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Analysis of the Fire Behavior Associated with Three 1988 Spring Wild Fires in Central Canada

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Abstract

Between April 30 and May 2, 1988 extreme fire behavior was exhibited by the Gull Lake and Brereton Lake wildfires in southeastern Manitoba and the Kenora #14/88 conflagration in northwestern Ontario. A strong upper ridge centered over northern Ontario blocked the movement of a very moist air mass approximately 120 km west of the fire areas. Open wind speeds during peak burning conditions averaged between 25 km/h and 50 km/h, with maximum gusts near 80 km/h. Five major fire runs in mature and immature jack pine stands were documented. The calculated values of the Canadian Forest Fire Behavior Prediction System compared favorably (±25%) to the actual head fire spread rates, which ranged from 0.8 km/h to 3.5 km/h.

Résumé

Entre le 30 avril et le 2 mai 1988 des comportements extrêmes du feu se sont produits piès des feux de friches du Lac Gull et du Lac Brereton 1988, au sud-est du Manitoba et la conflagration #14188 à Kenora au nord- ouest de l'Ontario. Une forte crête de haute pression centrée au-dessus du nord de l'Ontario a bloqué le déplacement d'un système d'air très humide à environ 120 km à l'ouest des régions où des incendies rageaient. Au cours de cette période où les conditions de brûlage étaient les meilleures la vitesse moyenne des vents oscillait entre 25 et 50 km/h, des rafales maximales de près de 80 km/h ayant été enregistrées. Cinq aggravations majeures de feu dans des peuplements de pins quis arrivés et pas encore arrivés à maturité ont été documentées. Les valeurs calculées à l'aide de la Méthode cnadienne de prévision du comportement des incendies de forêt (PCI) se sont comparées favarablement (±25%) aux taux actuels de propagation du feu sous le vent, qui se situaient entre 0.8 km/h à 3.5 km/h.

Introduction

The occurrence of wildfires prior to spring leaf-flush is a perennial problem in some areas of southeastern Manitoba and northwestern Ontario. In most instances these fires remain relatively small; however, occasionally large fires do occur. For example, of the over 800 fires that occurred prior to or during the month of May in southeastern Manitoba from 1976-86, 72% were less than 10 ha in size. The remaining 28% of the fires burned 138,000 ha of forested land or 99.3% of the region's total area burned during these months. Also significant is the fact that nearly 90% of all these fires were man-caused.

The primary values at risk in this area include rural homes, summer cottage developments, outdoor recreational areas, and forestry values. Because of this, wildfire suppression is a high priority in this region for both the Ontario Ministry of Natural Resources (OMNR) and Manitoba Natural Resources (MNR). One source of information that fire managers in this area and across Canada have increasingly used in their suppression operations is the Canadian Forest Fire Behavior Prediction (FBP) System[1] (Lawson et al. 1985). This system predicts fire behavior in specific fuel types for different weather conditions and topographic features. It has been utilized for pre-suppression planning, initial attack dispatch and both agencies have found it effective in project fire situations (Stocks and Flannigan 1987, Hirsch 1988a). It is based on over 400 experimental fires and well-documented wildfires, however, the need for additional information at the extreme end of the fire behavior scale still exists in order to verify or refine the FBP System (Alexander and Lanoville 1987). An effective

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way to meet this need is to gather information from large wildfires through formal documentation. A large number of case studies have been published for wildfires in northwestern Ontario (e.g., Stocks and Walker 1973, Stocks 1975, Street and Stocks 1983, Stocks and Flannigan 1987), Canada, and abroad[2] but none have been completed for any forest fires in Manitoba. In light of these factors, the purpose of this paper is to: (a) describe the fire weather conditions which contributed to the occurrence of extreme fire behavior on the Gull Lake and Brereton Lake Fires in southeastern Manitoba and the Kenora #14/88 Fire in northwestern Ontario, and (b) present a retrospective comparison of those values calculated by the FBP System with the actual fire behavior on each of these wildfires.

The Wildfire Chronologies

GULL LAKE FIRE

The Gull Lake Fire was detected and reported at 1430 Central Daylight Time (CDT) on May 1, 1988. The fire area was located approximately 60 km northeast of the city of Winnipeg (Figs. 1 and 2). Initially, this man-caused fire was burning in a grass field but by 1532 CDT strong southerly winds had pushed it northward to the edge of a long, narrow stand of 30-40 year old jack pine (Pinus banksiana). Because of the fire's intensity, direct ground attack was not possible and though airtanker support was requested, it was denied due to the high winds in Winnipeg which grounded the CL-215 skimmer aircraft. Indirect attack with bulldozers was attempted but proved to be hazardous for the operators. At 1628 CDT the head fire was reported to be under the hydroelectric power lines approximately 3.0 km north of where it entered the stand of jack pine. It continued to spread in a northerly direction placing a large number of rural homes and cottages at Gull Lake in jeopardy. By 1730 CDT the head fire had travelled 6.4 km and was approaching a large gravel pit. Concern was expressed that if the fire was not stopped at this point it could jump northwestward over Highway 59 and spread through unlimited fuels towards the highly populated recreational area of Victoria Beach. Around 1900 CDT the fire's flank did actually jump the highway, but it spread into a wet, treed-bog area that slowed its progress considerably. Backburning to ensure no further fire spread began at 1950 CDT; however, only five minutes later the wildfire virtually stopped due to a dramatic change in the weather.

On May 2, a full-scale suppression effort was undertaken and the few hotspots that did develop were suppressed with little difficulty. There was no further increase in the fire's size after May 2, resulting in a final area burned of 1620 ha.

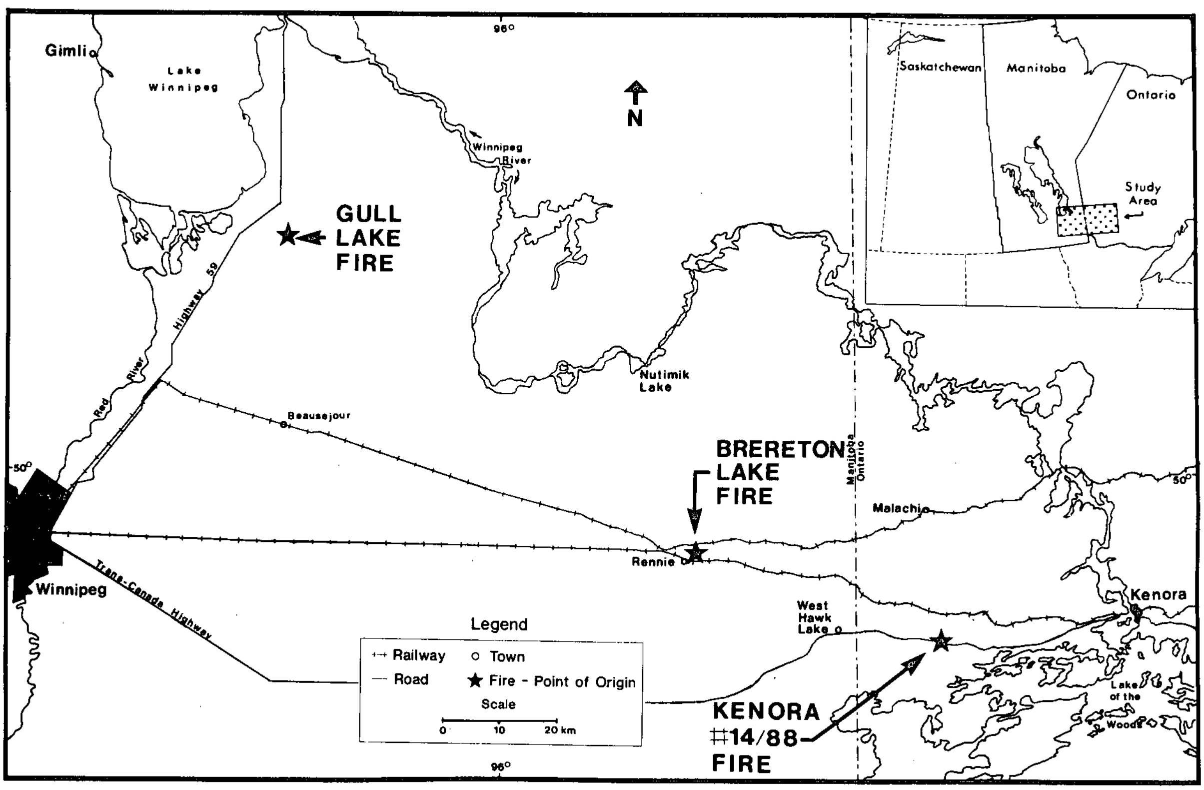

FIG. 1. Location of the Gull Lake, Brereton Lake and Kenora #14/88 Fires in southeastern Manitoba and northwestern Ontario.

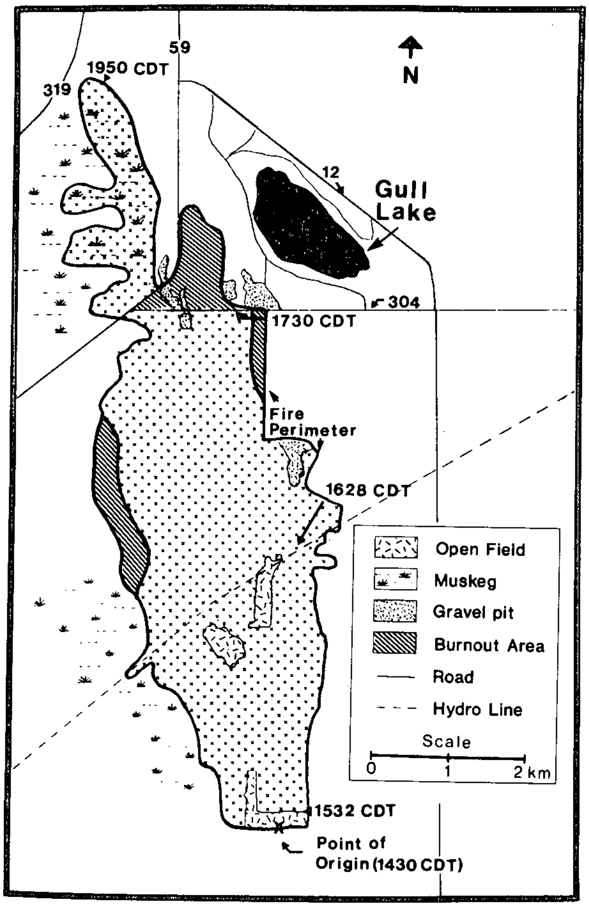

FIG. 2. Position of the head fire and final perimeter of the 1988 Gull Lake Fire in southeastern Manitoba.

BRERETON LAKE FIRE

The Brereton Lake Fire also started on May 1, 1988. A progress map of this man-caused fire is presented in Hirsch (1989). Its point of origin was near the town of Rennie along side the Canadian Pacific Railway (CPR) tracks approximately 120 km east of Winnipeg (Fig. 1). It was detected and reported at 1540 CDT at a size of less than 0.1 ha. The fire crowned almost immediately and began spreading northward towards the Brereton Lake cottage subdivision. By 1634 CDT the head fire had travelled 1.5 km and was approximately halfway to Brereton Lake. At 1753 CDT it crossed the Canadian National Railway (CNR) tracks near the cottage subdivision, 3.1 km from its point of origin.

By the evening of May 1 crews were able to secure a fireline completely around the fire using natural firebreaks and hand constructed fireguards. A major suppression effort on May 2, involving the use of three CL-215 airtankers, prevented any further flare-ups from occurring. The final area burned was estimated at 1300 ha. Five cottages and a number of smaller outbuildings were destroyed by the fire. It was also noted that the fire spread primarily on the jack pine ridges where it would frequently torch but did not spread continuously through the tree crowns. Fire spread in the black spruce (Picea mariana) stands was minimal due to the moist duff layer which was still frozen just below the ground's surface.

KENORA #14/88 FIRE

The Kenora #14/88 Fire was initially reported to the local OMNR office at 1330 CDT on April 30, 1988. This fire was also man-caused and it was located just north of the Trans-Canada Highway approximately 30 km west of the town of Kenora (Figs.1 and 3). The

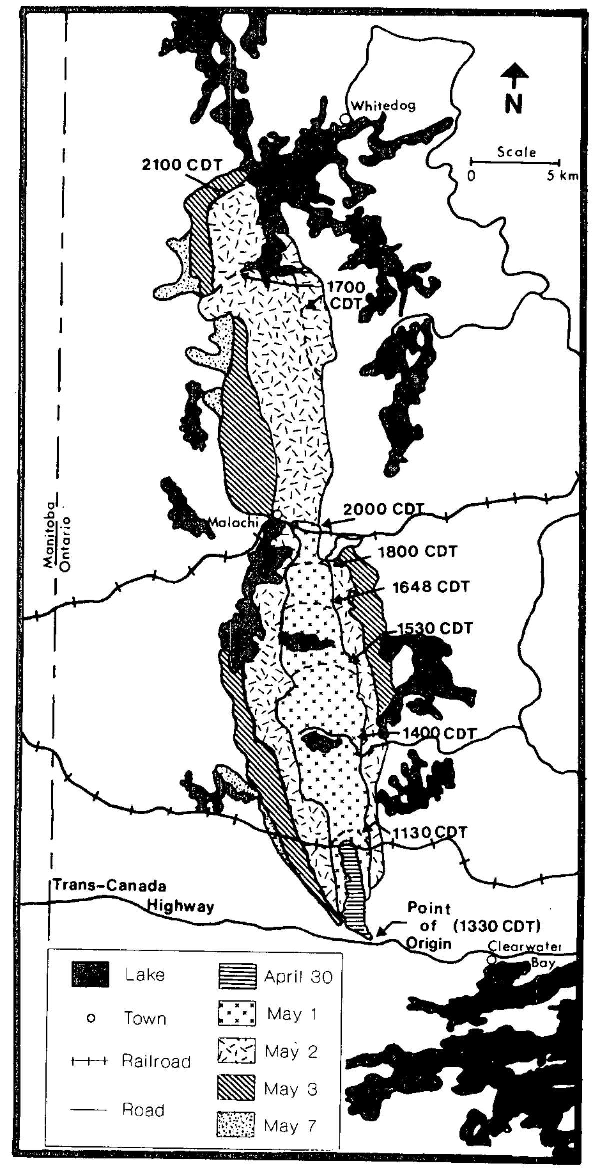

FIG. 3. Major fire runs and final perimeter of the Kenora #14/88 Fire in northwestern Ontario.

first suppression crew arrived at 1405 CDT and immediately asked for a second crew to be dispatched. By 1421 CDT the fire was estimated to be 2.0 ha in size and at 1545 CDT was reported to be "running". A birddog officer stated at 1548 CDT that a spot fire had developed 300 m west of the main fire and that the suppression efforts of the two crews and one CL-215 were not sufficient to hold the fire. At 1620 CDT the fire was estimated to be 140 ha in size and reached 500 ha by 1830 CDT when it was mapped by the fire behavior officer assigned to the overhead team.

At 0945 CDT on May 1 the fire had burned 798 ha and priority was given to protecting the cottage subdivisions in the area. By 1400 CDT the head fire had moved northward 6.0 km and crossed a secondary highway. It continued to spread northward and by 2000 CDT had travelled another 10.5 km at which time it crossed the CNR tracks by the hamlet of Malachi placing this subdivision in serious danger of being overrun by the fire.

On May 2, continued dry windy weather pushed the fire northward for another major run of almost 19 km. On-site observations made that afternoon indicated a consistent head fire rate of spread of 20 m/min with multiple torching and spot fires up to 500 m. Maximum flame heights during the major torching episodes reached 80 m.

The northerly spread of the fire diminshed on May 3 as the fire reached an area of high, well-exposed open bedrock with a sparse covering of jack pine. A fuel type change to predominantly overmature hardwoods along the northwestern flank also slowed the fire spread considerably. A change in weather resulted in no major fire growth on May 4-6 however, a few small outbreaks did occur on the northwest flank on May 7 after which no further expansion in the fire's perimeter occurred. When declared out, the fire was approximately 43.5 km in length and 9.0 in breadth at its widest point. The final size of the fire was estimated to be 22 700 ha.

Fuels

The area where these three fires occurred is located at the western edge of the Great Lakes-St. Lawerence forest region and the southern limit of the boreal forest (Rowe 1972). The Brereton Lake and Kenora #14/88 fire areas are characterized by sparsely stocked stands of jack pine situated on pre-cambrian "rock ridges". The soils and organic mantels on these upland sites are shallow and dry very quickly after snowmelt, negating within days any effect of overwinter precipitation (Stocks and Flannigan 1987). Surface vegetation consists of grasses and small shrubs. A fairly continuous layer of ground lichen is present but dead-down woody fuels are light in most areas. Interspersed amongst these jack pine stands are well-stocked stands of lowland black spruce underlaid by a thick layer of feathermoss with only a few shurbs and little downed woody fuel. The Gull Lake Fire area was dominated by moderately-well stocked stands of semi-mature jack pine with occasional pockets of trembling aspen (Populus tremulodies). Surface fuels consisted of a heavier grass layer (estimated to be 2-3 t/ha) along with shrubs such as willows, and wild rose. Roundwood fuels were also light in this area.

The FBP System presently has 14 major fuel types (Lawson et al. 1985, De Groot 1987, Hirsch 1988b) of which two are Mature Jack Pine (C-3) and Immature Jack Pine (C-4). The Gull Lake Fire area is classified as fuel type C-4 while the Brereton Lake and Kenora #14/88 Fire areas are considered fuel type C-3.

Topography

The elevations of the Gull Lake, Brereton Lake and Kenora #14/88 Fire areas are 245 m, 330 m, and 365 m above mean sea level (MSL), respectively. The terrain is gently rolling and there are no sustained slopes or significant changes in elevation.

Antecedent Climatic Conditions

The fall of 1987 was unusually warm and dry in southeastern Manitoba and northwestern Ontario (Fig. 4). From September to December 1987 precipitation levels were 68, 62 and 56 percent of normal (Anonymous 1982) at the Atmospheric Environment Service (AES) weather stations in Gimli, Winnipeg and Kenora, respectively (Anonymous 1977). This trend continued from January to April 1988 except for the month of March when a heavy snowfall did occur, especially in the Kenora area. Monthly mean daily temperatures for the same three stations averaged 8.8°C above normal from September to December 1987 and 3.1°C above normal from January to April 1988.

Given this area is susceptible to rapid drying in the spring, the effect of overwinter precipitation is often not as critical as the weather which occurs after snowmelt. In April 1988 temperatures were slightly above normal temperatures but, more significantly, it was a very dry month (Table 1). Low amounts of precipitation and relative humidity (RH) values below 40% occurred on numerous days. These conditions resulted in a rapid depletion of the snow pack and a steady reduction in the moisture content of the forest fuels.

Attendant Weather Conditions

From April 26 to May 1 an upper level ridge began to build over the fire areas causing a continuous rise in surface temperatures. By May 1 this ridge was centered north of Lake Superior (Fig. 5) with a surface low and cold front positioned just west of the fire areas (Fig. 6). Figure 7 shows the movement of the surface cold front and how it was blocked by the upper ridge in central Manitoba. It also illustrates that along with the sharp temperature gradient that existed across this cold front, there were strong southerly winds just ahead of it. The vertical wind profile from interna-

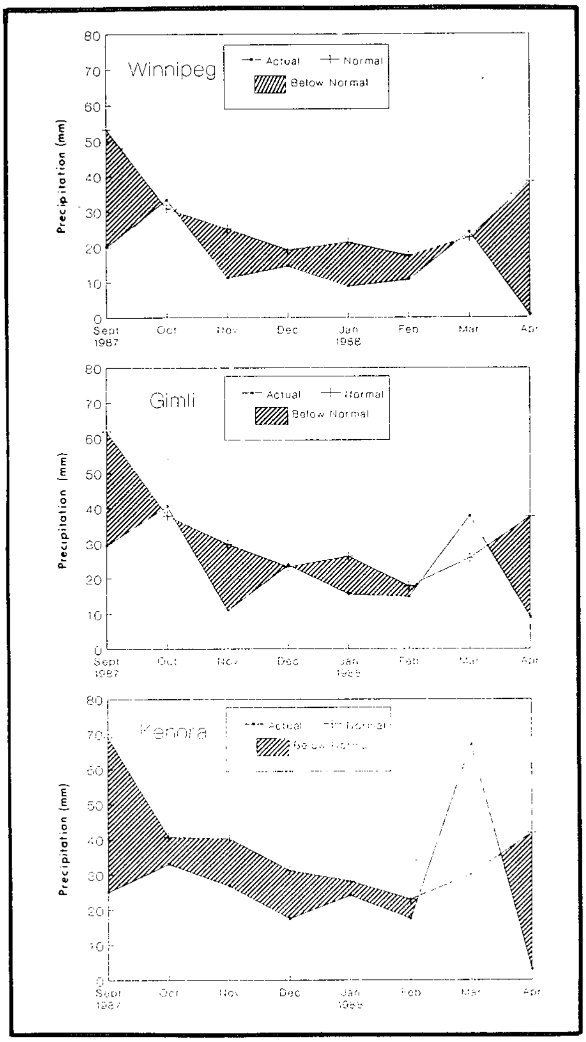

FIG. 4. Departure from the 1951-80 normal monthly precipitation amounts at three climatological stations in central Canada from September 1987 to April 1988.

Table 1. Climatological data for three meteorological stations in central Canada for April 1988 compared to the 1951-80 normals (where available).

Parameter	Winnipeg, MB		Gimli, MB		Kenora, ON	
	Actual	Normal	Actual	Normal	Actual	Normal
Precipitation (mm)	0.8	38.5	9.0	37.6	3.0	41.9
Daily temperatures (°C)						
Maximum	13.5	8.9	9.4	6.6	10.0	7.8
Minimum	-3.4	-2.2	-2.6	-4.0	-2.0	-2.5
Mean	5.1	3.4	3.4	1.3	4.0	2.7
No. of days RH ≤ 40%	23	n/a	10	n/a	22	n/a
Date of snow-free cover	04/02	04/11	04/08	04/20	04/09	04/26

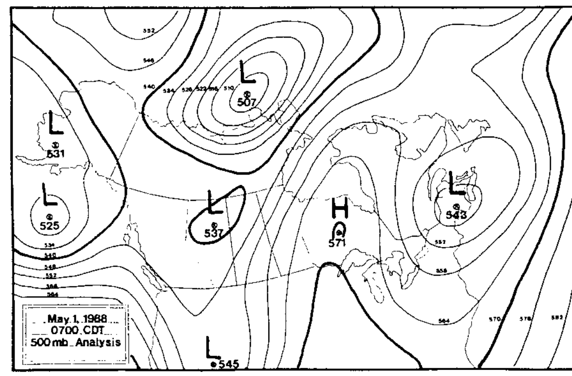

FIG. 5. 500 mb or 50 kPa chart for May 1, 1988, 0700 CDT.

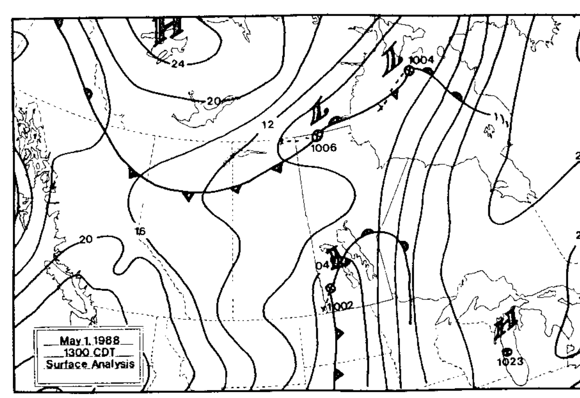

FIG. 6. Surface weather analysis for May 1, 1988, 1300 CDT.

tional Falls, Minnesota, on May 1, at 0900 CDT (Fig. 8), indicates that a low-level jet wind (Byram 1954, Alexander et al. 1983) was also present with the maximum velocity "point" located at 1220 m above the surface. Similar wind profiles also existed on April 30 and May 2. These strong surface and lower atmospheric winds were undoubtedly the major contributing factor to the rapid spread rates on all three fires.

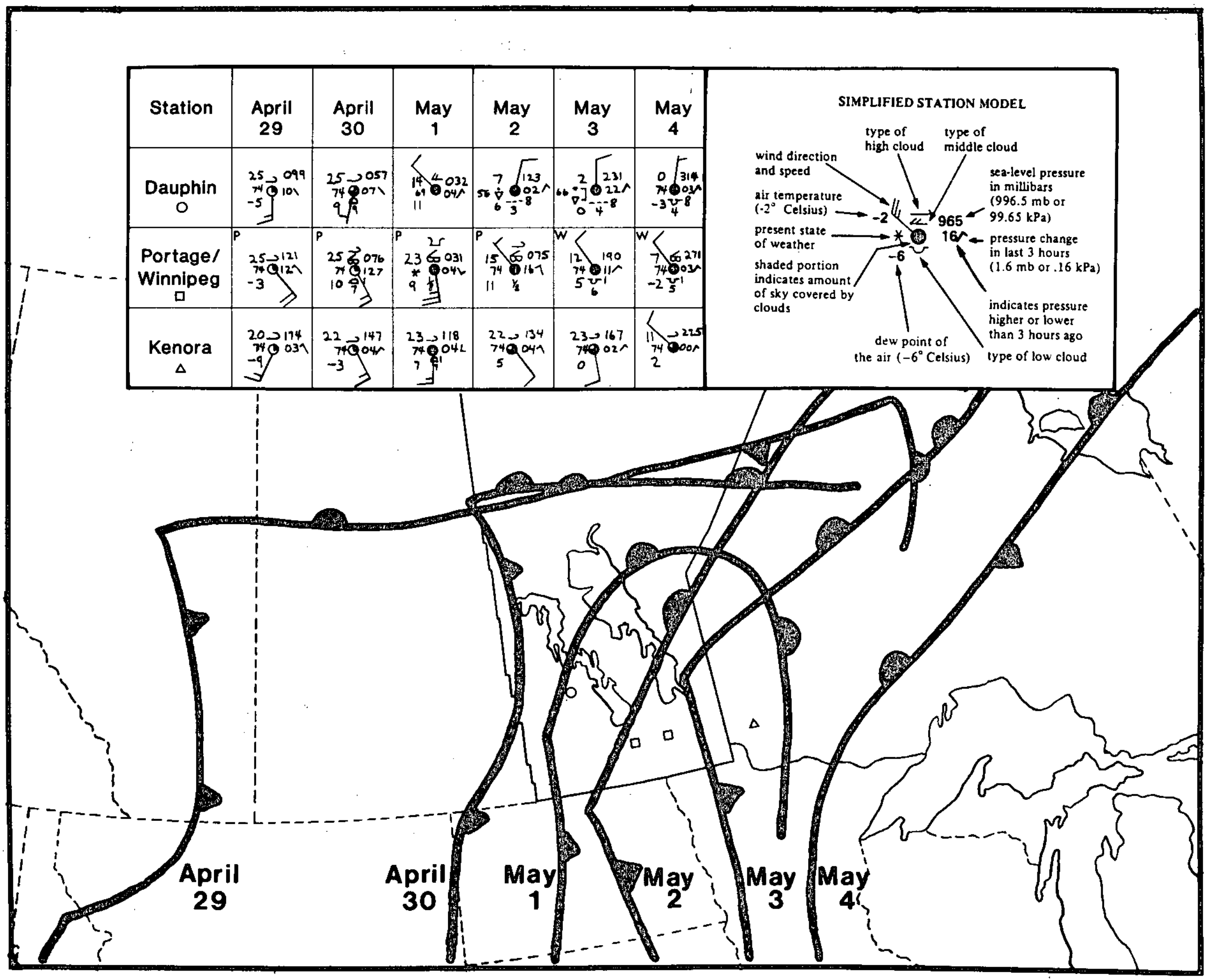

FIG. 7. The 1300 CDT location of surface frontal systems in west-central Canada from April 29 to May 4, 1988. Surface weather information for three stations is also denoted.

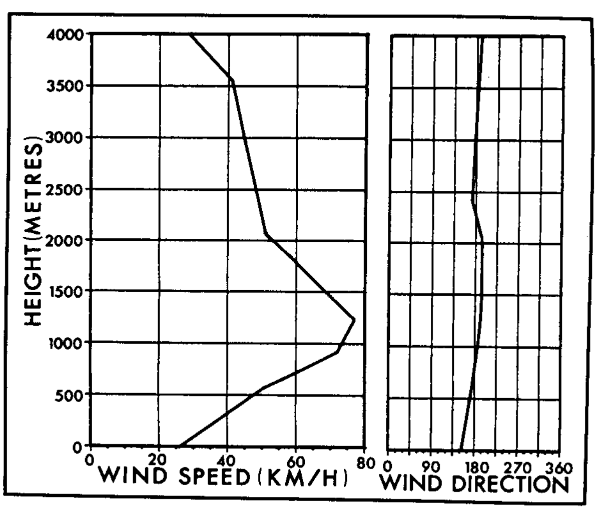

FIG. 8. Vertical wind profile above International Falls, MN, on May 1, 1988, 0900 CDT.

Ironically, while wildfires were burning out of control and destroying homes in eastern Manitoba the western section of the province was experiencing severe flooding. This was due to heavy rainfalls from the surface low which had settled directly over this area. This sharp and dramatic contrast in precipitation is exemplified by the fact that Swan River received 70.4 mm of precipitation from April 29 to May 3 while Portage la Prairie and Sprague (approximately 200 and 400 km eastward) received 9.4 mm and nil precipitation, respectively.

Fire Danger Indexes

The 1300 CDT fire weather observations and the calculated Canadian Forest Fire Weather Index (FWI) System values (Canadian Forestry Service 1984, Van Wagner and Pickett 1985, Van Wagner 1987) for each of the days with major runs are given in Table 2. A number of points are noteworthy. First, the Fine Fuel Moisture Code (FFMC) on the days the fires started

Table 2. Fire weather observations and fire danger indexes at 1300 CDT on the days of major fire runs at the Gull Lake, Brereton Lake and Kenora #14/88 Fires.

Calender date (1988)	(°C)	Dry-bulb temp. (%)	RH (km/h)	10-m open wind Speed Direction	FWI System components FFMC	DMC	DC	ISI	BUI	FWI
Gull Lake[a]										
May 1	20.4	43	24.0	SE	90.1	25	137	14.5	34	23
Brereton Lake[b]										
May 1	22.5	40	27.5	SE	91.0	40	260	20.9	58	39
Kenora #14/88[c]										
April 30	22.3	20	31.0	SE	94.8	32	61	40.4	32	45
May 1	23.2	35	31.0	SE	92.6	36	67	29.5	36	39
May 2	22.3	33	22.0	E	92.4	40	74	18.4	40	30

[a]Observations from the AES station at Gimli, MB (222 m MSL) located 40 km northwest of the Gull Lake Fire area (Fig. 1).

[b]Observations from the West Hawk Lake, MB (331 m MSL) and Nutimik Lake, MB (302 m MSL) fire weather stations were averaged to obtain these values. These stations are operated by MNR and are located 30 km southeast and north of the Brereton Lake Fire area, respectively (Fig. 1).

[c]Observations from the AES station at Kenora, ON (411 m MSL), located 30 km east of the Kenora #14/88 Fire area (Fig 1).

were all above 90 which implies a high ignition potential, especially for man-caused fires. Second, the high wind speeds resulted in extreme Initial Spread Index (ISI) values and, in turn, high Fire Weather Index (FWI) values. This indicates that the fire's rate of spread would be rapid and that it would be the major factor contributing to a very intense fire. Third, the Duff Moisture Code (DMC), Drought (DC) and the Buildup Index (BUI) values were relatively low meaning fuel consumption would probably be restricted to the fine fuels and that there would be little mop-up difficulty.

Fire Behavior Characteristics

FORWARD RATE OF SPREAD

The FBP System permits the calculation of head fire rate of spread (ROS) based on the ISI, fuel type and ground slope (McAlpine 1987). For each of the major fire runs, an ISI value was determined on the basis of the hourly weather observations at the nearest AES meteorological station and a diurnal FFMC value (Alexander 1982). These computed ISI values are presented in Table 3 along with a comparison of the calculated and observed head fire rates of spread. The results show that for the fire runs at the Brereton Lake Fire and on May 1 at the Kenora #14/88 Fire the ROS values are very similar with only an 11% and 14% difference. However, the actual spread rates for the Gull Lake Fire run and the May 2 run of the Kenora #14/88 Fire were underestimated considerably by the FBP System while the April 30 run of the Kenora #14/88 Fire was overestimated.

A variety of factors may cause discrepencies between the actual and calculated head fire ROS values. This includes variations in fuel type, spatial differences in weather conditions, or the influence of upper level winds on the fire, to mention only a few. To emphasize this point, a second set of FBP System calculations were made for the overestimated and underestimated fire runs using alternative wind speed observations (Table 4). It is interesting to note that in this second comparison the variation between the actual and predicted spread rates is substantially smaller. The implications of this are three-fold. First, in some instances it may not be appropriate to use the observations from the weather station closest to a particular wildfire because they are not representative of conditions at the fire area. Second, even though hourly information is available from AES meteorological stations the present network does not provide the coverage required to consistently make site specific fire behavior predictions. Third, the "noon" fire weather observations and fire danger indexes recorded at provincial fire weather stations can only serve as a general guide to potential fire behavior because timely observations during peak burning periods are often not available. Thus, the only way to ensure reliable fire behavior predictions is to accurately measure the input parameters, and especially wind speed, at or very near the fire site on a near-real time basis.

Table 3. A comparison of the actual versus predicted forward rate of spread (ROS) for the major fire runs of the Gull Lake, Brereton Lake and Kenora #14/88 Fires based on the ISI values determined from the wind speed observations taken at the nearest AES weather station.

Calender date (1988)	Local time (CDT)	FBPS fuel type	10-m wind[a] (km/h)	Hourly ISI	Predicted ROS (m/min)	Predicted Distance (m)	Actual ROS (m/min)	Actual Distance (m)
Gull Lake Fire								
May 1	1532-1628	C-4	30[b]	16.8	27.4	1 532	57.7	3 000
	1628-1730	C-4	28[b]	17.8	29.2	1 808	54.8	3 400
						3 340		6 400
Brereton Lake Fire								
May 1	1540-1753	C-3	30[c]	22.4	25.8	3 431	23.3	3 100
Kenora #14/88 Fire								
April 30	1545-2000	C-3	25[d]	26.6	34.9	8 902	21.6	5 500
May 1	1130-1400	C-3	33[d]	26.1	33.8	5 073	38.3	5 750
	1400-1530	C-3	31[d]	27.2	36.2	3 259	38.8	3 500
	1530-1648	C-3	32[d]	28.6	39.3	3 062	41.6	3 250
	1648-1800	C-3	23[d]	19.8	20.1	1 449	34.7	2 500
	1800-2000	C-3	20[d]	15.6	12.0	1 443	13.3	1 600
						14 286		16 550
May 2	0900-1700	C-3	25[d]	15.1	11.1	5 328	30.2	14 500
	1700-2100	C-3	18[d]	12.3	6.7	1 600	17.7	4 250
						6 928		18 750

[a]Wind speed observations are averaged over a 2-minute period.

[b]Observations from the AES station at Gimli, MB (222 m MSL) located 40 km northwest of the Gull Lake Fire area (Fig. 1).

[c]Based on on-site estimates by suppression personnel and substantiated by observations at the AES stations at Kenora, ON (75 km east; 411 m MSL), Winnipeg, MB (120 km west; 239 m MSL), and Sprague, MB (90 km south; 329 m MSL).

[d]Observations from the AES station at Kenora, ON (411 m MSL), located 30 km east of the Kenora #14/88 Fire area (Fig 1).

Table 4. A comparison of the actual versus predicted forward rate of spread (ROS) for selected major fire runs of the Gull Lake and Kenora #14/88 Fires based on the ISI values determined from wind speed observations taken at AES weather stations near the fire areas.

Calender date (1988)	Local time (CDT)	FBPS fuel type	10-m wind[a] (km/h)	Hourly ISI	Predicted ROS (m/min)	Predicted Distance (m)	Actual ROS (m/min)	Actual Distance (m)
Gull Lake Fire								
May 1	1532-1628	C-4	48[b]	41.7	64.9	3 635	53.6	3 000
	1628-1730	C-4	45[b]	42.0	65.2	4 045	54.8	3 400
						7 680		6 400
Kenora #14/88 Fire								
April 30	1545-2000	C-3	19[c]	19.6	19.9	5 067	21.6	5 500
May 2	0900-1700	C-3	32[d]	21.5	23.8	11 424	30.2	14 500
	1700-2100	C-3	22[d]	15.0	10.9	2 622	17.7	4 250
						14 046		18 750

[a]Wind speed observations are averaged over a 2-minute period.

[b]Observations from the AES station at Winnipeg, MB (239 m MSL) located 75 km southwest of the Gull Lake Fire area (Fig. 1).

[c]Observations from the AES station at Sprague, MB (329 m MSL) located 95 km southwest of the Kenora #14/88 Fire area.

[d]Based on observations from the AES station at Kenora, ON (30 km east; 411 m MSL) of the mean a value of the 2-minute average wind speed and the maximum gust during the same time period.

FRONTAL FIRE INTENSITY

On the basis of the BUI and hourly ISI components of the FWI System, the major runs can be placed into Fire Intensity Class 5 for the jack pine fuel type (Alexander and De Groot 1988). This intensity class has the following characteristics:

"Intermittent crown fire to active crown fire development (at > 10,000 kW/m). Very difficult to control. Suppression must be restricted to the fire's flanks. Indirect attack with aerial ignition (i.e., helitorch and/or A.I.D. dispenser) may be effective. Violent physical behavior probable at frontal fire intensities > 30,000 kW/m (i.e., blow-up or conflagration type fire run); suppression action should not be attempted until burning conditions ameliorate".

Certainly this description was very indicative of the general fire behavior and the relative effectiveness of the various types of suppression activities during all of the major fire runs.

Concluding Remarks

The prediction of forest fire behavior has often been referred to as both a science and an art. Case studies such as this one only seem to reinforce this point. Unique weather phenomena and variations in fuels and topography will never allow any fire behavior predictions to be 100% correct. However, the potential for error can be reduced significantly if predictions are based on accurate and timely, on-site fire weather observations. Furthermore, as more quantitative information is collected on large, well-documented wildfires such as the Gull Lake, Brereton Lake and Kenora #14/88 Fires, the more exacting the FBP System will become in forecasting extreme fire behavior. Ultimately, this greater understanding of fire behavior will contribute to the development of fire management programs which are, in turn, efficient and cost-effective.

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Endnotes

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