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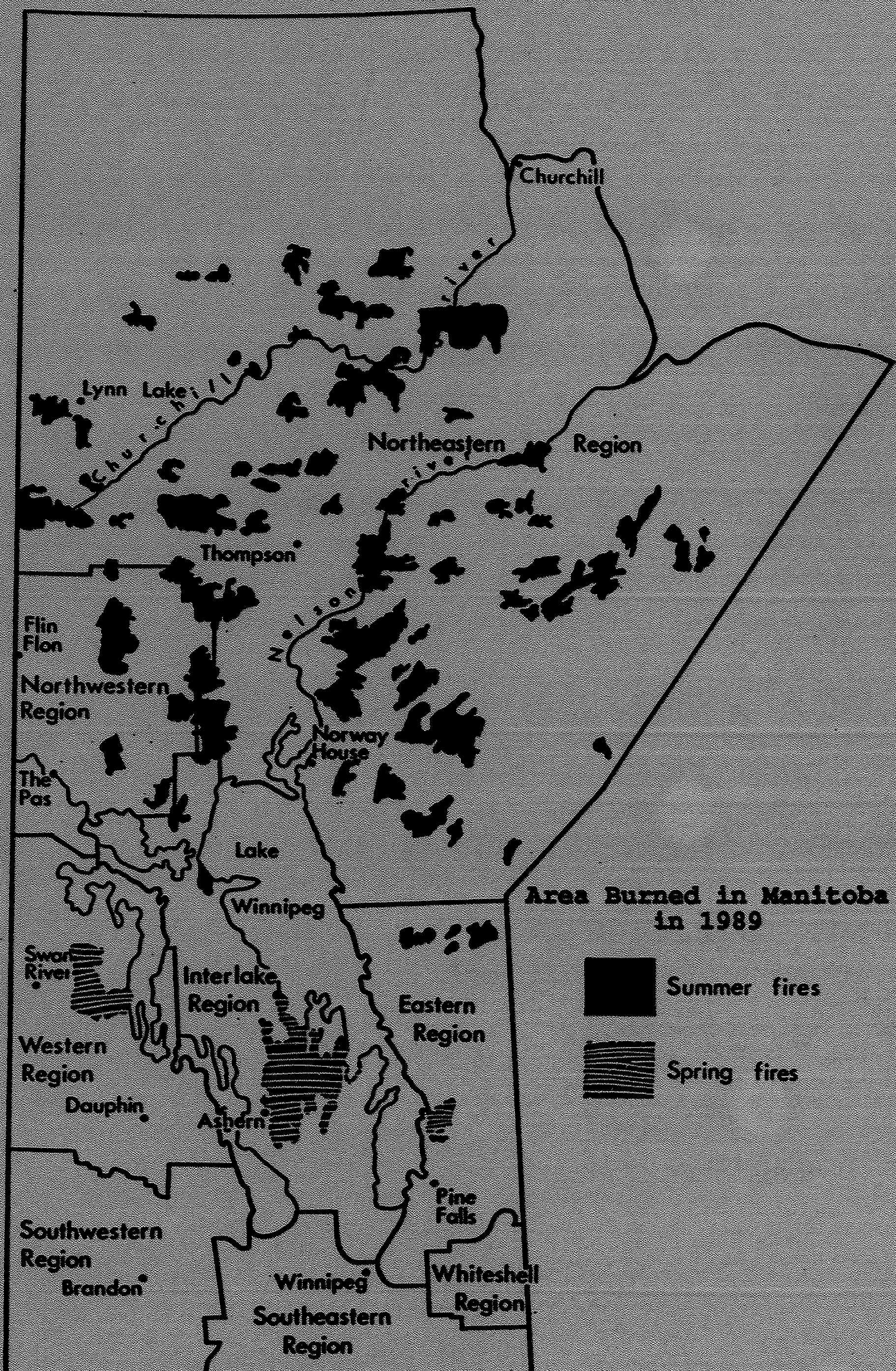
PROCEEDINGS OF THE SIXTH CENTRAL REGION FIRE WEATHER COMMITTEE

SCIENTIFIC AND TECHNICAL SEMINAR - April 6, 1989, Winnipeg, Manitoba



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April 4, 1989
Winnipeg, Manitoba

Compiled and Edited

by

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CONTENTS

Front Cover: Area burned in Manitoba during the 1989 fire season by fires greater than 5000 ha in size. Data compilation by Gilbert Daudet (Manitoba Natural Resources) and final figure preparation by Dennis Lee (Northern Forestry Centre).

FOREWORD

The 1975 Federal Department of the Environment (DOE) Policy on Meteorological Services for Forest Fire Control sets out the responsibilities of the Atmospheric Environment Service (AES) and Forestry Canada (formerly the Canadian Forestry Service) in provision of fire weather forecasts, fire danger forecasts, and other weather-related services to the various fire control agencies in Canada. Briefly, this policy gives AES the responsibility of providing current and forecast fire weather and fire danger indexes in accordance with the needs of fire control agencies. The Forestry Canada role is that of research and development of improved fire weather indices, research on fire behavior relationships with weather factors, and cooperation with AES in preparation of training aids and manuals. Both AES and Forestry Canada share the responsibility of improving meteorological services for fire control in Canada.

In 1976, six regional committees were formed to facilitate the implementation of the DOE Policy on Meteorological Services for Forest Fire Control. These committees were aligned on the basis of the existing AES administrative boundaries, namely: Pacific (British Columbia); Western (Yukon, Northwest Territories, and Alberta); Central (Saskatchewan, Manitoba and northwestern Ontario); Ontario; Quebec and Atlantic (Nova Scotia, New Brunswick, Newfoundland and Prince Edward Island). The original "charter" for these regional fire weather committees was stated as follows.

<u>Membership</u>: 1 or more AES representatives designated by AES Regional Director; 1 or more Forestry Canada representatives designated by Forestry Canada Regional Director; and 1 or more fire management agency representatives designated by the provincial or territorial chief(s) of forest fire management.

<u>Terms of Reference</u>: Each Regional Committee will make recommendations to the Regional Directors of DOE Services (i.e., AES and Forestry Canada) for the development and implementation of a program of Meteorological Services for Forest Fire Control which is suited to the needs of the Region and is within the DOE Policy and Guidelines.

<u>Guidelines</u>: Regional Committees will be responsible for:

(a) identifying the needs of regional fire management agencies for meteorological services;

(b) making recommendations of the services identified in sub-section (a);

(c) monitoring the program and implementing changes, as required;

(d) coordinating with the Development Committee; and

(e) referring to the Development Committee the recommendations that the Regional Directors of DOE Services have been unable to implement.

The function of the Development Committee referred to above is to coordinate, in consultation with the Regional Committees, the development of meteorological services for forest fire management. This is to be done through contacts at the technical level between representatives of the fire management agencies and research and development officers of AES and Forestry Canada as well as operational supervisors in the AES field establishments.

It is also worth noting that the original DOE policy as established in 1976 is currently under review. In recent years AES, and to some extent Forestry Canada, have begun to review the fire weather related services they provide to the fire management agencies in Canada. This has resulted from a number of changes in internal policy (such as cost recovery of "non-essential" services by AES) and has necessitated the development of an offical policy on Meteorological Services for Forest Fire Management. Such a policy is expected to be completed in the near future.

INTRODUCTION

The Central Region Fire Weather Committee (CRFWC) currently holds two meetings each year. Annual business meetings, which started in 1976, are usually held between the months of November and January while the Technical Sub-Committee, formed in 1983, meets each April. CRFWC member agencies currently include:

- Atmospheric Environment Service, Prairie Region,
- Canadian Parks Service, Prairie and Northern Region,
- Forestry Canada, Northwest Region,
- Manitoba Natural Resources,
- Ontario Ministry of Natural Resources (Sub-Committee participants only), and
- Saskatchewan Department of Renewable Resources.

In conjunction with the Technical Sub-Committee meeting, which has always been held in Winnipeg, a half-day Scientific and Technical Seminar is conducted. The purpose of these seminars is to "provide opportunity for the presentation and discussion of scientific and technical papers on subjects relating to forest fire meteorology in the region". Normally 4 or 5 presentations are made at each seminar and though the topics have been very diverse, attempts have always been made to obtain a balance in the program between fire and meteorological oriented subjects as well as between operational and research topics. A listing of the presentations from the previous five seminars is given at the back of this document.

This report provides a summary of three of the four presentations made at the sixth seminar. The information and findings in these papers are interesting and thought provoking and may have potential benefits for both forest meteorologists and fire managers. If detailed information is required on any of the papers in this report, the reader is encouraged to contact the author(s) directly. Please note that a fourth presentation given by Don McIver of the Atmospheric Environment Service (Downsview, Ontario) entitled, *The Greenhouse Effect: Implications for Fire Management* was unfortunately not available for publication in this proceedings.

The CRFWC seminar series has proven to be an excellent forum for the exchange of information and ideas on current and/or timely fire weather related topics. It has attempted to enhance the operational programs of the member agencies of the CRFWC and its future success will continue to rely on the direct and indirect support provided by each agency.

The sixth seminar was supported financially by AES - Prairie Region and Forestry Canada - Manitoba District Office. The cooperation of Dale Henry (Chief, Weather Services - AES) and John McQueen (District Manager - Forestry Canada) in obtaining this funding was appreciated. The assistance of D. Vandevyvere and R. Raddatz of AES with the local arrangements is also gratefully acknowledged. Finally, a special word of thanks is extended to all of the presenters for participating in this seminar and making it a success.

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CRFWC Seminar Coordinator

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ATMOSPHERIC STABILITY AND WIND CONDITIONS ALOFT CONDUCTIVE TO EXTREME FOREST FIRE BEHAVIOR[1]

by

E.R. Reinelt[2]

Abstract

Forest fire behavior is markedly influenced not only by ambient surface conditions of wind, temperature and humidity, but also by air-mass stability, temperature and moisture distribution aloft, low-level jet winds and related atmospheric conditions, such as vertical wind shear, to heights of about 3000 metres.

The wind-profile classification devised by Byram in 1954 provides a useful measure of the effect of upper winds and wind shear on forest fires. Moreover, temperature and moisture conditions aloft may be combined into a single atmospheric variable related to stability, the so-called wet bulb potential temperature. It is suggested that a simple code figure descriptive of wind shear, and a stability index based on the wetbulb potential temperature be used in combination with (or as an addition to) the Canadian Forest Fire Weather Index (FWI) System.

Introduction

The influence of synoptic weather conditions on the development of extreme forest fire behavior, especially the effect of slowly changing weather patterns on temperature, relative humidity, wind and atmospheric stability, has been documented by many authors. However, to date, not all of these weather elements have been fully incorporated into the Canadian Forest Fire Weather Index (FWI) System (Van Wagner 1987, Van Wagner and Pickett 1985). For instance, atmospheric stability, which may enhance or suppress convective activity is not included. Of even greater importance to the evolution of a forest fire may be the presence of low-level jet winds and the vertical wind profile, as described by Byram (1954). It appears that jet winds and the induced vertical wind shears may be critical to the incidence and severity of blow-up fires. A wind profile that may significantly alter forest fire behavior is one containing a layer of high-speed wind close to the surface, a feature commonly referred to as a low-level jet-stream (LLJ). Such

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[1] Summary of a presentation made at the Sixth Central Region Fire Weather Committee Scientific and Technical Seminar, April 4, 1989, Winnipeg, Manitoba.

[2] Professor Emeritus, University of Alberta, Department of Geography, Division of Meteorology, Edmonton, Alberta, T6G 2H4.

jet winds are fairly common features of the lowest layers of the atmosphere, most often confined to the surface boundary layer, say the lowest 1000 metres. LLJs are frequently associated with fast-moving cold fronts and some may be subject to modification by topographic features, such as wind gaps, valleys and ridges. However, most LLJs are probably independent of the nature of the underlying surface and are the result of dynamic causes such as convergence, strong thermal gradients and fronts.

Low-Level Jet Winds in the Context of Byram's Wind Profiles

Byram (1954) distinguished and classified ten upper wind profiles, of which five contain jet winds of different shapes and core speeds. He recognized jet winds as being significant in causing problematic fire behavior such as blow-ups, spotting and similar hazards. Byram's classification of upper wind profiles is shown in the ten plots of Figures 1 and 2. Arranged in decreasing order of importance, winds having Type 1-a profile are claimed to be most troublesome and severe, whereas winds of Type 4-b and 4-c are of little concern. It should be pointed out, however, that it is not the jet per se that is responsible for increasing the fire danger, but rather that portion of the profile where the wind decreases with height. A wind (V) decreasing with height (z) is said to have a cyclonic (or negative) wind shear, i.e., $\partial V/\partial z < 0$. This is important in that a cyclonic shear has "vorticity", a physical property which tends to produce rotation of the air about a horizontal axis in such a way as to favour updrafts and hence the formation and maintenance of convection columns.

The likely effect on two fires of an upper wind distribution containing a jet is suggested in Figure 3. It will be noted that the fire below the jet core will be relatively safe, since it is burning in a region having anticyclonic or positive shear, i.e., the wind increases with height. On the other hand, the second fire on the higher ground, is likely to go out of control since it is located in a zone of cyclonic wind shear and thus, subject to vortex motion favouring the generation of updrafts and the formation of a strong convection column. Hence, as can be seen on the sketch, fires burning on higher and exposed ground are more susceptible to being affected by jet winds, than fires on low-lying and flat terrain. Exceptions are the two rare wind profiles of Type 1, where the decrease of wind with height begins within the lowest few metres of the surface.

"False Jet Wind" Profiles

What have come to be known as "false jet winds" are the result of inadequate upper wind measurement techniques. The commonly-used Single Theodolite Pilot Balloon (STPIBAL) observations may be misleading and should be treated with caution, especially if taken under turbulent, unstable atmospheric conditions, such as may prevail on hot, thundery afternoons.

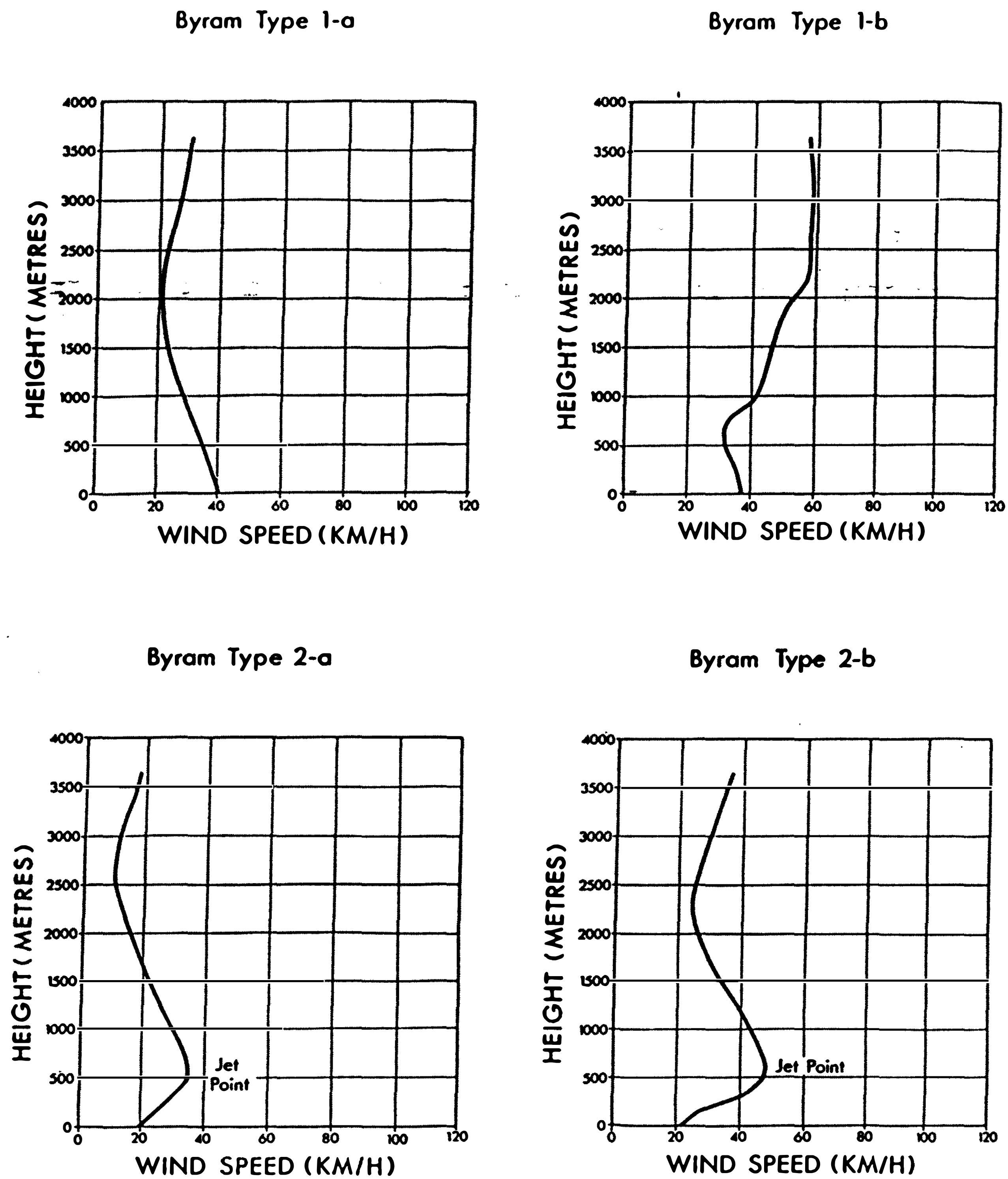

FIGURE 1: Byram Wind Profiles of Type 1 and 2

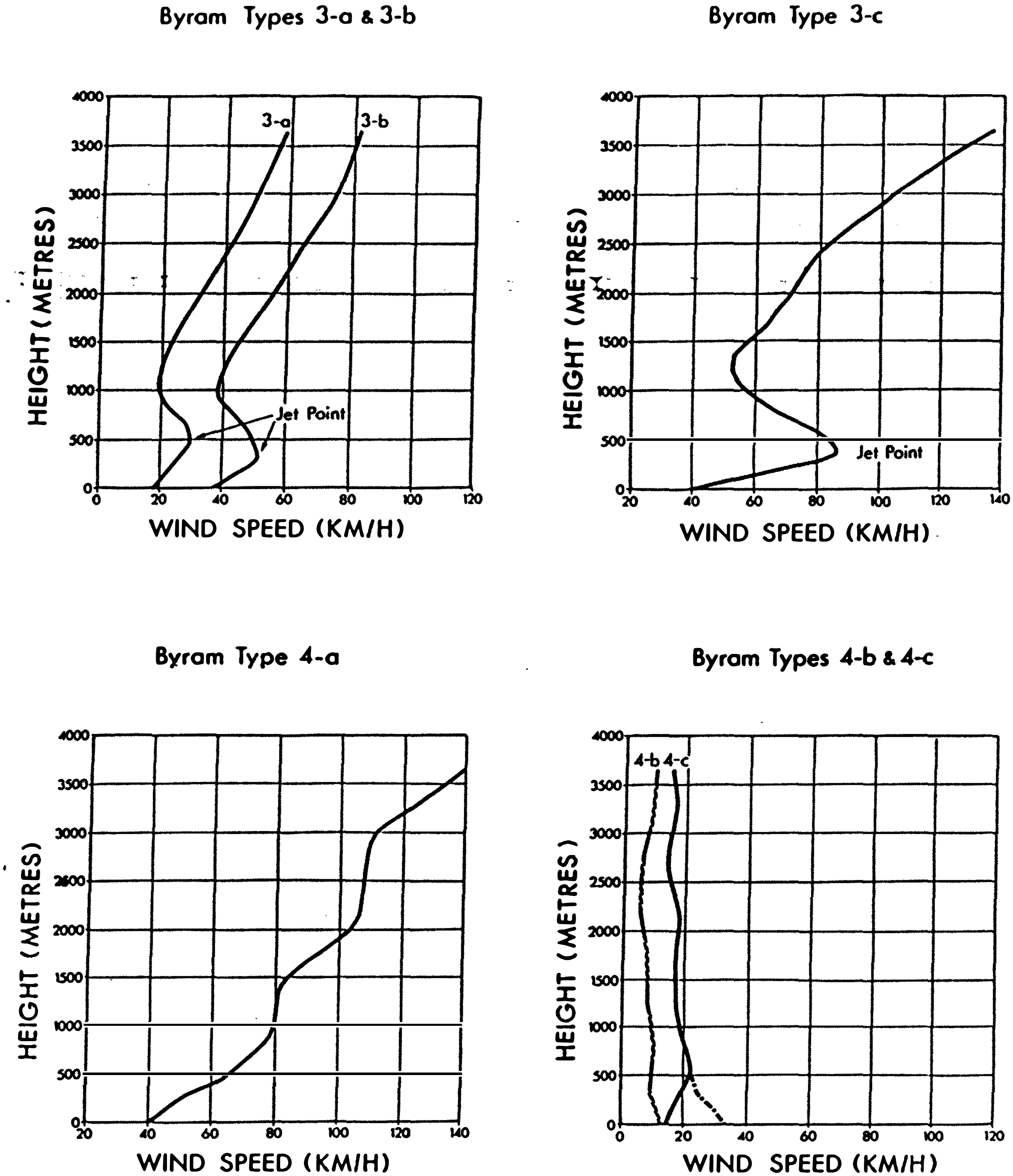

FIGURE 2: Byram Wind Profiles of Type 3 and 4

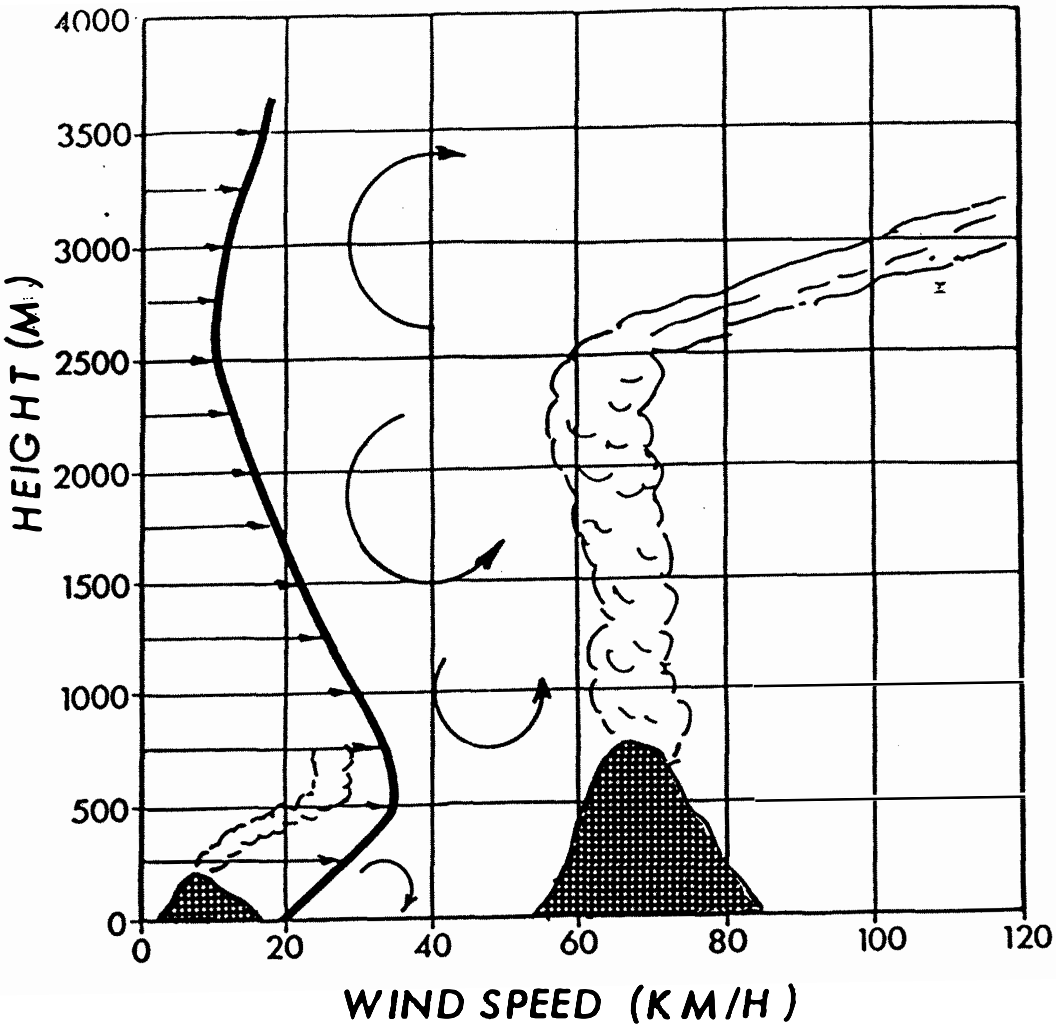

FIGURE 3: The Effect of Wind Shear on the Intensity of Forest Fires (See Text).

The errors result from the action of convection currants on the rising balloon. Thus for example, a strong downdraft in the lowest few hundred metres will prevent the balloon from rising at its normal rate, leading to a fictitiously high wind speed report as the balloon is carried downwind at a diminished rate of ascent. If, subsequently, the balloon should enter an updraft, its now increased rate of ascent will be interpreted erroneously as a lower wind speed. Therefore, a balloon ascending through consecutive layers of subsiding the rising air will be recorded as having encountered a jet wind.

The problem of "false jet winds" may be avoided by the use of Two- or Double-Theodolite balloon tracking, but this method is not currently employed in routine PIBAL observations. Of course, regular radiosonde observation procedures are much less subject to such tracking errors.

Distribution and Frequency of LLJ Winds

Analysis of some 20 years of radiosonde and PIBAL data pertinent to the Western and Northern Canada has revealed that about 10 % of the wind profiles have shapes similar to Byram's ten principal types, but without matching them precisely level for level. If the selection is limited to profiles with surface wind speeds equal to Byram's speeds, then the percentage drops to less than 3 %. Considering the relative rarity of LLJ winds and their narrow band structure, the chances of any one fire coming under the influence of a jet is estimated to be less than 0.5 % for small fires that can be extinguished or controlled within three days. The odds increase to about 2 % for campaign fires lasting a week. In any event, any cold front approaching a fire is suspect, since it may produce convergence and generate a low-level jet.

Locating LLJs and similar problem profiles will require careful observation and judicious forecasting, especially of cold fronts and zones of air-mass convergence. These features can usually be detected and appreciated to best advantage on 850-mb contour charts and on stream-line charts, respectively. Fire weather forecasters are urged to give special attention to the 850-mb level, especially when assessing the fire potential on high ground (e.g., the east slopes, Swan Hills, Cypress Hills, etc.) since the higher ground is at or close to the height of the 850-mb surface ($\simeq$ 1500 m). This circumstance makes these charts more representative of the actual fire potential at higher elevations than the conventional sea-level isobar chart.

Atmospheric Stability and Convection

It has long been known that air-mass stability may enhance or suppress convective activity and the vertical motion of the air making it an important factor to be considered by the fire weather forecaster. The stability condition of the air can be expressed in numerous ways by means of stability indices. Useful summaries are given by Sackiw (1986) and by Peppler (1988). Some indices such as the Showalter Index are very simple and easy to use, whereas others are quite complicated and not always soundly based on theory, but deduced empirically, and frequently applicable only to local or highly restricted situations. Moreover, current stability indices available to forecasters and fire managers are those designed for assessing and predicting the development of convective cloud, thunderstorms and tornadoes.

To date, no stability index has been designed specifically for forecasting fire-weather conditions. Of those readily available, only the Lifted Index (LI) will be mentioned, since it is routinely calculated and distributed by The Atmospheric Environment Service (AES) on its facsimile circuits in the form of isopleths plotted on maps. This index, based on the "parcel" method, may be useful as a guide to prevailing and predicted stability conditions. It is obtained by lifting a parcel of air from the surface layer first dry-adiabatically until saturation is reached, and then pseudo-adiabatically to the 500-mb level. The difference between the temperature T_5 environment and that of the lifted parcel T_x is the Lifted Index.

< 1 > $$LI = T_5(°C) - T_x(°C)$$

A negative index denotes a convectively unstable atmosphere, near-zero values indicate quasi-neutral conditions, and positive indices a stable atmosphere.

An index for general use in fire weather forecasting should be soundly based on thermodynamics, and yet be easy to calculate and use. Having considered many different indices described in the literature, it appears that none fully serves the needs of the fire manager. It is proposed, therefore, that a new index be introduced and tested under field conditions during the fire season.

The index, to be known as the THETA Index, is defined as the difference between the pseudo-adiabatic potential temperatures at the 700-mb level and the surface, i.e.

< 2 > $$THETA = \theta W_7 - \theta W_o$$

This index has the advantage in that it is a conservative property of the air mass, includes a measure of the temperature and the moisture distribution of the lowest 3000 metres of the atmosphere, and provides a ready appreciation of the shape of the ascent curve as determined by a radiosonde.

Typical ascent curves for air masses commonly found in Western Canada in the summer are shown plotted on the tephigram in Figure

4. It will be noted that the curves closely follow the shape of the pseudo-adiabatic (or wet-bulb) potential temperature θw) lines for moist, saturated air. From warmest on the right to coolest on the left, the plot shows maritime tropical air (mT), maritime polar (mP), maritime arctic (mA) and (cmA), a colder variety of maritime arctic air.

Air masses with temperature profiles similar to a given θw curve will be potentially unstable, if near saturation. Ascent curves that depart from neighbouring θw curves (such that the upper part of the ascent has higher θw values than the lower) near surface θw will indicate a stable atmosphere. The larger the (positive) difference between the upper and lower levels the more stable the atmosphere. If, on the other hand, the upper-level θw is lower than the surface θw, then the negative difference signals instability, in much the same way as the Lifted Index, LI.

In the strictest sense, the use of θw as a measure of stability applies only to the wet-bulb curve, rather than the dry-bulb ascent curve. When the air mass is saturated, the two curves coincide and, at any given level, the (dry-bulb) temperature T, the wet-bulb temperature Tw and the dewpoint Td are equal. When the air is not saturated, then the three temperatures are related through the inequalities

< 3 > $$Td < Tw < T$$

such that, on a tephigram plot, the wet-bulb curve will lie approximately halfway between the dewpoint curve and the temperature curve.

For most practical purposes the wet-bulb curve and the desired θw values may be obtained by a simple, graphical method on a tephigram. The procedure is demonstrated on the plot of Figure 5, a temperature ascent curve for Norman Wells. With the surface temperature and the dewpoint plotted on the surface isobar, a triangular area is traced out when the temperature is allowed to decrease along its dry adiabat, while the dewpoint is dropping and moving along its associated mixing ratio line. The required θw_o value is found at the point where the two lines intersect, namely at the apex of triangle. Similarly, the value of θw_7 may be obtained from the temperature and dewpoint at the 700-mb level. The actual, numerical values of θw are determined by reference to the numbering on the nearby θw curves.

In the example of Figure 5, for

T_o = 21.0°C and Td_o = 11.5°C (RH 71%) at the surface,

T_7 = -3.8°C and Td_7 = -18.0°C (RH 33%) at 700-mb,
We readily find

θw_o = 14.6°C and θw_7 = 9.0°C

whence THETA (θI) = 9.0°C - 14.6°C = -5.6°C.

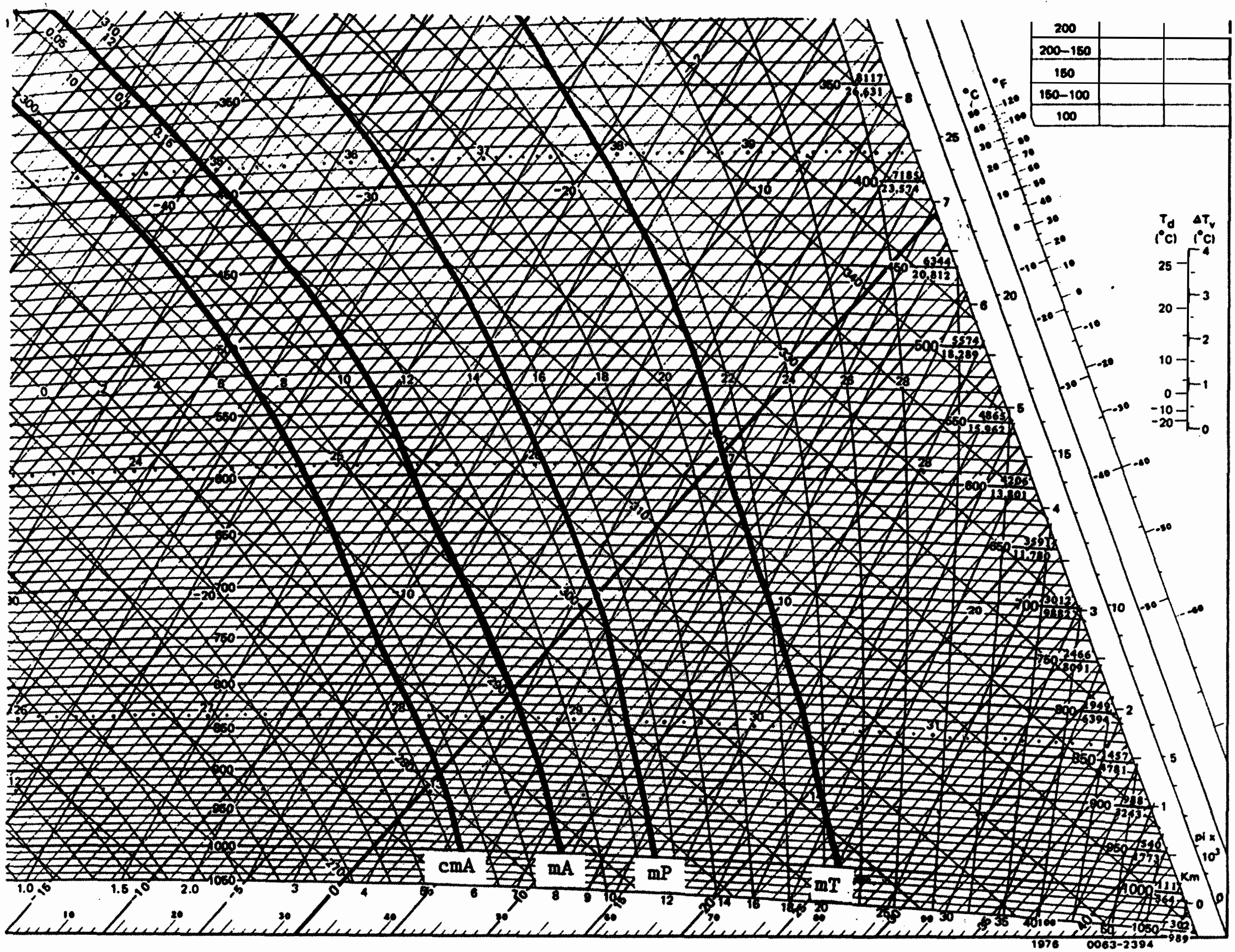

FIGURE 4: Ascent Curves of Typical Air Masses Found in Summer in Western Canada.

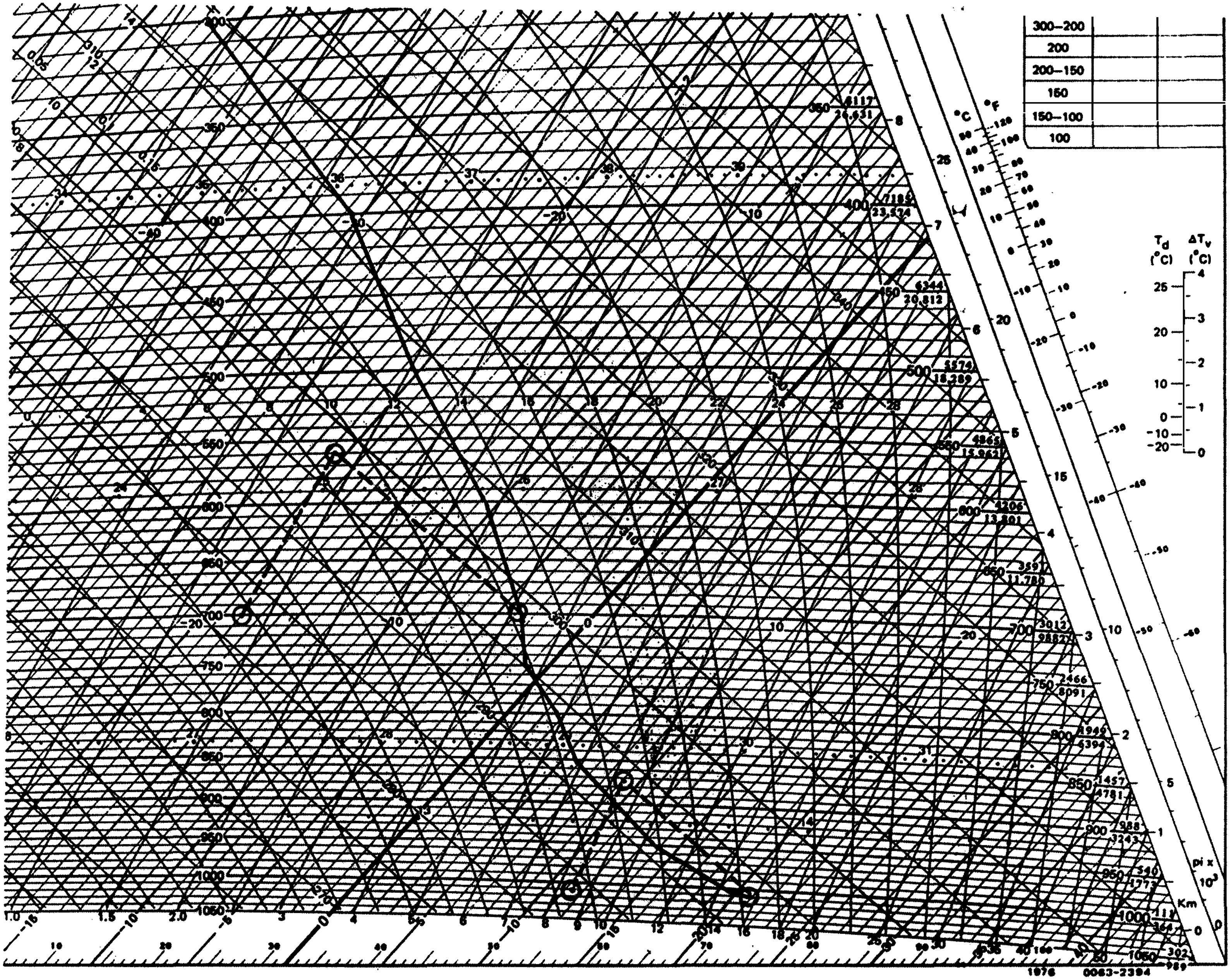

FIGURE 5: An Ascent Through an Unstable, Modified mA Air Mass, Norman Wells, NWT. 0000Z, 8 June 1964. A Graphical Method for Determining the Instability Index θI is indicated in the Diagram.

Since the index θI is negative, the air mass is unstable. Indeed, an index of -5.6°C denotes very unstable air. For the ascent of Figure 5, parcels of air from the surface layer could potentially rise to heights of some 8000 metres and lead to the formation of thunderstorms.

A surface-based inversion will usually result in a large positive θI, as would be expected with stable configurations of this kind. However, the large, positive θI values associated with fronts, though genuine, must be treated with circumspection, since dynamic action of the frontal surface may release instability. Moreover, a frontal passage may not only cause a marked shift in wind direction, but signal also the presence of a low-level jet, or some other unusual wind profile.

Though of considerable interest to the forecaster, it is obviously not necessary to plot the complete ascent curves if only the θ-Index is to be deduced from the radiosonde data. Given the temperatures and dewpoints (or RH) at the surface and at 700 mb, the θ-Index can be readily calculated also from the basic thermodynamic relationships for moist air.

Wind shear, Instability and the FWI System

Since any modification to the FWI System is a matter of concern to fire managers, and subject to sanction by the appropriate authorities of the Forestry Canada Fire Danger Working Group, only suggestions can be made at this stage as to how wind shear and instability might be incorporated in the FWI. In the absence of field testing and operational experience with a modified FWI, the proposals listed below must therefore considered to be tentative.

When reliable upper wind reports are available, they should be encoded as risk figures ranging from 10 to 1, in conformity with Byram's classification of profiles in decreasing importance to the spread of forest fires:

Type 1a	10	Type 1b	9
Type 2a	8	Type 2b	7
Type 3a	6	Type 3b	5
Type 3c	4	Type 4a	3
Type 4c	2	Type 4b	1

These figures should simply be added to the FWI computed in the prescribed manner, to indicate the added risk to fire management. Missing upper winds and wind profiles that do not fit this classification should be assigned a figure 0 and hence neglected, unless there are special reasons to consider a higher value.

When the atmosphere is unstable, the θ-Index will be negative, with values ranging from just below zero to about -8, for a highly unstable condition. If the θ-Index is to be added to the FWI, it is first necessary to drop the minus sign, i.e., its absolute value must be added to obtain a higher FWI. Initially at least, it may be desirable not to modify the FWI, but simply to use the wind and instability indices as separate indicators of increased fire hazard.

Acknowledgements

This paper is a summary of two chapters of a lengthy research report prepared for, and supported financially by Forestry Canada, under the terms of the Program for Research by Universities in Forestry (PRUF). I am much obliged to Mr. Marty Alexander of the Northern Forestry Centre, Edmonton, for introducing me to fire weather problems and for suggesting this topic to me. I am also pleased to thank Mr. Kelvin Hirsch, Fire Research Officer, Forestry Canada, and Mr. Dale Henry, Regional Director, AES Winnipeg, for giving me the opportunity to present this paper at the 6th Central Region Fire Weather Committee Scientific and Technical Seminar.

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ANALYSIS OF THE 1988 FIRE DANGER FORECASTS FOR ONTARIO[1,2]

by

R. Frech[3] and D. White[4]

Introduction

Daily forest fire weather forecasts are provided to the Ontario Ministry of Natural Resources (OMNR) by the Atmospheric Environment Service (AES) throughout the fire season. These forecasts are used to assess the fire environment and predict the potential for fire ignitions and the possible fire behavior in Ontario. Therefore, knowing the accuracy of the forecasts and understanding how this influences the predicted fire danger conditions is of great significance to the fire manager who must use forecasted information in presuppression and suppression planning.

The forecasted values of the Canadian Forest Fire Weather Index (FWI) System (Van Wagner 1987; Van Wagner and Pickett 1984) are one of the primary sources of information used to assess the fire danger conditions in a given area. The FWI System components[5] provide a numerical rating of relative fire potential in a standard fuel type (i.e., a mature pine stand) on level terrain (Merrill and Alexander 1987). They are based on consecutive observations of temperature, relative humidity (RH), wind speed and precipitation taken at 1300 Local Daylight Time (LDT). The purpose of this paper is to examine the accuracy of the forecasted FWI System values in Ontario during the 1988 fire season. A review of the 1988 forecasts in relation to the previous 2 years is also provided along with a

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[1] A presentation at the Sixth Central Region Fire Weather Committee Scientific and Technical Seminar, April 4, 1989, Winnipeg, Manitoba.

[2] This paper is an abbreviated version of a more comprehensive report entitled "Analysis of the 1988 AES Forest Fire Weather Forecasts for Ontario" by R. Frech and D. White, Ontario Ministry of Natural Resources, Aviation and Fire Management, October 31, 1989. AFMC Pub. No. 269.

[3] Fire Intelligence Technician, Ontario Ministry of Natural Resources, Aviation and Fire Management, P.O. Box 310, Sault Ste. Marie, Ontario, P6A 5L8.

[4] Fire Centre Manager, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario.

[5] The FWI System is comprised of three fuel moisture codes and three fire behavior indexes. The three moisture codes represent the moisture content of the fine fuels (Fine Fuel Moisture Code - FFMC), loosely compacted decomposing organic matter (Duff Moisture Code - DMC), and the deep layer of compact organic matter (Drought Code - DC). The three fire behavior indexes, which are derived from the moisture codes and the surface wind, indicate the rate of initial fire spread (Initial Spread Index - ISI), total available fuel (Buildup Index - BUI), and the intensity of a spreading fire (Fire Weather Index - FWI).

comparison of the forecasts issued by the Ontario Weather Centre (OWC) and the Prairie Weather Centre (PWC).

Methodology

By reviewing the daily AES weather reports, 23 hour (PM) and 5 hour (AM) forest fire weather forecasts were obtained for the 1988 fire season. The forecasts were entered into a data file that included the date, weather sector, wind direction, wind speed, temperature, RH and precipitation. Since the forecasts represent the expected weather at the centre of the sector, the OMNR primary weather station located closest to the centre of the sector was used to verify the forecast for that sector.

The sample of data used for this study began on April 21 and included every third day of the fire season. The first sample day for a given sector was the first day of the selected sample period that had a corresponding AM and PM forecast along with observed weather records. Each sample day thereafter was included in the sample population until either the OMNR station stopped recording observed weather or the AES forecasts ceased. If observed or forecast weather data was not available for a sample day, then that day was excluded from the study. Figure 1 delineates the boundaries of each weather sector, locates the primary weather stations used in this study, and also indicates which sectors were forecast by the Prairie Weather Centre (PWC) and the Ontario Weather Centre (OWC).

The forecasted components of the FWI System were calculated for each sample day using the previous day's actual values taken from the OMNR station used to represent that particular sector. A comparison between the actual FWI System values and those calculated using the forecasted fire weather observations were conducted for both the AM and PM forecasts. Note also that the forecasted wind speed as provided by AES are for airport winds but since OMNR stations record forest winds, it was necessary to convert the AES forecasts. This was done on the basis of Turner and Lawson (1978) who established that forest winds are approximately 60% of airport winds.

Acceptable forecast accuracy ranges have not been established for the FWI System components; the rationale being that a change of 2 or 3 in a value is relative depending on whether that index is in the low or extreme range (i.e., a change of 2 in the FFMC when it is at 67 is not the same as when it is at 89). Therefore, to check the accuracy, we compared the number of times a forecasted and actual index value fell into a particular danger rating class. That is, if the actual FWI value was high and the forecasted FWI value was high then the forecast was accurate. If the actual FFMC was low and the forecast FFMC was moderate then the forecast was high. Table 1 lists the Forest Fire Weather Index Classes used in Ontario.

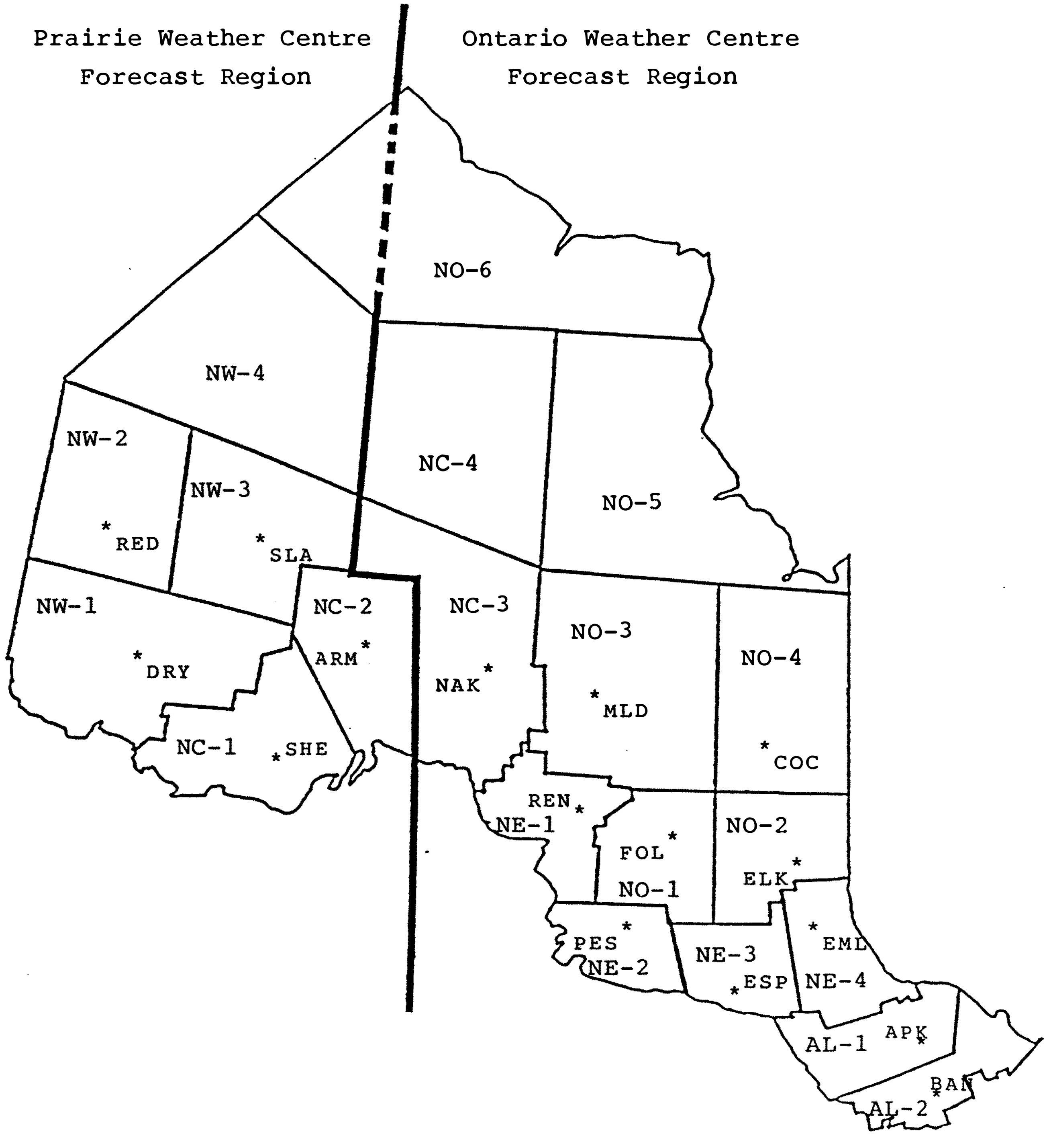


Figure 1. Weather sector boundaries and forecast regions for Ontario. Primary weather stations used in this study are indicated with an asterik.

Table 1. The Ontario Fire Danger Classes.

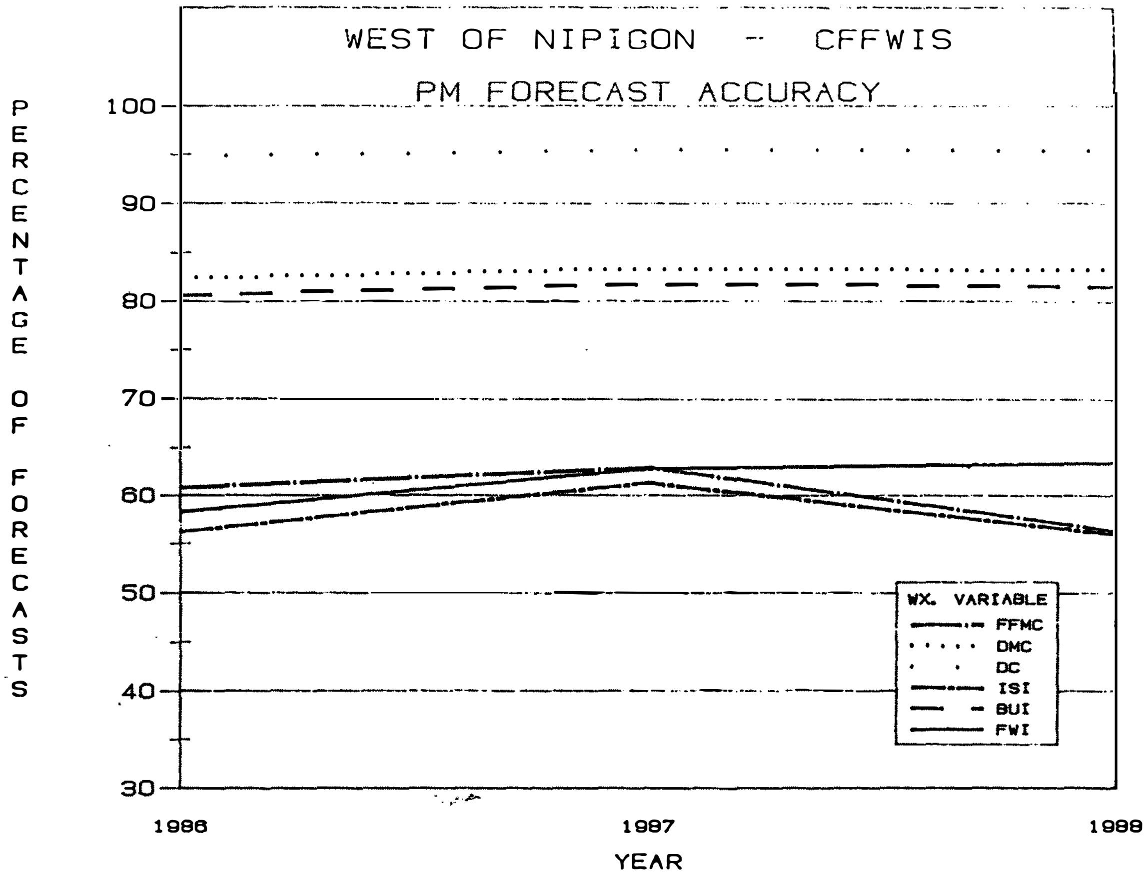
Fire danger class	FWI System Component					
	FFMC	DMC	DC	ISI	BUI	FWI
Low	0-80	0-15	0-140	0-2.2	0-20	0-3
Moderate	81-86	16-30	141-240	2.3-5.0	21-36	4-10
High	87-90	31-50	241-340	5.1-10.0	37-60	11-22
Extreme	91+	51+	341+	10.1+	61+	23+

Results

In Table 2, data for 1988 indicating the percentage of days on which the forecasted FWI System value was within the same danger class as the actual value is provided for both the PWC and the OWC. This information shows that for all indices the AM forecasts were more accurate than the PM forecasts and that the differences in forecast accuracy between the two weather centres were less than 5%. Furthermore, the FFMC, ISI and FWI had the lowest levels of accuracy for both the AM and PM forecasts and there was considerable variation in accuracy between sectors for a given index.

Figures 2 and 3 show a comparison of the 1988 forecasts to the two previous years for both weather centres. For the PM forecasts, accuracy levels for the DMC, DC and BUI have remained relatively constant over the three year study period. However the FFMC, ISI and BUI accuracy dropped 10% - 12% at the OWC while at the PWC these indices fell back to their 1986 levels of accuracy after a mild peak in 1987.

With respect to the AM forecasts, the DC values have remained constant for the three years at both weather centres. However, all the other indices have shown marked improvement in forecast accuracy between 1986 and 1988. It is suspected that part of the reason for this improvement is due to a change in the calculation of the AM precipitation forecast. The new approached used in 1988 calculated the AM forecast values by combining the AES AM forecast precipitation with the AM OMNR stations readings. This may have had significant benefit to the accuracy of some indices especially those which are most rain sensitive.



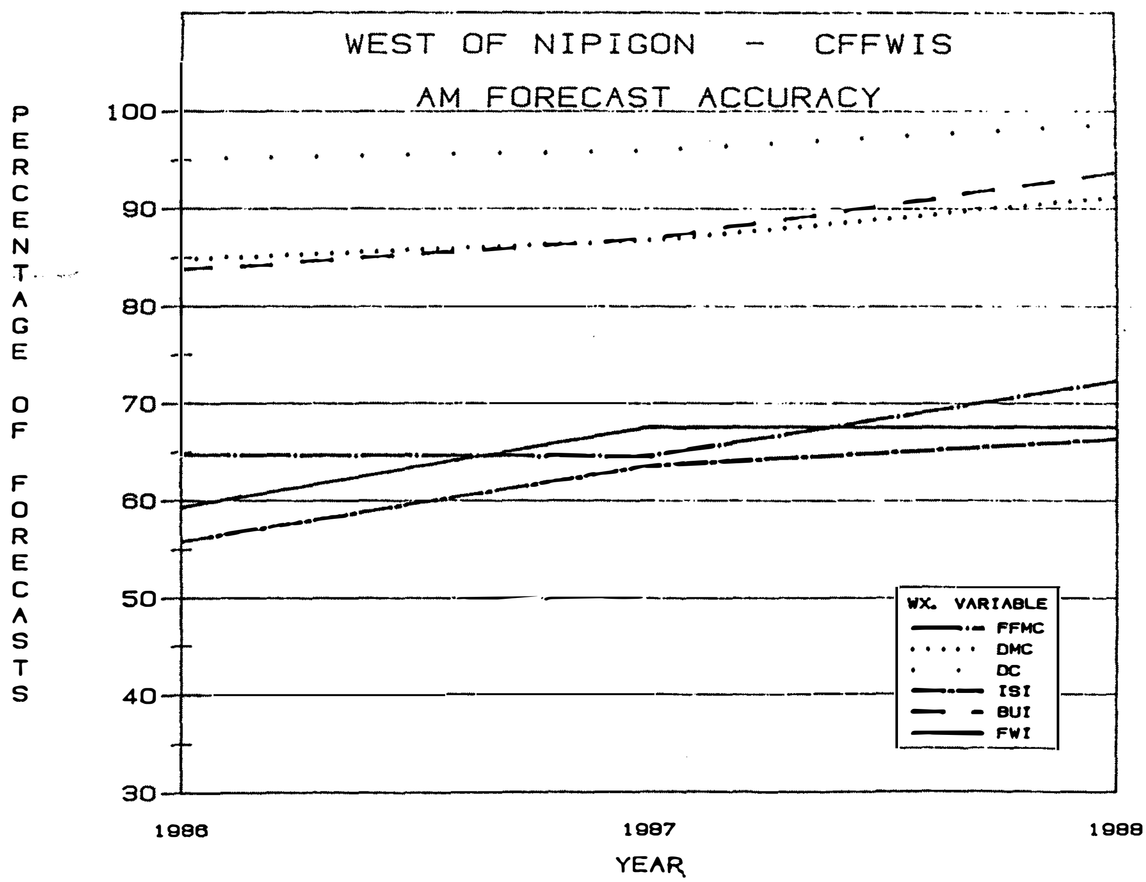
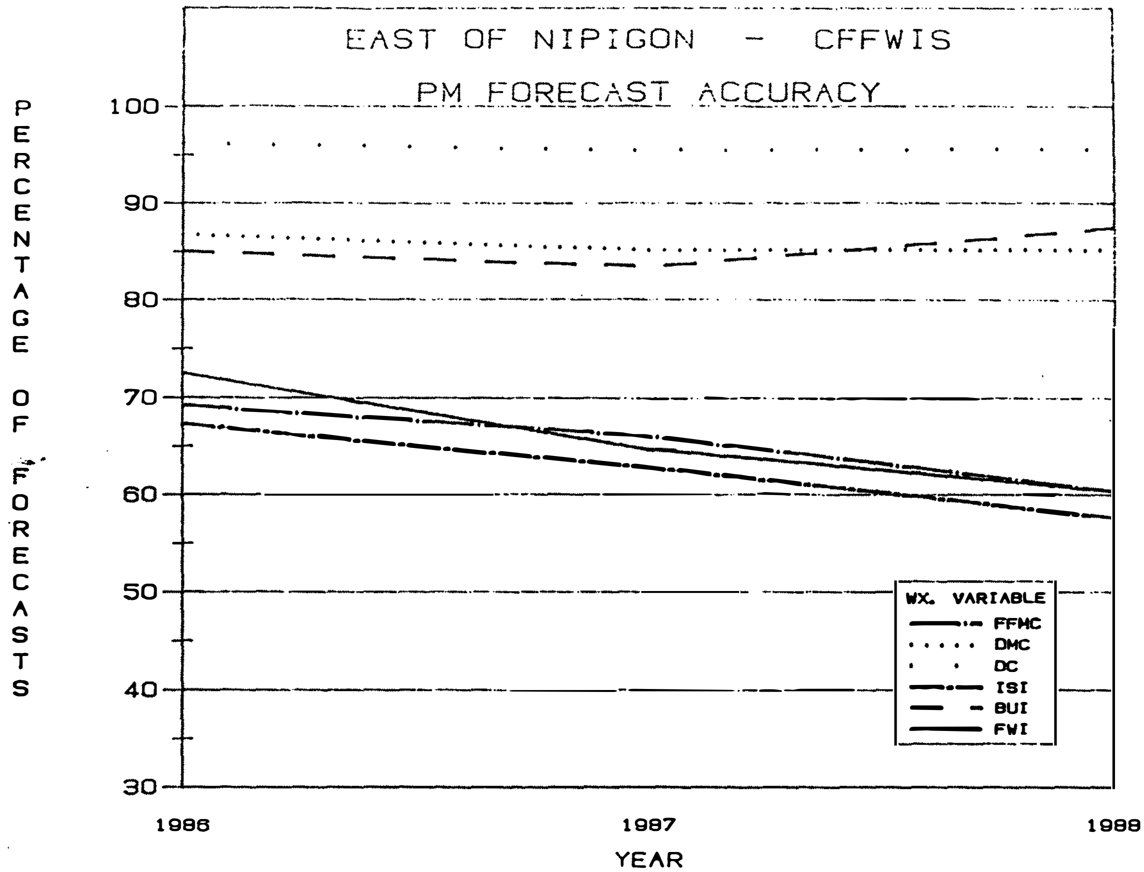


Figure 2. Percentage of accurate fire danger forecasts for northwestern Ontario from 1986 to 1988 as issued by the Prairie Weather Centre.



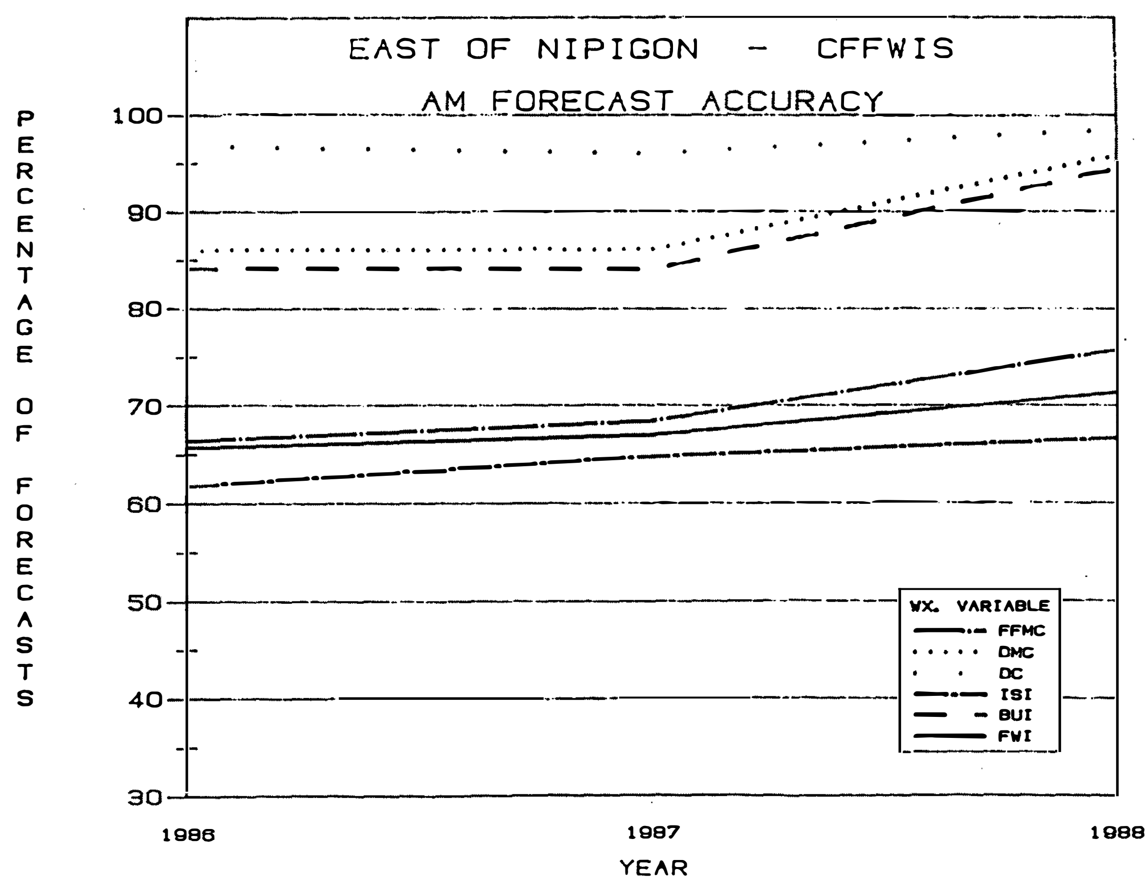


Figure 3. Percentage of accurate fire danger forecasts for northeastern and central Ontario from 1986 to 1988 as issued by the Ontario Weather Centre.

Table 2. The percentage of days in 1988 that the forecasted and actual FWI System values for Ontario were in the same fire danger class.

FWI System component	Prairie Weather Centre		Ontario Weather Centre	
	AM[1]	PM[2]	AM	PM
FFMC	72.3	56.3	75.7	60.3
DMC	91.2	83.2	95.8	85.2
DC	98.7	95.4	98.6	95.6
ISI	66.4	55.9	66.7	57.6
BUI	93.7	81.5	94.4	87.5
FWI	67.6	63.4	71.3	60.3

[1] AM refers to the morning or 5 hour forecast.
[2] PM refers to the afternoon or 17 hour forecast.

Concluding Remarks

Though this study has only looked at a few years of data, a number of interesting trends can be identified. First, both the OWC and the PWC are relatively equal in their ability to forecast the fire danger levels of the FWI System components. Second, the FFMC, ISI and FWI have the lowest forecast accuracy probably due to the sensitivity of these indices to wind speed and RH which are the most difficult parameters to forecast. Third, there has been an improvement in AM forecast accuracy in 1988 likely because of a change in how the forecast precipitation is calculated. Finally, given that the forecast accuracy has not changed dramatically over the 3 year study period the fire manager must accept that there are limitations in the accuracy of the fire weather forecasts. Understanding these limitations and when they occur is therefore a significant factor for fire managers to consider in their daily presuppression and suppression planning process.

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DEVELOPMENT OF SASKATCHEWAN'S FIRE SUPPRESSION PREPAREDNESS SYSTEM[1]

by

W.J. De Groot[2]

Introduction

Historically, the major portion of annual forest fire losses is attributed to relatively few fires. In Saskatchewan, this was most evident during the 1987 and 1988 fire seasons. Even though both these years set new records for fire starts (980 and 1064 respectively), only a few fires each year accounted for over 90% of the area burned in the primary protection zone. The suppression costs alone for some of these "campaign" fires was over $3 million each. Following the devastating fire seasons of 1987 and 1988, the Forest Fire Management Branch (FFMB) of Saskatchewan Parks, Recreation and Culture (SPRC) initiated the development of a fire suppression preparedness system. The purpose of this system was to reduce the total number of campaign fires through enhanced initial attack capabilities.

The primary concept of a preparedness system is to reduce total fire costs (and area burned) by using a portion of campaign fire costs to increase initial attack resource levels during critical burning periods. The preparedness system provides decision-aid tools for matching resource levels to fire danger conditions on a daily basis. Using this manning-up procedure, together with forecast fire danger conditions, fire management operations are better able to prepare for fire problems. As previous experience has shown, a successful fire management program must anticipate rather than react to serious fire situations.

Preparedness System Requirements and Standards

The objective of this preparedness system is to match fire suppression capabilities to fire danger conditions. The Canadian Forest Fire Danger Rating System (CFFDRS) is used as a tool to quantify fire danger and determine suppression needs. The CFFDRS allows fire managers to predict these needs in advance, but it

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[1] A presentation made at the Sixth Central Region Fire Weather Committee Scientific and Technical Seminar, April 4, 1989, Winnipeg, Man.

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requires forecasted fire weather information. As well, it requires information regarding fuel type and topographic situation. In turn, the CFFDRS provides information regarding expected fire behavior which is used to determine resource requirements.

This initial version of the Preparedness System was developed without fuel or topography data bases being available. This means that the areal extent of expected fire behavior is not known to the fire manager. Therefore, this initial version requires two assumptions to be made concerning the forest fuel type and topography conditions.

The first assumption requires a standard fuel type(s) be selected on which to base the system. On one hand, a preparedness system should provide the ability to prepare for the most serious situations. Therefore, a worst case scenario should be developed by choosing the most volatile fuel type. On the other hand, the system should also be representative of major provincial fuel types. Choosing a fuel type with the highest rate of spread would cause over-preparedness during the majority of the fire season if this same fuel type was not the most representative of the province. This Preparedness System is based on the fire behavior associated with two fuel types in order to strike a compromise. The C-2 (Boreal Spruce) fuel type of the Canadian Forest Fire Behavior Prediction (FBP) System (a subsystem of the CFFDRS) was selected because it is representative of fuel types in the province, and because it exhibits high rates of fire spread and fire intensity (allowing preparedness for the more extreme situations). The C-3 (Mature Pine) FBP System fuel type was selected as well because it also is a major component of the provincial forests.

Note that use of a computerized fuel type data base allows the fire manager to estimate the fire danger conditions occurring in any particular fuel type (based on areal extent and distribution). Although this removes the assumption of a standard fuel type for the system, it requires the same assumption to be made later on in the decision-making process (where it is made with better information): which fuel type should be prepared for?

The second assumption concerns the specification of a standard topographic situation. Any number of slope and aspect combinations are possible. However, because forested land in Saskatchewan is generally rolling, gently rolling or flat, a standard slope of 0% was selected. This can be justified because the effect of minor relief changes are usually negligible on fire behavior.

Weather information is the third and most critical requirement for determining fire behavior (and preparedness levels). Forecast weather is provided by the Weather Section of the FFMB. Although there are no 'standard' weather conditions (as with fuel type and topography), this System uses a minimum wind speed of 15 km/h, and zero rainfall for isolated showers. The reasons for this are discussed later in the "Operational Considerations" section.

Escaped Fire Causes

In order to decide initial attack requirements, the reasons for an unsuccessful initial attack need to be examined. A review of previous campaign fires results in two general causes of an initial attack failure: extreme burning conditions and/or multiple fire starts.

Regarding extreme burning conditions, there are two physical reasons[3] for a fire to escape:

1. Rate of spread (ROS) is too fast for initial attack resources to keep up with.

2. Head fire intensity (HFI) is too great for initial attack resources to be effective.

It is a commonly known fact that the time it takes to make an initial attack is critical for success. Figure 1 illustrates this using ROS and HFI. This figure shows the upper limits, or thresholds, of suppression capabilities for the two major initial attack resources: helitack crews and air tankers. Once a fire starts, it accelerates in both ROS and HFI until it reaches a steady state level. Using this information, it is possible to determine the amount of time that initial attack has to be successful.

Multiple fire start situations, on the other hand, usually result in escaped fires because there is an insufficient amount of initial attack resources. This can be overcome by augmenting initial attack crews with auxiliary or extra firefighters. In the case where extreme burning conditions exist during multiple fire starts, initial attack time is reduced by increasing the number of active initial attack bases (because of extreme burning conditions), and the auxiliary firefighter resource levels available to each initial attack base are also increased (because of multiple fire starts).

This Preparedness System uses burning conditions to determine initial attack time (and consequently, the number of initial attack bases); and fire start information (or probabilities) to determine auxiliary firefighter resource levels available at each initial attack base.

Initial Attack Time

Determination of initial attack time is based on the fire's maximum ROS and HFI, and the time it takes to accelerate to that

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[3] Note that a fire does not escape because it is big. A large fire size is the result of an escaped fire; it is not considered the cause of a fire escape.

level. The maximum level can be predicted (Alexander et al 1984), but the acceleration phase can only be roughly estimated (McAlpine 1988). However, it is generally accepted that a fire reaches 90% of its maximum ROS in about 30 minutes (Van Wagner 1985). For the purposes of this system, HFI is considered to accelerate to its maximum level at the same rate as ROS[4].

Selecting initial attack time standards was a relatively easy process. One category must represent the minimum attack time required to successfully[5] control a fire under the most extreme burning conditions. Of course, the number (and cost) of bases increases exponentially as you decrease the distance between bases. Therefore, a compromise must be struck between the number of bases and initial attack time. A report entitled "A fire control strategy for Saskatchewan" (Anonymous 1982) states that the optimum distance from an attack base to any fire is 15 minutes flying time. This is probably the most realistic value to select for extreme burning conditions when fire acceleration and the cost of decreasing attack time are weighed.

Once the shortest attack time has been selected, a few assumptions are made. In this case, it is assumed that any fire can be contained if initial attack occurs within 15 minutes of detection. It is also assumed that detection is possible at the time a fire starts to accelerate.

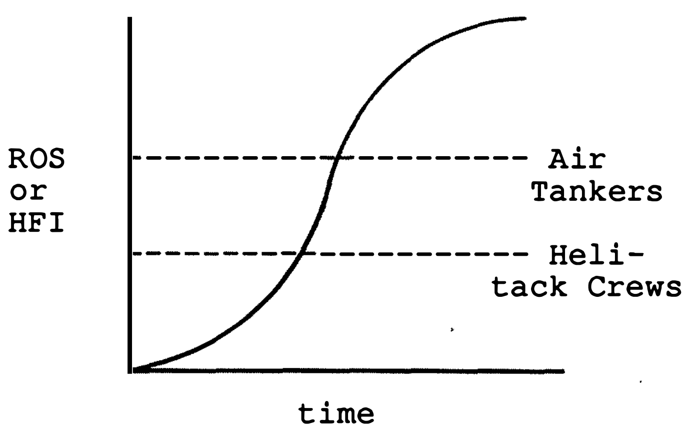

Figure 1. Generalized fire acceleration curve showing limits of suppression capability for helitack crews and air tankers.

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[4] Based on $I = Hwr$, where I = intensity, H = heat of combustion, w = weight of fuel consumed, and r = rate of spread. In this situation, w will be considered a constant. Although that is not absolutely true, it is acceptable for pre-suppression planning purposes.

[5] A successful initial attack is defined here as one which puts the fire into a state of 'being held' within 90 minutes of detection.

A 30 minute attack time was selected as the second category because ROS and HFI can be reasonably-well predicted for this point in time using the rule of 90% acceleration at 30 minutes. Therefore, this can be used as a point where the limits of successful initial attack can be defined. A third attack time is set at 60 minutes because ROS and HFI can be predicted for this point in time, and because it makes a convenient time for setting dispatch standards.

This creates four initial attack time categories: 15 min., 30 min., 60 min., and greater than 60 min. The last category is open-ended because it is assumed that if a fire can be initial attacked one hour later and still be controlled within 90 minutes of detection, then there really is no serious initial attack time requirement. The preparedness system uses these four categories to classify all potential fires.

Figure 2 shows a simple example of how these attack times relate to generalized fire acceleration curves. A slow spreading fire can be successfully initial attacked by either suppression resource, at any time. A moderately fast spreading fire can be successfully initial attacked by a helitack crew in 30 minutes, or by an air tanker strike at any time. A fast spreading fire can be successfully initial attacked by either resource in 15 minutes. This generalized example illustrates the process that the Preparedness System uses to determine attack time requirements.

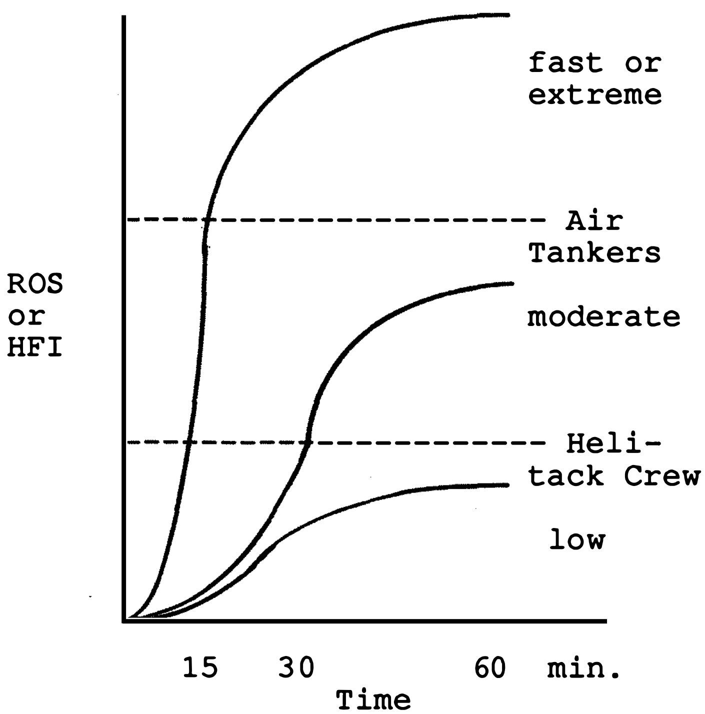


Figure 2. Three generalized fire acceleration curves showing limits of suppression capability for each fire based on the 15-, 30-, and 60-minute initial attack time categories.

Application of the CFFDRS

Figure 3 illustrates the process used to develop the Preparedness System. Both the FBP System and the Canadian Forest Fire Weather Index (FWI) System (another sub-system of the CFFDRS) were used to link suppression capabilities with burning conditions. This procedure defines the boundaries of successful initial attack based on initial attack time and fire potential (using the Fire Weather Index (FWI) and Initial Spread Index (ISI) components of the FWI System as estimators of HFI and ROS, respectively). This information was then used to develop the final 5-level Preparedness System.

Calibrating the Preparedness Level Graph

The Preparedness Level Graph in Figure 3 shows the primary criteria used to define each of the 5 levels. A requirement in the design of this System was to ensure that the highest level of preparedness had all suppression resources on a 15-minute initial attack, while the lowest level of preparedness had no initial attack requirement (i.e., a stand-down day). The differences in suppression capabilities between air tankers and helitack crews is reflected in helitack requiring a faster initial attack for the same Preparedness Level (except for the highest and lowest levels which were already defined). This ensured the System remained simple by reducing the number of levels that would result.

It should be stressed that this Preparedness System was developed so that helitack crews could provide entire coverage for the primary zone of the province. Air tankers are considered a back-up or assistance resource. This provides greater assistance during multiple-fire start situations, and it allows some leeway during periods when helicopter resources are difficult to obtain.

Once the general framework of the Preparedness Level Graph had been determined, the next step was to calibrate the FWI and ISI scales to the 5 levels. This was done following the information flow in Figure 3, and is explained in four stages: establishing initial attack capabilities; defining successful initial attack boundaries; relating initial attack boundaries to the FWI System; and selecting final FWI System limits for Preparedness Levels.

Establishing Initial Attack Capabilities

Initial attack capabilities vary by the suppression resource used. For instance, an air tanker is capable of handling a fire of greater ROS and HFI than a ground crew. Therefore, an air tanker will usually have a greater amount of time to make a successful initial attack because it can handle a fire which accelerates to a higher ROS and HFI value.

Initial attack capabilities for air tankers and helitack crews

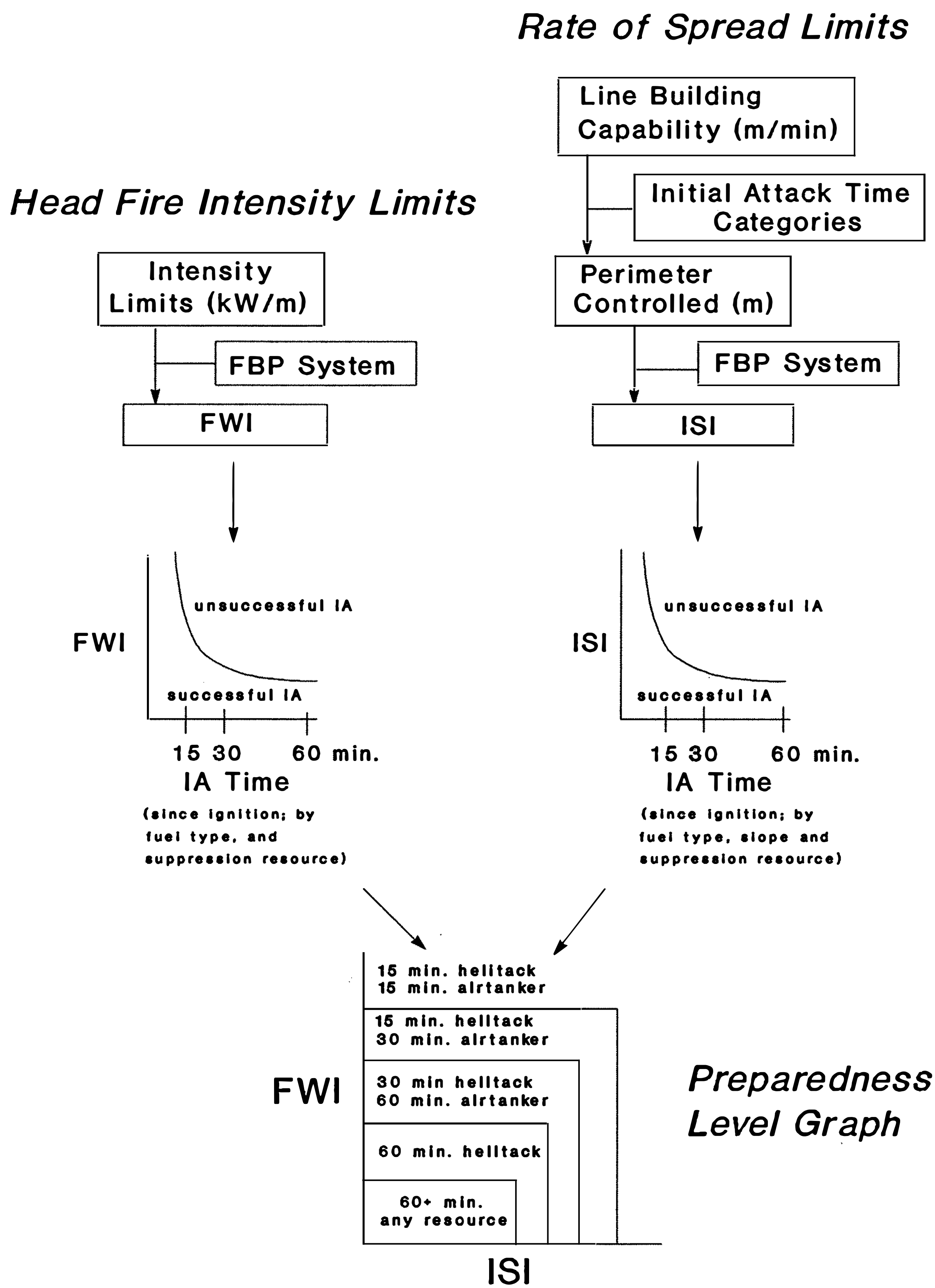


Figure 3. Information flow used to develop Preparedness System.

were delineated by the rate at which they construct a held-line, and by the fireline intensity which they can handle.

Rate of Spread Limits

Although there is still a lot of research to be done on fireline construction rates for initial attack crews, a study by Quintilio et al (1988, 1989) shows an average hot-spotting line construction rate of 15.5 m/min for a 4-man crew in the C-2 (boreal spruce) fuel type, and 18.8 m/min for a 4-man crew in the C-3 (mature jack pine) fuel type (Table 1).

Air tanker capabilities were similarly determined using information provided by Newstead (1981) and Campbell[6]. Table 1 provides a summary of values.

Head Fire Intensity Limits

Alexander and De Groot (1988) provide information relating HFI and suppression capabilities to the FBP System C-3 fuel type. Although that publication deals only with the C-3 fuel type, the HFI values can be applied to other fuel types. The HFI component of this Preparedness System uses the following limits defined by Alexander and De Groot (1988):

Suppression Resource	Frontal Fire Intensity (kW/m)
Helitack Crew	2000
Air Tanker	4000

Defining Successful Initial Attack Boundaries

Rate of Spread Limits

Initial attack capabilities were compared to fire perimeter length tables provided by Alexander (1988). These tables are a summary of calculations using the FBP System, and do not include the acceleration phase. This provides a conservative estimate of initial attack capabilities since these tables assume that a fire spreads at its maximum rate immediately following ignition.

[6] Personal communication. M. Campbell is a bird-dog officer with the Forest Fire Management Branch of Saskatchewan Dept. of Parks and Renewable Resources, and he provided further information on line construction rates for Saskatchewan air tankers from his field experience.

Table 1. Fireline construction rates were based on the following:

Fuel Type	Initial Attack Crew	CL-215[a]	Tracker[b]
C-3	282 m/man-hour or 18.8 m/4 man-min	16 m/min	225 m (one strike)
C-2	232 m/man-hour or 15.5 m/4 man-min	16 m/min	225 m (one strike)

[a] Based on two tankers per team, using water, each creating an effective line of 40 m per drop, using a 5 minute turn-around time.

[b] Based on three tankers per team, dropping long-term retardant and each creating an effective line of 75 m per drop. Using the 40% of fireline rule, 225 m of effective line will control a fire with a perimeter of 560 m.

A couple of rules were used to determine a successful initial attack. Firstly, control is achieved if the constructed fireline is at least 40% of the total fireline (i.e., controlling the head of the fire). Secondly, control must be achieved within 90 minutes of detection if it is to be successful. This is based on the assumption that if a fire has been actioned and can't be contained by initial attack forces within 90 minutes, it has most likely escaped initial attack. A standard wind speed of 15 km/h was used in order to maintain a constant length to breadth (L/B) ratio (1.41). This also allowed for a conservative estimate of suppression capabilities since the total perimeter length decreases with increasing wind speed for any given ISI value and time period.

Total length of constructed fireline was calculated for both the air tankers, and helitack crews. This was done for the three attack times (60, 30 and 15 minutes) to determine what ISI level can be handled, while still meeting the requirement of controlling 40% of the total fireline within 90 minutes of detection. Obviously, a shorter attack time results in a greater amount of constructed fireline within the first 90 minutes following detection, and the ability to control a faster spreading fire. Alexander's (1988) tables show that the rate of perimeter growth starts slow and accelerates quickly. Therefore, a fast initial attack is capable of handling higher ISI values.

Table 2 provides a sample of these tables and shows the initial attack boundaries for a helitack crew making a 15-minute initial attack, and spending 15 minutes building fireline (for a total time of 30 minutes since ignition). In this example, a helitack crew would be able to construct 232.5m (15.5m/min X 15 min) in 15 minutes. If this were 40% of the fireline, then the

Table 2. Sample of fire perimeter length tables by Alexander (1988).

<u>FBP System Fuel Type</u>: C-2 (Boreal Spruce) <u>10-m Open Wind Speed</u>: 15 km/h <u>Ground Slope</u>: 0%

	FFMC	Elapsed Time Since Ignition (min)																	
		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
		Fire Perimeter Length at time "T" (m)																	
	70	1	3	6	10	14	18	22	27	32	36	41	46	51	56	61	66	71	75
	71	1	3	6	10	14	19	24	29	34	39	44	49	54	59	64	70	75	80
	72	1	3	7	11	15	20	25	31	36	41	47	52	58	63	69	74	80	85
	73	1	4	7	12	17	22	27	33	39	44	50	56	62	68	74	80	86	92
	74	1	4	8	13	18	24	29	36	42	48	54	61	67	74	80	86	93	99
	75	1	4	9	14	20	26	32	39	46	53	60	67	74	81	88	95	102	109
	76	1	5	10	15	22	29	36	43	51	59	66	74	82	90	98	106	114	121
	77	2	5	11	17	25	33	41	49	58	67	75	84	93	102	111	120	129	137
	78	2	6	13	20	29	38	47	57	67	77	87	97	107	117	128	138	148	158
	79	2	7	15	24	34	44	55	67	78	90	102	114	126	138	150	162	174	186
	80	2	9	18	28	40	53	66	80	94	108	122	136	150	165	179	193	208	222
	81	3	11	21	34	49	64	80	97	114	131	148	165	183	200	217	235	252	270
	82	4	13	26	42	60	79	99	119	140	161	182	203	225	246	268	289	311	333
	83	5	16	33	53	75	98	123	149	174	201	227	254	280	307	334	361	388	415
	84	6	20	41	66	94	124	155	187	219	252	286	319	353	386	420	454	488	521
	85	7	26	52	84	119	157	196	236	278	319	361	404	446	489	532	574	617	660
	86	9	33	66	107	151	199	249	300	353	406	459	513	567	621	675	730	784	839
	87	12	42	84	136	192	253	317	382	449	516	584	653	721	790	859	928	997	1067
	88	15	53	107	172	245	322	403	486	570	656	742	829	917	1004	1092	1180	1268	1355
	89	19	67	136	218	310	408	510	615	723	831	941	1051	1162	1272	1384	1495	1606	1718
	90	24	85	171	275	391	**514**	643	776	911	1048	1187	1326	1465	1605	1745	1886	2026	2167
S	91	30	107	215	345	490	645	807	973	**1143**	1315	1488	**1662**	1837	2013	**2188**	2364	2540	2717
C	92	37	133	268	430	610	803	1004	1212	1423	1637	1852	2069	2287	2506	2724	2943	3163	3382
	93	46	164	331	531	753	991	1240	1496	1757	2021	2287	2555	2824	3094	3364	3634	3905	4176
	94	56	200	404	649	922	1213	1517	1831	2150	2473	2799	3127	3456	3786	4116	4447	4778	5110
	95	68	243	490	787	1117	1470	1839	2218	2604	2996	3391	3788	4187	4586	4987	5388	5789	6191
	96	82	291	587	943	1339	1762	2204	2659	3122	3591	4065	4541	5019	5498	5978	6459	6940	7421

<u>Note</u>: An * denotes less than 0.5 m but not 0.0. The surface (S)/crown(C) fire threshold has been identified.

total fire perimeter length would be 581m. Under the column for 30 minutes elapsed time since ignition, the nearest corresponding value would be 514m, which has an equivalent Fine Fuel Moisture Code (FFMC) value of 90. The results of similar calculations done for a 15-minute initial attack using fireline construction times of 30, 45, 60, and 75 minutes (which correspond to 45,60 75, and 90 minutes after ignition) are also shown. This set of values defines the boundaries of a 15-minute helitack strike that meets the '90-minutes to control' criteria.

Head Fire Intensity

Because head fire intensity affects initial attack capabilities only in terms of its upper threshold value, there is only one value used to define successful initial attack boundaries (either 2000 or 4000 kW/m). These limits can be directly interpreted in terms of the FWI System (Alexander and De Groot 1988).

Relating Initial Attack Boundaries to the FWI System

Rate of Spread

The final ISI values are determined using the FFMC values from the perimeter length tables, and the ISI tables in the Tables for the Canadian Forest Fire Weather Index System (Canadian Forestry Service 1984) using the standard wind speed of 15 km/h.

Head Fire Intensity

Alexander and De Groot (1988) provide the following values for the C-3 fuel type:

Frontal Fire Intensity (kW/m)	FWI
2000	23
4000	28

Selecting Final FWI System Limits for Preparedness Levels

The final stage of calibrating the Preparedness Level Graph was to stratify the FWI and ISI scales according to the Preparedness Level criteria (summarized in Table 3) using the initial attack boundary information determined in the previous stage. Table 4 provides an expanded list of pre-suppression activities associated with each Preparedness Level that was also used to select the final FWI System limits.

Table 3. Summary of Preparedness Level criteria.

Level	Description
1	Initial attack time not critical
2	Initial attack crew successful with 60 min. attack time
3	Initial attack crew successful with 30 min. attack time or Air tankers successful with 60 min. attack time
4	Initial attack crew successful with 15 min. attack time or Air tankers successful with 30 min. attack time
5	Initial attack crew or air tankers successful with 15 min. attack time

Rate of Spread

In dividing the ISI scale to fit the 5-level Preparedness System, it was apparent that there was no clear-cut definitive boundaries. This is due to the wide variation in suppression capabilities that occur between fuel types, as well as between the air tankers. It was decided that both C-2 (Boreal Spruce) and C-3 (Mature Pine) would be used for comparison, with stronger emphasis on C-2, the more volatile fuel type. Air tankers were also individually compared for both of these fuel types. Table 5 summarizes the results.

Head Fire Intensity

The FWI scale was matched to the 5 preparedness levels using the 5 fire intensity classes of Alexander and De Groot (1988). The suppression capabilities described by the intensity classes were originally used to define the criteria for the Preparedness Levels. Therefore, the intensity class scale was applied directly to the Preparedness System. Figure 4 illustrates the final scale selected.

Table 4. Preparedness Level descriptions[a].

1	All resources on GREEN Alert No Detection
2	Tower Detection 1300 - 1700 hrs Air Tankers - 1/2 on BLUE - 1/2 on GREEN Helitack Crews at 60-minute bases on BLUE
3	Tower Detection 1200 - 1800 hrs Aerial Detection - mid-afternoon over critical areas Air Tankers - 1/2 on YELLOW (60-min. attack time) - 1/2 on BLUE Helitack Crews at 30-min. bases on YELLOW 25% of full man-up
4	Tower Detection 1100 - 1900 hrs Aerial Detection - general regional coverage Air Tankers - 1/2 on RED (30-min. attack time) - 1/2 on YELLOW Helitack Crews at 15-min. bases on RED Loaded helicopter patrols in critical areas (to 30% of minimums) 50% of full man-up
5	Tower Detection 1000 - 2000 hrs Aerial Detection - general regional coverage, and multiple patrols of critical areas Air Tankers - all on RED (15-min. attack time) Helitack Crews at 15-min. bases on RED Loaded helicopter patrols in critical areas (to 50% of minimums) 100% of full man-up AID Machine, Operator, and Helicopter on RED Overhead and Support Teams on standby

[a]Description of coloured alert schedules found in Tables 9 and 10.

Multiple Fire Starts

The previous procedure to determine a Preparedness Level based on initial attack limits was done solely in regards to burning conditions. As stated earlier, many campaign fires are the result of multiple fire start situations. A preparedness system must also accomodate the need for increased resource levels during periods of multiple starts.

This Preparedness System was developed with the approach that burning conditions were the primary consideration for preparedness decisions, and concern about multiple starts was secondary in nature. For instance, full preparedness (Level 5) will occur

Table 5. Summary of ISI limits by initial attack resource for various Preparedness Levels and forest types.

	Preparedness Level 1	2	3	4	5
	ISI LIMIT				
Helitack	Corresponding Attack Time[a]				
Crew (4-man)	nil	60 min	30 min	15 min	15 min
C-2[b]	**4**	**6**	**8.5**	**11**	**11**
C-3	**9**	**11**	**13**	**16**	**16**
	Corresponding Attack Time				
CL-215	nil	nil	60 min	30 min	15 min
C-2			**7.5**	**11**	**16**
C-3			**12**	**15**	**20**
	Corresponding Attack Time				
Tracker	nil	nil	60 min	30 min	15 min
C-2			**5.5**	**10**	**20**
C-3			**10**	**14.5**	**21+**
Final ISI category selected	**0-3**	**4-6**	**7-9**	**10-13**	**14+**

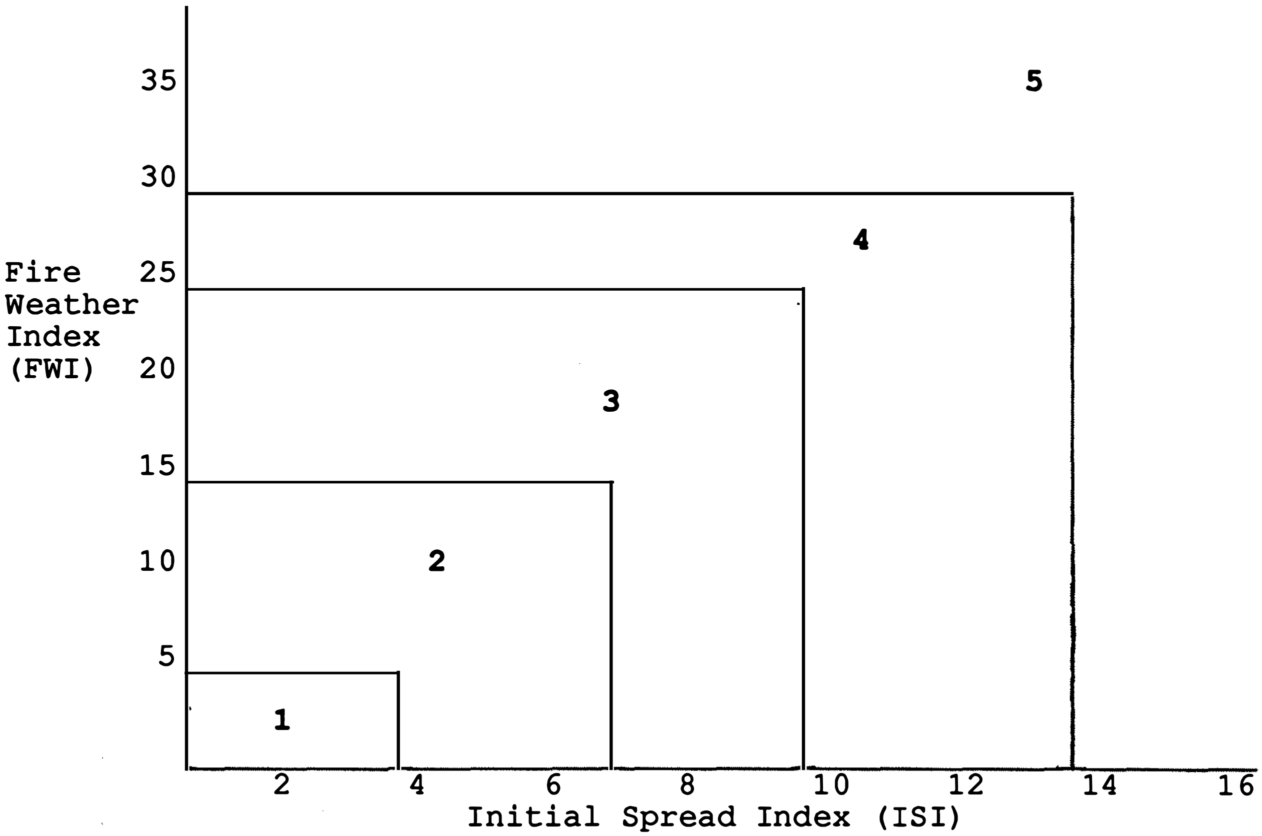
[a] These attack times correspond to the standards described by that Preparedness Level. For instance, at Preparedness Level 3 the air tankers have a 60-minute attack time, and the helitack crews have a 30-minute attack time requirement.
[b] FBP System fuel types.

during extreme burning conditions regardless of the possibility (or probability) of fire starts.

The Preparedness System accomodates this approach by calculating a Preparedness Level with burning conditions, and then checking if the potential for multiple fire starts warrants a higher Preparedness Level. In most situations though, increased resource levels (from higher Preparedness Levels) are the result of burning conditions.

Unfortunately, accurately predicting fire starts is a difficult task because there are no good models with which to estimate fire risk. However, the FFMC component of the FWI System can be used in a subjective manner since it acts as a general in-

Preparedness Levels



Initial Attack Times

Preparedness Level	Helitack Crew	Air Tankers
1	NA	NA
2	60 min.	NA
3	30 min.	60 min.
4	15 min.	30 min.
5	15 min.	15 min.

Figure 4. Preparedness Level graph and corresponding initial attack times.

dicator of fire starts. Because a preparedness system deals with manning-up on a provincial level, use of a broad indicator can be justified. It should be noted that development of the Canadian Forest Fire Occurrence Prediction (FOP) System is in progress. The FOP System will have a great effect on this Preparedness System, although it will not likely be operationally useable for at least five years.

In order to keep the Preparedness System simple, it was decided that the FFMC component should be incorporated (if possible) into the current Preparedness Level graph rather than create a separate table or graph. This way, a Preparedness Level could be calculated by burning conditions and probability of fire starts, using one simplified graph. The following criteria were selected to address multiple fire start situations:

FFMC	Probability of Fire Starts	Man-up Level*	Preparedness Level
0 -76	Very Low	Nil	1
77-84	Low	Nil	2
85-88	Moderate	25%	3
89-91	High	50%	4
92+	Very High	100%	5

*as a percent of full man-up.

Man-up was dealt with as an increase in auxiliary manpower only. These workers could be considered mop-up crews or extra firefighters. During a multiple fire start situation, these extra workers are divided into crews with one or two helitack crewmembers in charge. In this way, the total number of initial attack crews is increased proportionally to the increased probability of fire starts. Because man-up levels are aligned with Preparedness Levels, it is possible for extra firefighters to be hired on during periods of severe burning conditions, even though there is no probability of multiple fire starts. In this case, the extra workers provide assistance as mop-up crews. This ensures that the helitack crews are capable of providing continuous initial attack coverage throughout the day.

Determination of full man-up levels was a totally subjective exercise done by field and management staff from each region. Because there is little information available on manpower requirements, it was decided that experience (solely) would provide the best estimate of manpower needs.

Incorporating the FFMC into the Preparedness Level graph can be easily done, since ISI is determined by FFMC and wind speed. Because manning-up occurs only in Preparedness Levels 3-5, it is only necessary to match the FFMC values to the corresponding ISI values using wind speed for these three levels. For instance, an

FFMC of 85 corresponds with an ISI of 7 at a wind speed of 23 km/h. The wind speeds required to match these values range from 23-18 km/h. Because 18 km/h fits Preparedness Level 5 and man-up is most important at the higher Preparedness Levels, a value near 18 km/h would suffice since FFMC is only being used as a subjective indicator. A value of 15 km/h was selected even though it delays man-up activity to the FFMC levels in Table 6.

This lower wind speed value was chosen because of the costs associated with increasing Preparedness Levels. A higher wind speed value would cause Preparedness Levels to increase at lower FFMC values. Increasing to Preparedness Level 3 or 4 requires an increase in short-term helicopter contracts because of the corresponding change in attack time requirements. This is acceptable when dealing with burning conditions, but early contracting of helicopters should not be decided solely by the probability of fire starts.

This method of incorporating a 'multiple fire start' component into the Preparedness System illustrates the fact that the problems of burning conditions and multiple fire starts are not mutually exclusive in their solutions. Compensation must be made between inital attack time and auxiliary manpower requirements for both situations, and this balance should be struck in a (realistically) simplified manner.

Operational Considerations

Use of the FWI and ISI poses logistical problems when increasing (or decreasing) resources. Because both these indexes are highly variable over the short term, suppression resource levels could swing widely on a daily basis if their variability is not accounted for. This causes problems when dealing with short-term helicopter contracts and resource deployment. Use of a more stable and predictable indicator would buffer these swings and enhance the logistics of preparing. However, such indexes do not indicate the severity of hourly suppression problems during peak critical periods. The greater sensitivity of the FWI and ISI provides better information in terms of resource and attack time requirements.

Table 6. FFMC levels corresponding to the ISI values associated with Preparedness Levels 3-5 when using a standard wind speed of 15 km/h.

Man-up Level	Preparedness Level	Corresponding FFMC
25%	3	88-90
50%	4	91-92
100%	5	93+

To compensate for their variability, the causes have to be operationally "accounted for". Sensitivity to rainfall and wind speed are the primary causes, and the problem is that both are difficult to predict for any specific location at any time. Using a minimum (moderate) wind speed of 15 km/h will prevent gross under-preparedness in all but the most severe situations. In such instances, the System would already indicate serious potential for extreme conditions. It is the responsibility of the fire weather section to provide advanced notification of conditions supporting the most severe burning situations. Under-preparedness due to the highly unpredictable nature of isolated showers can only be compensated by using zero rainfall, unless organized precipitation is obviously going to reduce fire hazard.

Use of the 15 km/h and zero rainfall rule (for unorganized precipitation) does not create an over-preparedness problem since these are minimum levels which should be prepared for. Additional buffering of wide swings in the Preparedness Level can be achieved simply through an extended forecast. By providing a 48 to 72 hour trend forecast of Preparedness Levels, each region can determine how best to accomodate anticipated sharp changes in burning conditions. As long as the fire manager is provided with a 2 or 3 day notice of probable resource needs, then resource scheduling can be properly co-ordinated.

It should also be noted that there will be days when Preparedness Level 5 will occur and no fires start. This is not a limitation of the System. This occurs during extreme burning conditions because any fire start on such a day can result in a campaign fire.

Operational Application

Development of the Preparedness System required considerable involvement by the regions (which are ultimately responsible for fires). If the system was to be used operationally, it would have to satisfy the needs of the field users.

The first step was to have each region identify preferred locations for initial attack bases which met the attack time criteria (i.e., 15-, 30-, and 60-minute bases). Base locations were determined using the following airspeeds: 200 km/hr for helicopters; 260 km/hr for CL-215's; and 325 km/hr for Trackers. Overlap between regions was accomodated during this procedure (Table 7). Each of the regions was also asked to provide a schedule for full man-up (Table 8).

Several presentations explaining the use of the Preparedness System were given to regional (and some district) staff. Through this process, it was decided that field fire managers would be allowed to increase a Preparedness Level when justification is provided. In this way, local knowledge and field experience would not be suppressed by the system. For instance, the lack of an

Table 7. Attack Base Summary[a].

	Regions			
	Hudson Bay	La Ronge	Prince Albert	Meadow Lake
15-minute Attack Base (Levels 4 and 5)	Cumberland House Squaw Rapids Pasqua Hills Mistatim McBride Lake	Emmaline Tower Sandfly Lake[b] La Ronge Missinipi[b] Uskik[b] Sandy Bay[b] Jan Lake Puskwakau River Denare Beach	Clark Lake Weyakwin Candle Lake Lower Fishing Lakes Prince Albert English Cabin	Clearwater Bridge La Loche Buffalo Narrows Turner Lake Dillon Lake Dipper Lake Beauval Waterhen River Lac des Iles campground Loon Lake Chitek
30-minute Attack Base (Level 3)	Hudson Bay	Pelican Narrows[b] Stanley Mission Road	Prince Albert Thunder Mountain Lower Fishing Lakes	La Loche Ile a la Crosse Dorintosh
60-minute Attack Base (Level 2)	Hudson Bay	La Ronge	Prince Albert	Buffalo Narrows Meadow Lake

a Additional: i) Cypress Hills - rotary wing for levels 3, 4, and 5.
ii) Southend, Walloston, Stony Rapids, and Uranium City manned-up as required.

b Denotes possibility of substituting a fixed wing for a helicopter.

Table 8. Full man-up schedule.

Region	Location	Man-Up
Meadow Lake	Chitek	10-man crew
	Glaslyn	8 men
	Dorintosh	10-man crew
	Pierceland	10-man crew
	Meadow Lake	10-man crew
	Green Lake	10-man crew
	Beauval	4x10-man crews
	Buffalo Narrows	3x10-man crews
	Dillon	10-man crew
	Turnor Lake	10-man crew
	La Loche	3x10-man crews
	Total	178 men
La Ronge	Pinehouse	15 men
	La Ronge	3x10-man crews
	Pelican Narrows	3x10-man crews
	Creighton	15 men
	Sandy Bay	15 men
	Total	105 men
Prince Albert	Dore Lake	5x10-man crews
	Weyakwin	5x10-man crews
	Christopher Lake	5x10-man crews
	Candle Lake	5x10-man crews
	Lower Fishing Lakes	5x10-man crews
	Prince Albert	5x10-man crews
	Total	300 men
Hudson Bay	Cumberland House	25 men
	Squaw Rapids	10-man crew
	Sauders Camp	10-man crew
	Hudson Bay	3x10-man crews
	Bainbridge Lodge	10-man crew
	McBride Lake	10-man crew
	Greenwater	8 men
	Preeceville	8 men
	Total	111 men

operational FOP System requires fire managers to make a few decisions based solely on experience and judgement. Previous experience with people-caused fires and information from lightning location maps are two important factors which could cause manual adjustment of the Preparedness Level.

Discussions and involvement with the regions definately facilitated better use and acceptance of the System. As well, keeping the System simple also assisted in its operational application.

Description of Daily Procedures

Following the collection of fire weather data (at 1200 Local Standard Time), Preparedness Levels are immediately calculated by computer at the FFMB in Prince Albert. These Levels are valid for that day. At the same time, Preparedness Levels are calculated for the next day using forecast weather and FWI System values. This information is sent to all regional duty officers with a two-day trend forecast (and relayed to the districts from the regions). Using this information, regional and provincial duty officers decide initial attack requirements for the following day. The two-day trend forecast is used to assist in determining short-term helicopter levels and possible contract lengths.

It is at this point that experienced judgement by the duty officers is required. Because weather stations and attack bases are usually at different locations, duty officers will be required to interpret Preparedness Levels across the region (or province), in consultation with the weather section at FFMB. Lightning and forest use activity may cause Preparedness Levels to be upgraded. A partial upgrade (such as in detection only) is also possible.

Next, they decide the attack times required for each area based on the Preparedness Levels and Attack Times found in Figure 4 (and described in Table 4). Using the provincial Fire Suppression Preparedness map and coloured attack base circles, the initial attack bases (listed in Table 6) are manned-up according to the required attack times. Note that one region could have a mix of 60, 30 and 15-minute attack bases for any given day. The number of bases, their location, and attack time (or circle radius) is based solely on the duty officers' interpretation of the Preparedness Level calculations.

Once attack bases have been selected, the duty officer makes arrangements for the required helicopter (and helitack crew) resources, taking into account the trend forecast. The duty officer determines the alerts for the helitack crews and air tankers following the Preparedness Level description (Table 4). The appropriate alert schedules are described in Tables 9 and 10. Any man-up, or man-down, that is required (following the Preparedness Level description in Table 4) is done by the regions

Table 9. Helitack crew alert schedule.

Colour	Get-away Time	Travel Time	Attack Time
GREEN		----------- No Alert ------------	
BLUE	10 min.	50 min.	60 min.
YELLOW	5 min.	25 min.	30 min.
RED	3 min.	12 min.	15 min.

following the man-up schedule (Table 10). Table 4 also outlines the other pre-suppression requirements.

An update of calculated Preparedness Levels for the day are sent out in the morning to the regions. Adjustments to the previous days suppression plan can be made during the morning briefing.

Measuring System Performance

To determine the cost-effectiveness of this system, it was tested using the 1988 fire season data (1987 weather data was not available). Increased up-front costs (short-term helicopters) totalled $1.2 million (for May 1 to August 31), or 12.6% of the original pre-suppression budget of $9.5 million. Total fire costs for 1987 and 1988 was $34 million and $32 million, respectively. There were 50 large fires during this two-year period which totalled $24.4 million in suppression costs. If the increased up-front costs of $1.2 million for 1988 was also used for 1987 (as an estimate), then it is estimated that 10% (or $2.4 million) of large fire costs for 1987 and 1988 ($24.4 million) would pay for complete implementation of the Preparedness System for that same two-year period. In other words, there was a potential to spend $22 million less during this period. Even though a totally successful initial

Table 10. Air tanker alert schedule.

Colour	Dispatch*
GREEN	No Alert
BLUE	1 hr
YELLOW	1/2 hr
RED	Immediate

* note that dispatch time refers to time until engine start-up, and is not the same as get-away time

attack program is not likely, there is a great deal to be saved through increased preparedness funding.

Measuring the System by its potential to reduce costs is acceptable for justification of its use. However, it should also be measured on an annual basis in terms of the success of its implementation. In this case, the objective is to reduce total fire costs by reducing the number of campaign fires through improved initial attack capabilities. Determining the number of campaign fires which did not occur as a result of this System is difficult to do. At present, there is no absolute and objective way of doing this. Comparing the total number of campaign fires from year to year also is not indicative of performance. The problem is that fire seasons vary from year to year, making yearly comparison inappropriate.

To properly measure the success of implementation, there must be some measure of fire danger levels (or severity) and fire starts in relation to the number of escaped fires. For instance, a successful initial attack of 3 fires at Preparedness Level 5 is of greater value than 30 fires at Preparedness Level 2.

For the present, it was decided to measure System performance by determining the success/failure rate for initial attack in terms of severity, and comparing this value to similar previous periods in time. This is done using the Daily Severity Rating (DSR) because it can be used cumulatively for a variable time frame (daily, weekly, monthly, seasonally). This allows greater ability for comparison to other similar periods in other years. An example would be to use a 1989 5-day fire bust having a cumulative DSR of 30, 200 fire starts, and 2 escaped fires costing $5 million. This is then compared to periods in previous years having similar DSR and fire starts. System performance is then measured in terms of improvement in initial attack success rate, and the resulting difference in total suppression costs (in 1989 dollars).

Although this procedure is still somewhat subjective and may not include a lot of management variables, it provides a couple of important common denominators for measuring performance: initial attack success rate (relative to the potential for campaign fires), and dollars.

Future Changes to the System

Completion of the FOP System will have some major implications in the use of the Preparedness System. The FOP System will incorporate lightning and man-caused fire starts using probabilistic determination, and it will likely be done on a computerized regional basis. Again, this enhancement of the system is at least 5 years in the future.

In a shorter time frame, the Preparedness System will be computerized on a provincial basis in 1-2 years. This is already being done for the Prince Albert Region during the 1989 fire season through the Integrated Fire Management Information System (IFMIS) (Lee and Anderson 1990). At this stage, the Preparedness System receives some major improvements through a few changes.

IFMIS deals with the system on a spatial basis by incorporating fuel type data and extrapolated weather data. The result is a visual display showing the protection area by initial attack time category. The Preparedness Level graph (Figure 4) is no longer valid at this point because it was based solely on the ISI and FWI limits of the C-2 and C-3 fuel types. IFMIS calculates a Preparedness Level using new ISI and FWI limits for each fuel type based on the same ROS and HFI criteria described earlier, and new line productivity rates. However, the Initial Attack Times described in Table 3 and the Preparedness Level Description (Table 4) are still valid.

Lastly, this System will undergo annual changes since it should be reviewed on a yearly basis for operational adjustments. It was developed with operational expertise, and annual review will ensure that it remains current with changing fire management approaches.

Concluding Remarks

Saskatchewan's Fire Suppression Preparedness System was developed for decision-making use at the regional and provincial levels. It provides a standard scale for measuring resource requirements across the province, and assists in defining resource levels, base locations, and pre-suppression activities. It is meant to be used as an unbiased indicator, but not necessarily as a strict set of rules. Fire managers are still required to make experienced judgement calls (based on this system and other fire management information) even though this decision-aid simplifies the presuppression planning process.

More specifically, this System determines Preparedness Levels based on anticipated fire behavior following ignition, and suppression capabilities. It does not include any determination of ignition probability, or utilize any fire occurrence predictor. Therefore, information on lightning occurrence and forest use activity must be incorporated through the judgement of the duty officer for the System to utilized effectively.

The System is also slightly conservative in its estimate of suppression capabilities. This occurs because the acceleration phase is not included in the estimates of fire growth[7]; therefore, there is a little more time available for initial attack forces to

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[7] An updated version of the FBP system which incorporates the acceleration phase was released in December 1989. However, the initial development of this System (described by this paper) occurred prior to this date.

be successful. As well, this System was developed for complete coverage of the primary zone using helitack crews only. Any coverage by air tankers is considered 'padding' or extra coverage which becomes very important during multiple fire starts or extreme burning conditions. The System was built around helitack crews because it takes a crew on the ground to control a fire; air tankers provide support for the ground crews.

This System was developed using research information and the experience of Saskatchewan's management and field staff. The Preparedness Systems from Alberta (Alberta Forest Service 1989) and the Northwest Territories (Anonymous 1987) were used as examples and provided considerable information. Although there are differences in the procedures and approaches taken by all three Preparedness System's (Table 11) due to the different fire management situations, all contain the primary concept of reducing total fire suppression costs (and area burned) through enhanced pre-suppression funding.

Finally, development of a Preparedness System does not ensure reduced total costs. To make the preparedness strategy work, there must be a commitment to spending extra fire fighting dollars before fires start.

Acknowledgements

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Table 11. Comparison of Preparedness Systems[a].

	Saskatchewan	Alberta	NWT
Name	Fire Suppression Preparedness System	Presuppression Preparedness System	Forest Fire Preparedness System
Levels	5 Preparedness Levels	6 Manning-up Levels	4 Preparedness Levels
First year of use	1989	1983	1987
Method of Calculation	FWI vs ISI and FFMC	FFMC vs BUI (with wind and 500mb categories)	FWI vs FFMC
Wind speed input	15 km/h or greater	variable	20 km/h
Fuel Type	C-4 (FWI) C-2,C-4 (ISI)[b]	variable	C-2
Total Man-up	33 helicopters 33x4-man IA crews 70x10-man crews	130 helicopters 150x8-man squads	57 helicopters 106 IA Crews
Area: (sq. km)			
primary	159,385	381,246	252,000
secondary	167,825		975,000[c]
green zone	28,130		
Ave. fires per year (79-88)	822	1067	296

[a] as of March, 1989.
[b] will be variable with implementation of IFMIS.
[c] observation zone.

PREVIOUS PROCEEDINGS
IN THE
CENTRAL REGION FIRE WEATHER COMMITTEE
SCIENTIFIC AND TECHNICAL SEMINAR SERIES

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- The Lightning Location and Protection (LLP) System: Alberta's operational experience -- Nicholas Nimchuk
- Operational Lightning Fire Occurrence Prediction in Ontario -- Richard A. White
- Use of the 500 mb Height Anomaly Chart in Fire Management -- Ben Janz
- Addendum to the Literature on Australia's 1983 "Ash Wednesday" Fires -- compiled by Martin Alexander

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- Accuracy and Efficiency of the Ontario Ministry of Natural Resources Lightning Locator Network -- Bill Droog

- Fire Weather/Behavior Analysis and Information Systems -- Ugo Feunekes and Ian R. Methven

- An Overview of the 1987 Wallace Lake Fire, Manitoba -- Kelvin G. Hirsch

- Fire Behavior on the 1987 Elan Fire, Saskatchewan -- William J. De Groot

- The Fire Weather Report -- What does it tell us? -- Ben Janz

LIST OF SEMINAR ATTENDEES

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[1] AES=Atmospheric Environment Service, CIFFC=Canadian Interagency Forest Fire Centre, CPS=Canadian Parks Service, DND=Department of National Defence, FFMB=Forest Fire Management Branch, Saskatchewan, For. Can.= Forestry Canada, MNR=Manitoba Natural Resources, OMNR=Ontario Ministry of Natural Resources.