FFMC	ISI	Head Fire ROS (m/min)
CASE A	24.5	17.5	51	87.6	8.4	10.4
CASE B	25.0	17.0	46	88.8	9.9	13.7
CASE C	25.5	16.5	41	89.8	11.4	16.8



NOTE: The free-burning fire growth predictions given above are based on no rain FFMC calculation, 10-m open wind of 20 km/h, 0% ground slope, FBP System Fuel Type C-4, burning conditions (i.e., fire weather observations & fire danger ratings) recorded at the Pelican Narrows fire weather station, and an elapsed time of 5 hours.

Figure 13. An example of the possible outcomes in FBP System projections which could occur when dry-and wet-bulb temperature observations are rounded to the nearest whole degree Celsius (°C) based on the 1980 Chachukew Fire run of July 9.

of 17 000 kJ/kg, this translates into 14 025 kW/m as an estimate of the "peak" frontal fire intensity (I) (Byram 1959; Alexander 1982b) for the Chachukew Fire run of July 9. This level of intensity is substantiated by several 35 mm slides taken by a Pelican Narrows RCMP officer as the Chachukew Fire crossed Highway 135. The above calculation ($I = Hwr$) is of course for a full-fledge active crown fire (Van Wagner 1977b; Merrill and Alexander 1987). For a surface fire, prior to the onset of crowning (Van Wagner 1977b), the calculated frontal intensity is 8 910 kW/m (i.e., H = 18 000 kJ/kg, w = 1.5 kg/m^2, and r = 0.33 m/sec). This is moderately higher than that suggested by the 'fire intensity rank chart and table' (Fig. 11), although it's impossible to quantify the effect crowning had on the final spread rate (Van Wagner 1977b). The predicted frontal fire intensity for an ISI 13 and BUI 77 is ~ 7270 kW/m.

Disregarding the frontal fire intensity implications for a moment, if the two S_2F Trackers based at La Ronge had been available, could they have contained the escape at 1400 h CST on July 9 simply on the basis of their line-building capability (Martell et al. 1984; Mees 1985; Loane and Gould 1986; Smith 1986)? Note that the normal cruise speed of a loaded Tracker is ~ 300 km/h (Grigel et al. 1975; McDonald 1976; Anon. 1981). It's estimated that it would take 40 min for the Trackers to deliver their loads (i.e., minimum 30 min travel time + at least 10 min for take off and climb to cruise speed plus time to assess the fire prior to dropping). According to the FBP System, the projected area and perimeter length of the fire at 1440 h CST would have been about 16.9 ha and 1982 m, respectively. If 40% of the perimeter must be contained in order to control the fire (Potter et al. 1981), then the two Trackers must be capable of jointly constructing at least 793 m of retardant line. According to the best estimates available from research (e.g., Newstead and Lieskovsky 1986) and operational experience, the combined maximum possible "fireguard" that could be delivered would be in the form of four 2-door string drops for a total of 172 m of effective line (R.G. Newstead, pers. comm.). What about allowance in the area and perimeter length computations for the time required of the fire to reach its equilibrium spread rate (Cheney 1981)? Using a semi-theoretical approximation, the fire is estimated to have an area of 8+ ha with a perimeter length of 1300+ m at 40 min elapsed time since ignition. Therefore, at least 550 m of fireguard must be built to contain the fire.

FIRE MANAGEMENT IMPLICATIONS

The CFFDRS is not only sensitive to precipitation, but to all of the required fire weather elements. Examination of the fire danger records for the Pelican Narrows fire weather station revealed that temperatures were being rounded to the nearest whole degree Celsius. The impact of such observing practices on FBP System projections is summarized in Figure 13. Case B represents the values recorded at 1200 h CST prior to the main run of the Chachukew Fire. Cases A and C represent the two extremes which could have been recorded instead of Case B. The difference in fire area predictions for Case A and C is over 550 ha. The fact that 0.5°C has this effect on the CFFDRS illustrates not only the significance of proper observation and recording practices, but also the importance of ensuring that weather stations meet location and instrument exposure standards (Turner and Lawson 1978), fire weather observers receiving fundamental training, and that quality control criteria are established and maintained (e.g., annual equipment checks).

Isolated showers can cause calculated FWI System component values to indicate conditions that are only valid for a very limited area, even though the information is being used for an entire district. For fire weather stations receiving precipitation from isolated shower activity, a second, "no-rain" calculation of the FWI System could be made to more accurately reflect burning conditions in those areas which did not receive rain. The resulting values could also be used for FBP System projections. In addition, if a significant change in the weather occurs after the noon LST weather observations, then another recalculation of the FWI System components could be done with new observations (the original "noon" fire weather observations, including rain from isolated showers, would still be used for the following day's calculation. Thus, fire managers at the district level must be able to do FWI System calculations, whether by tables (Canadian Forestry Service 1984) or computer (Van Wagner and Pickett 1985). In the same vein, fire danger forecasts issued by AES should also be updated whenever forecasted weather conditions drastically change.

The conclusion from this single case study is that there appears to be nothing out of the ordinary about fire behavior in terms of the fuel component of the fire environment on Saskatchewan's portion of the Canadian Shield. In fact, the FBP System would appear to produce reasonably accurate predictions of fire growth and intensity. However, the Shield's terrain undoubtedly affects local surface wind conditions in complex ways (Buck 1964; Schroeder and Buck 1970).

If the fire manager understands how the CFFDRS works, and appreciates the sensitivity of the subsystems, then he is in a better position to apply common sense adjustments to accommodate local, site-specific conditions. This fine-tuning of CFFDRS applications is the 'art' required to make the danger rating 'science' an accurate and useful tool for fire operations.

CONCLUDING REMARKS

Case studies of selected wildfires have a value in their own right in terms of training material and as a data source for research (Alexander 1982e). The Chachukew Fire case study has already been used in several SDPRR courses this year by the first author. In addition, the head fire spread rate and attendant burning conditions for the July 9 run have now been incorporated into the data base associated with the continuing development of the FBP System.

ACKNOWLEDGMENTS

Appreciation is extended to Fred Luciow of AES Central Region office, Winnipeg for his assistance in acquiring weather data and maps utilized in this paper. Ben Janz of the Alberta Forest Service (AFS) fire weather section and Al Schmidt of the AES Prince Albert Weather Office were very helpful with interpreting the synoptic-scale weather features associated with the 1980 Chachukew Fire run. Dick Smith, Canadian Forestry Service (Edmonton), completed the final copy of Figure 2. The AFS fire weather section kindly provided Figure 5.

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