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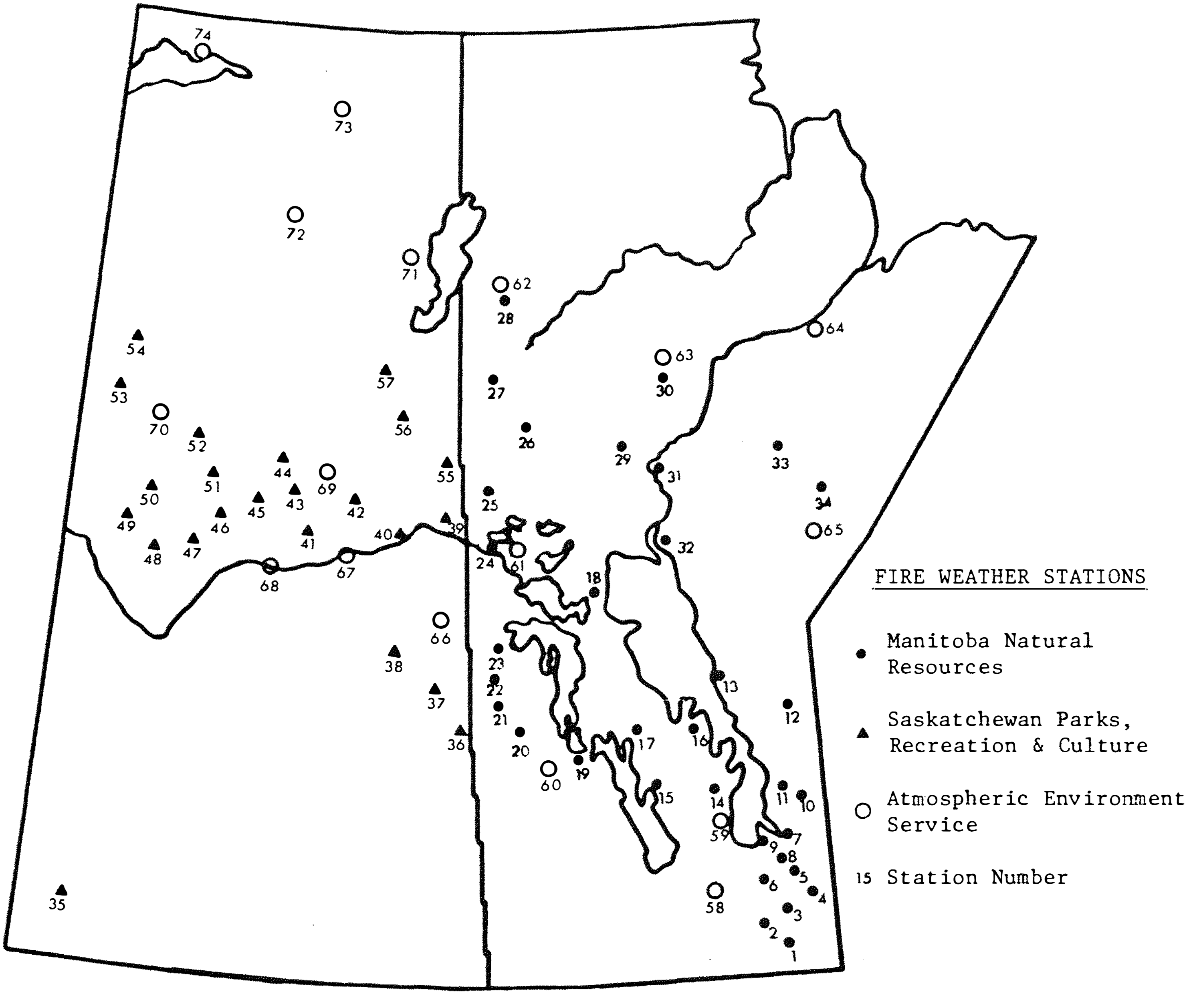
PROCEEDINGS OF THE FOURTH CENTRAL REGION FIRE WEATHER COMMITTEE

SCIENTIFIC AND TECHNICAL SEMINAR - April 2, 1987, Winnipeg, Manitoba



NAMES OF THE FIRE WEATHER STATIONS OPERATING IN MANITOBA AND SASKATCHEWAN AS OF APRIL 1, 1987

Station Number	Station Name	Station Number	Station Name
	Manitoba Natural Resources		
1	Piney	18	Grand Rapids
2	Marchand	19	Manipogo
3	Hadashville	20	Wellman Lake
4	West Hawk Lake	21	Swan River
5	Nutimik Lake	22	Hart Mountain
6	Beausejour	23	Mafeking
7	Pine Falls	24	The Pas
8	Lac Du Bonnet	25	Cranberry-Portage
9	Grand Beach	26	Snow Lake
10	Black Lake	27	Pukatawagan
11	Bissett	28	Lynn Lake
12	Little Grand Rapids	29	Wabowden
13	Berens River	30	Thompson
14	Riverton	31	Cross Lake
15	Ashern	32	Norway House
16	Lake St. George	33	Oxford House
17	Gypsumville	34	Gods Lake
	Saskatchewan Parks, Recreation and Culture		
35	Cypress Hills	47	Chitek Lake
36	Duck Mountain	48	Divide
37	Ushta	49	Loon Lake
38	Green Water Park	50	Meadow Lake Park
39	Cumberland House	51	Beauval
40	Squaw Rapids	52	Ile la Crosse
41	Candle Lake	53	Buffalo Hills
42	Little Bear	54	La Loche
43	Weyakin	55	Creighton
44	Besnard	56	Pelican Narrows
45	Wakesiu Lake	57	Southend
46	Big River		
	Atmospheric Environment Service		
58	Winnipeg, Man.	66	Hudson Bay, Sask.
59	Gimli, Man.	67	Nipawin, Sask.
60	Dauphin, Man.	68	Prince Albert, Sask.
61	The Pas, Man.	69	La Ronge, Sask.
62	Lynn Lake, Man.	70	Buffalo Narrows, Sask
63	Thompson, Man.	71	Collins Bay, Sask.
64	Gillam, Man.	72	Cree Lake, Sask.
65	Island Lake, Man.	73	Stony Rapids, Sask.
		74	Uranium City, Sask.

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April 2, 1987
Winnipeg, Manitoba

Compiled and Edited

by

Kelvin G. Hirsch
Fire Research Officer

Study NOR-36-03-1 File No. 3

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Manitoba District Office
Canadian Forestry Service
104-180 Main Street
WINNIPEG, Manitoba
R3C 1A6

CONTENTS

Front Cover: Status of the fire weather station networks in Manitoba and Saskatchewan as of April 1, 1987. Station names are given on the inside cover.

FOREWARD

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 Canadian Forestry Service (CFS) in provision of fire weather forecasts, fire danger forecasts, and other weather-related services to the various fire control agencies. Briefly, this policy gives AES the responsibility of providing current and forecast fire weather and Fire Weather Indices in accordance with the needs of fire control agencies. The CFS role is that of research and development of improved cooperation with AES in preparation of training aids and manuals. Both AES and CFS share the responsibility of improving meteorological services for forest fire control in Canada. Van Wagner (1984)[1] recently re-emphasized these specific obligations.

In 1976, six regional committees[2] were formed to facilitate the implementation of the DOE Policy on Meteorological Services for Forest Fire Control. The "charter" for these regional fire weather committees is as follows:

Membership: 1 or more AES representatives designated by AES Regional Director; 1 or more CFS representatives designated by CFS Regional Director; and 1 or more fire management agency representatives designated by the Provincial or territorial chief(s) of forest fire management.

Terms of Reference: Each Regional Committee will make recommendations to the Regional Directors of DOE Services (i.e., AES and CFS) 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.

Guidelines: Regional Committees will be responsible for (a) identifying the needs of regional fire management agencies for meteorological services; (b) making

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[1] Van Wagner, C.E. 1984. Forest fire research in the Canadian Forestry Service. Agriculture Canada, Canadian Forestry Service, Petawawa National Forestry Institute, Chalk River, Ont. Information Report PI-X-48. 45 p.

[2] These were aligned on the basis of the existing AES administrative boundaries: 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).

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 those recommendations which 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 through contacts, at the technical level, between research and development officers of AES and CFS, operations supervisors in the AES field establishments and technical representatives of fire management agencies.

INTRODUCTION

The inaugural meeting of the Central Region Fire Weather Committee (CRFWC) was held at the Atmospheric Environment Service's (AES) Central Region Office in Winnipeg, Manitoba, on January 26, 1976. CRFWC member agencies currently include Saskatchewan Parks, Recreation and Culture, Manitoba Natural Resources, Canadian Parks Service - Prairie Region, AES - Central Region, and Canadian Forestry Service (CFS) - Western and Northern Region. In 1983, a "technical sub-committee" was formed; representatives of the Ontario Ministry of Natural Resources have begun to attend these mettings. The terms of reference prepared for the CRFWC Technical Sub-committee state that it ". . . may (and is encouraged to) provide the opportunity for the presentation and discussion of scientific and technical papers on subjects relating to forest fire meteorology in the Region". The concept of a scientific and technical seminar series was originally initiated by the Western Region Fire Weather Committee[1] in 1983. Subsequent gatherings occurred in 1984 and 1986 and will continue to occur on a biennial basis. There have now been four seminars held in conjunction with the CRFWC Technical Sub-committee's annual spring business meeting; these have all taken place at the AES's Central Region office in Winnipeg. Attempts have been made each year to have the presentations strike a balance between research and operations as well as between fire and meteorology. A list of the presentations from the first three seminars is given at the back of this document. This report constitutes a summary of the four presentations which took place at the fourth seminar. An attendance list is appended. The CRFWC seminar series provides an excellent forum for the exchange of information, ideas, etc. on current and/or timely fire weather related topics of direct interest to all CRFWC member agencies. At the 1986 CRFWC Technical Sub-committee meeting the present format for the Scientific and Technical Seminar was re-affirmed and all agencies expressed the desire to have these seminars continued.

The financial support for the fourth seminar was provided jointly by the CFS Manitoba and Saskatchewan District offices and is gratefully acknowledged; special thanks to District Managers J.A. McQueen (Winnipeg) and R. Fautley (Prince Albert) in this regard. The continued assistance of D.A. Vandevyvere, C. Klaponski and R. Raddatz of AES with local arrangements is sincerely appreciated. Also, special thanks are necessary for M.E. Alexander and

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[1] Proceedings for each of the first three Western Region Fire Weather Committee Scientific and Technical Seminars were compiled and distributed on a limited basis by M.E. Alexander of the Northern Forestry Centre, 5320-122 Street, Edmonton, Alberta, T6H 3S5

W.J. DeGroot for their guidance and assistance. Finally, I would like to thank S. Sokol for her fine efforts with the word processing associated with the production of this report.

Kelvin G. Hirsch[2]
CRFWC Seminar Coordinator

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[2] Fire Research Officer, Canadian Forestry Service, Manitoba District Office, 104-180 Main Street, Winnipeg, Manitoba, R3C 1A6

INTERPRETING THE CANADIAN FOREST FIRE WEATHER INDEX (FWI) SYSTEM[1]

by

William J. De Groot[2]

Introduction

Fire danger is defined by the Canadian Committee on Forest Fire Management (Merrill and Alexander 1987) as:

> A general term used to express an assessment of both fixed and variable factors of the fire environment which determine the ease of ignition, rate of spread, difficulty of control and fire impact.

The Canadian Forest Fire Danger Rating System (CFFDRS) is the national system for rating fire danger in Canada. The Canadian Forest Fire Weather Index (FWI) System is a sub-system of the CFFDRS and has been in its present form since 1970, with the fourth version of the tables for the FWI System now being used (Canadian Forestry Service 1984; Van Wagner 1987). The purpose of the FWI System is to account for the effects of weather on forest fuels and forest fires. Other factors affecting fire danger (i.e., fuels, topography) are dealt with elsewhere in the CFFDRS.

The FWI System is comprised of six components (see Fig. 1): three fuel moisture codes and three fire behavior indexes. Each component has its own scale of relative values. Even though the scales for the six components are different, all are structured so that a high value indicates more severe burning conditions.

The FWI System uses temperature, relatively humidity, wind speed, and 24-hr precipitation values measured at noon Local Standard Time (LST). These values are used to predict the peak burning conditions that will occur during the heat of the day, near 1600 h LST, assuming that the measured weather parameters follow a normal diurnal pattern (Turner and Lawson 1978; Van Wagner 1987).

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[1] A presentation made at the Fourth Central Region Fire Weather Committee Scientific and Technical Seminar, April 2, 1987, Winnipeg, Manitoba.

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

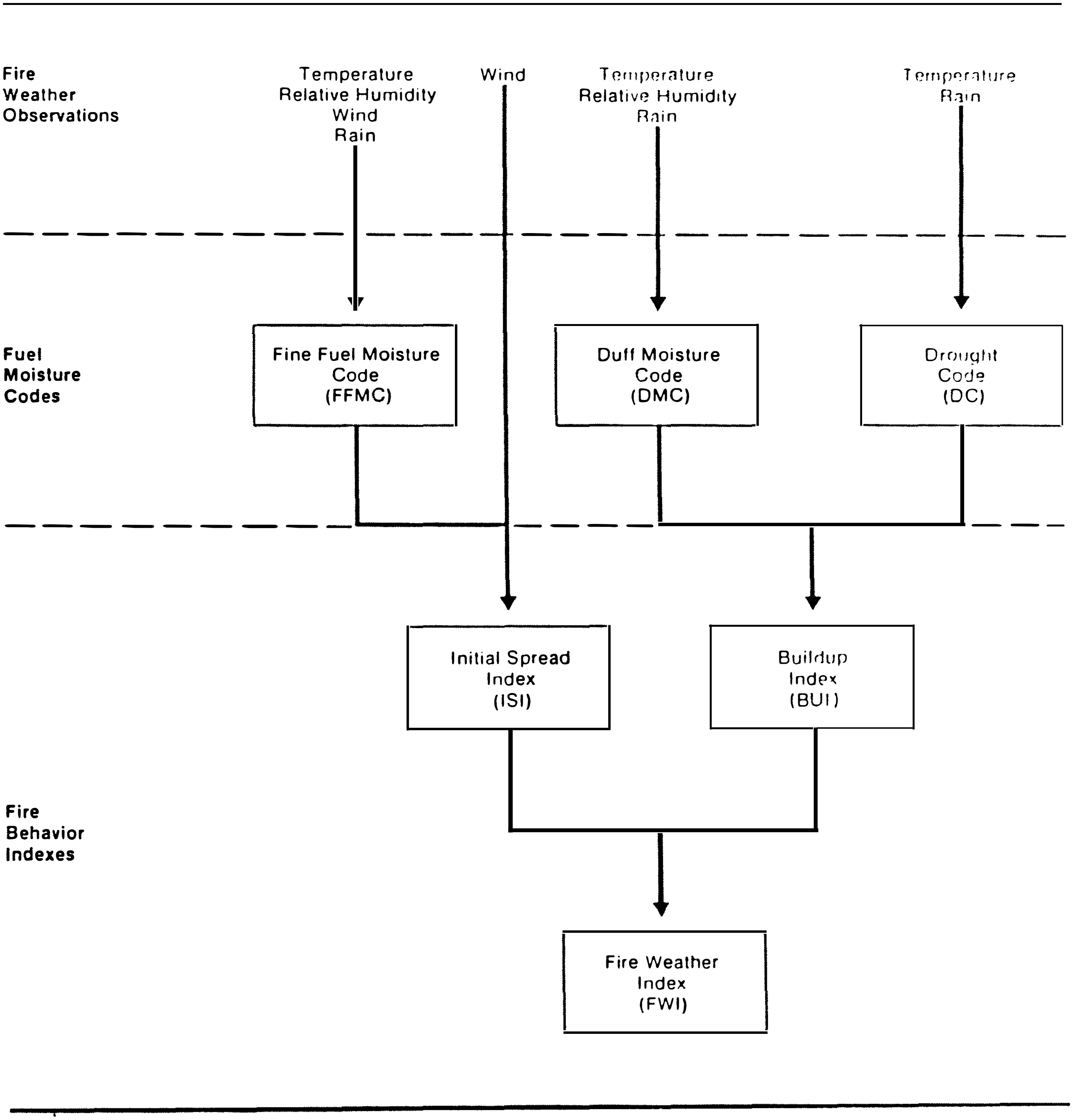

Figure 1. Structure of the Canadian Forest Fire Weather Index (FWI) System.

Fuel Moisture Codes

The FWI System evaluates fuel moisture content and relative fire behavior using the past and present effect of weather on forest floor fuels. The three moisture codes represent the fuel moisture content of three classes of forest floor fuels in the "standard" mature pine stand (Fig. 2). The moisture codes calculate the net effect of a daily drying and wetting phase, similar to a bookkeeping system of moisture losses and additions.

Fine Fuel Moisture Code (FFMC)

The FFMC is a numerical rating of the moisture content of litter and other cured fine fuels (needles, mosses, twigs less than 1 cm in diameter). The FFMC is representative of the top litter layer 1-2 cm deep, and has a typical fuel loading of about 5 tonnes per hectare (t/ha).

FFMC fuels are affected by temperature, wind speed, relative humidity, and rain. However, to account for the interception of rain by the forest canopy, the wetting phase of the FFMC is not initiated if the 24-hr rainfall is 0.5 mm or less.

The rate at which fuels lose moisture is measured in terms of timelag, similar to the 'half-life' decay rate of radioactive material. Timelag is the time required for fuel to lose two-thirds of its free moisture content with a noon temperature reading of 21°C, relative humidity of 45%, and a wind speed of 13 km/h (Lawson 1977). The timelag for **FFMC** fuels is two-thirds of a day.

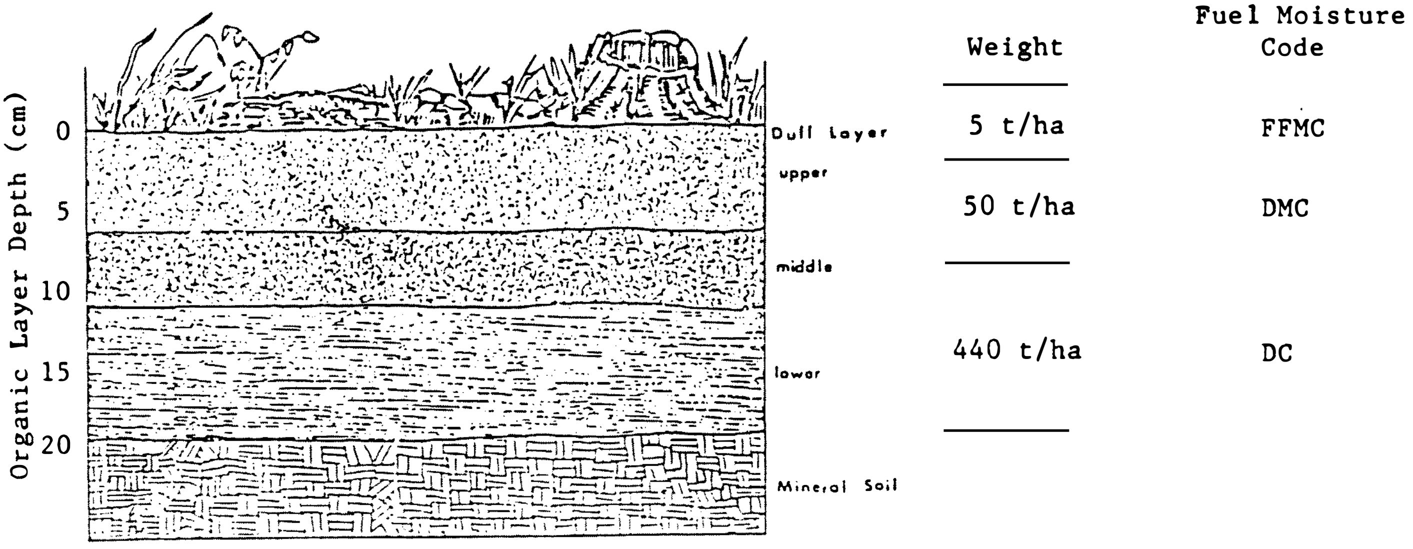

Figure 2. Representation of forest floor fuels by Fuel Moisture Codes of the FWI System.

FFMC values change rapidly because of a high surface area to volume ratio, and direct exposure to changing environmental conditions. This characteristic of rapidly changing moisture content causes the FFMC to have a short-term memory and only reflects the weather conditions that have occurred over the past three days.

The FFMC can be adjusted for times other than 1600 h LST (Van Wagner 1972, 1977; Alexander 1982a; Alexander et al. 1984) to account for changing moisture content of the fine fuels throughout the day or to allow for an irregular diurnal pattern of temperature or humidity.

Because fires usually start and spread in fine fuels, the FFMC is used to indicate ease of ignition, or ignition probability (Fig. 3). The FFMC scale ranges from 0-99 and is the only component of the FWI System which does not have an open-ended scale. Generally, fires begin to ignite at FFMC values near 70, and the maximum probable value that will ever be achieved is 96. At the high end of the scale, a general rule of thumb is that the fuel moisture content is 101 minus the FFMC value. Of importance is the fact that fire starts increase exponentially with an increase in FFMC values at the high end of the scale. In the boreal forest, a high potential for fire starts exists once the FFMC reaches 86-89.

Duff Moisture Code (DMC)

The DMC indicates the moisture content of loosely-compacted organic layers of moderate depth. It is representative of the duff layer that is 5-10 cm deep, and has a fuel loading of about 50 t/ha.

DMC fuels are affected by rain, temperature and relative humidity. Because these fuels are below the forest floor

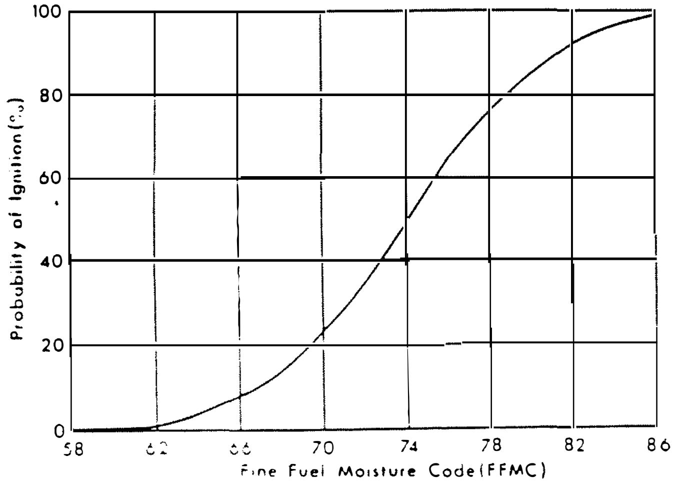

Figure 3. Ignitability of 'shaded' slash pine needle litter under 'no wind' conditions as a function of the Fine Fuel Moisture Code (adapted from Blackmarr 1972 by M.E. Alexander based on Van Wagner 1987).

surface, wind speed does not affect the fuel moisture content. A 24-hr rainfall of less than 1.5 mm has no effect on the DMC because of interception by the forest canopy and the fine fuel layer.

The DMC fuels have a slower drying rate than the FFMC fuels, with a timelag of 12 days. Due to the slower drying rate, the length of daily drying time is important. Therefore, a seasonal day-length factor has been incorporated into the drying phase of the DMC.

Although the DMC has an open-ended scale, the highest probable value is in the range of 150. The DMC is often used to assist in predicting the probability of lightning fire starts (Fig. 4) since lightning strikes usually result in fires smoldering in the duff layer.

Drought Code (DC)

The third moisture code is the DC, and it is an indicator of moisture content in deep, compact organic layers. This code represents the fuel layer approximately 10-20 cm deep, having a fuel loading of about 440 t/ha.

Temperature and rain affect the DC, although wind speed and relative humidity do not because of the depth of this fuel layer. A 24-hr rainfall greater than 2.8 mm is required to affect the moisture content due to interception by upper fuel layers and the forest canopy.

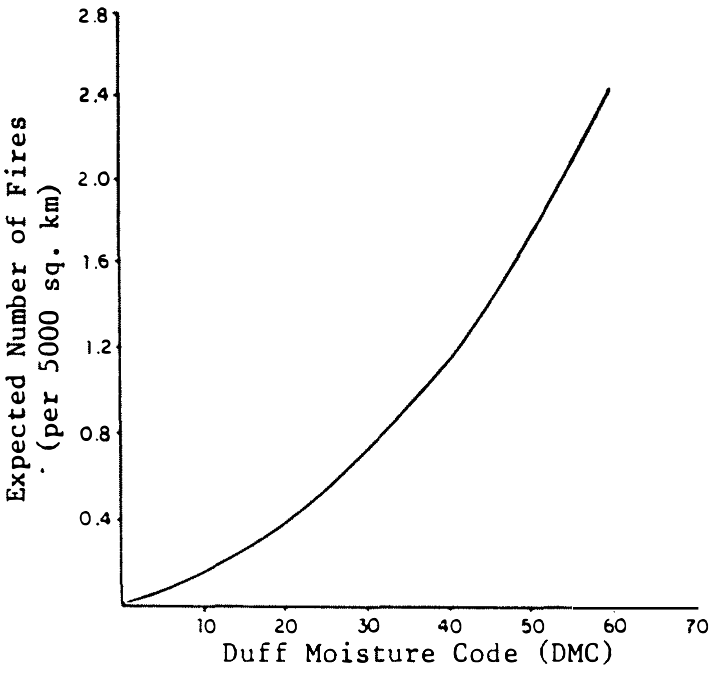

Figure 4. Typical relationship between DMC and lightning fire starts (adapted from Martell 1976).

The DC fuels have a very slow drying rate, with a timelag of 52 days. Therefore, a seasonal day-length factor is also incorporated in the drying phase.

The DC is indicative of long-term moisture conditions and can be used in estimating mop-up difficulty due to deep burning fires (Table 1). The DC scale is open-ended, although the maximum probable value is about 800.

Because of the slow drying rate of DC fuels, the amount of overwinter precipitation is critical to calculating spring starting values. If there has not been sufficient overwinter precipitation to recharge moisture levels in the deep organic layers, then an upward adjustment of the DC in the spring must be done to reflect the drier conditions (Turner and Lawson 1978; Alexander 1982b, 1983).

Table 2 provides a summary of features for all the Fuel Moisture Codes.

Fire Behavior Indices

Initial Spread Index (ISI)

The ISI combines the FFMC and wind speed to indicate the expected rate of fire spread (Fig. 5). Generally, a 13 km/h increase in wind speed will double the ISI value. The ISI is accepted as a good indicator of fire spread in open light-fuel stands with wind speeds up to 40 km/h.

Table 1. Mop-up recommendations as determined by the Drought Code (adapted after Muraro and Lawson 1970; Canadian Forestry Service, 1971).

DC	INTERPRETATION
< 300	Moisture will increase with depth. Usual attention to mop-up and patrol, with closer attention to critical perimeters as a DC value of 300 is approached.
300 - 500	Moisture content may decrease with depth. Extensive mop-up of edges should be initiated as control problems could be posed by critical edges.
> 500	Moisture content will most likely decrease with depth. Extensive mop-up and patrol of all edges is required.

TABLE 2. Summary of Fuel Moisture Code Features.

ITEM	FFMC	DMC	DC
Fuel Association	litter and other cured fine fuels	loosely-compacted organic layers of moderate depth	deep, compact organic layers
Fire Potential Indicator	ease of ignition	probability of lightning fires; fuel consumption in moderate duff	mop-up difficulty; fuel consumption of deep organic material
Depth (cm)	1 - 2	5 - 10	10 - 20
Fuel Loading (t/ha)	5	50	440
Required Weather Inputs:			
Dry-bulb Temperature	X	X	X
Relative Humidity	X	X	
Wind Speed	X		
Rain	X	X	X
24-hour Rainfall Threshold (mm)	0.5	1.4	2.8
Timelag Constant (days)	2/3	12	52
Value Range	0 - 99	0 - 350[1]	0 - 1200[1]
Maximum Probable Value	96	150	800
Spring Starting Value	85	6	15[2]

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[1] An open-end scale; the upper value is shown for convenience of comparing the relative range of scales.

[2] This value may be adjusted upwards to account for lack of sufficient overwinter precipitation.

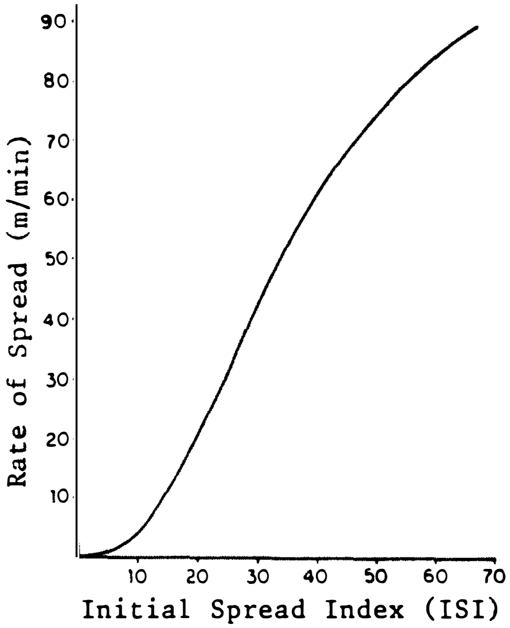

Figure 5. Rate of spread for the mature jack or lodgepole pine fuel type on level terrain as a function of ISI (from Alexander, Lawson, Stocks and Van Wagner 1984).

Buildup Index (BUI)

The BUI is a weighted combination of the DMC and DC to indicate the total amount of fuel available for combustion by a moving flame front (Fig. 6). The DMC has the most influence on the BUI value. For example, a DMC value of zero always results in a BUI value of zero regardless of what the DC value is. The DC has strongest influence on the BUI at high DMC values, and the greatest effect that the DC can have is to make the BUI value equal to twice the DMC value. This weighting procedure makes the BUI an upper organic layer moisture monitor with a deep duff indicator built in. The BUI is often used for presuppression planning purposes.

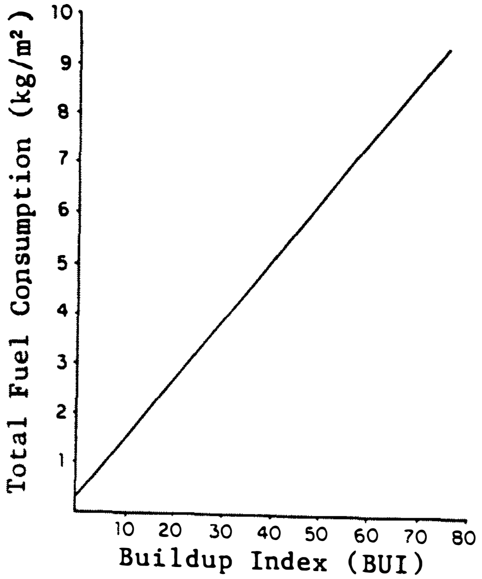

Figure 6. Relationship between total fuel consumption and BUI in jack pine slash (from Stocks and Walker 1972).

Fire Weather Index (FWI)

The FWI is a combination of ISI and BUI, and is a numerical rating of the potential frontal fire intensity (Fig. 7). In effect, it indicates fire intensity by combining the rate of fire spread with the amount of fuel being consumed. Frontal fire intensity is useful for determining fire suppression requirements, as shown in Alexander and De Groot (1988). As well, the FWI is used for general public information about fire danger conditions.

Operational Application

The FWI System provides relative numerical ratings of fire potential over a large area represented by an individual fire weather station site. Understanding the limits of such a system will ensure its proper application. For instance, to account for isolated rainfall at a weather station, the fire manager must also calculate a second set of FWI System values using no-rain to represent areas which did not receive any precipitation (the calculation using the actual rainfall at the weather station is used for the following days calculation). A recalculation of the FWI System would also have to be done if normal diurnal conditions did not occur between noon and the peak burning period. For example, this would typically be done after a frontal passage and would only be valid for that afternoon (but not used for the following days calculation).

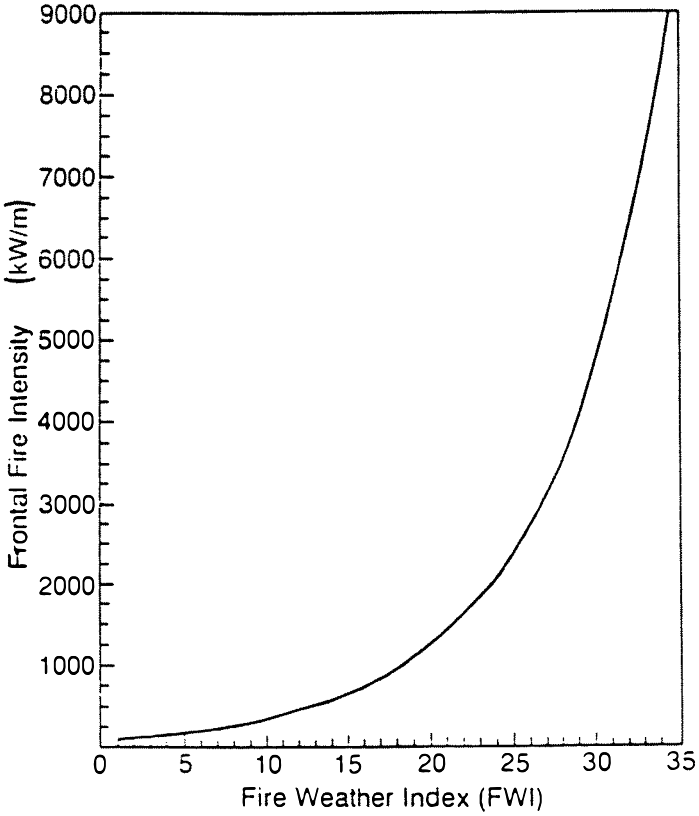

Figure 7. Frontal fire intensity in mature jack pine as a function of the FWI (from Alexander and De Groot 1988).

Concluding Remarks

An understanding of the sensitivity of the FWI System can only be gained by daily observation of the component values and changing weather conditions. By comparing fire activity (fire starts, rate of spread, difficulty of control, etc.) to the values produced by the FWI System, fire managers will gain an expertise in interpreting the FWI System.

ACKNOWLEDGEMENT

Slides for this presentation were obtained from a previous publication by Lawson (1977). The comparative effects of different FWI System component values were illustrated with slides from the Darwin Lake and Big Fish Lake Experimental Burning Projects which were conducted jointly by the Canadian Forestry Service and Alberta Forest Service.

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THE MINISONDE AS A MANAGEMENT TOOL IN PLANNING AND CONDUCTING A PRESCRIBED BURN[1,2]

by

Howard G. Wailes[3]

Introduction

The study of the relationship of uppper winds and lapse rates to fire behavior can assist the Fire Behavior Specialist and improve many of the planning aspects of a prescribed burn. Upper air data used for fire behavior modelling has for many years been, as a result of necessity, obtained from upper air observing stations operated by federal government agencies in both Canada and U.S.A. These observing stations are part of a worldwide network whose operations are overseen by the World Meteorological Organization (WMO) in Switzerland.

At each of these stations two observations are taken simultaneously each day at 0000 h Greenwich Mean Time (GMT), which is 0800 h Eastern Daylight Time (EDT) and 1200 h GMT or 2000 h EDT. For prescribed burns conducted by the Ontario Ministry of Natural Resources (OMNR) these observation times could not be more inappropriate. Most prescribed burns are now ignited between 1300 h and 1900 h EDT during which time the temperature and wind in the portion of the atmosphere lying generally below 2000 m undergoes rather large diurnal changes. It is obvious that upper air data gathered at 0800 h EDT would be of little use, or even misleading, in predicting fire behavior for a prescribed burn being ignited at, for example, 1600 h EDT, after eight hours of atmospheric modification. Also of concern is the need to extrapolate the data from these sites, as is often the case in Canada, over a distance of several hundred miles to the prescribed burn site. This often proves impractical when, for example, a frontal zone exists between the two locations.

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[1] Summary of a presentation made at the Fourth Central Region Fire Weather Committee Scientific and Technical Seminar, April 2, 1987, Winnipeg, Manitoba.

[2] This paper was also presented at "Forest Climate '86: A Symposium/Workshop on Climate Application in Forest Renewal and Forest Protection", Nov. 17-20, 1986, Geneva Park, Orillia, Ontario.

[3] Fire Weather Technician, Ontario Ministry of Natural Resources, Northern Region, R.R.#2, Timmins, Ontario
P4N 7C3.

This paper will look at a typical minisonde as it pertains to prescribed burning operations in order to see what it does and how its portability overcomes the problems of space and time that are commonly found in the upper air data from WMO stations. The approach of this study is empirical and it appears that it will be continuing for a number of years. Therefore, this paper should be regarded as only an introduction to the topic and the results and conclusions should be carefully scrutinized.

The Minisonde And Its Operation

The minisonde used by the OMNR consists of four major parts. They are:

(1) the airborne radio transmitter with integrated temperature sensor,
(2) a balloon to carry the transmitter aloft,
(3) a radio receiver and processor, and
(4) a printer (manufactured by Aero-Aqua Inc., Markham, Ontario).[4]

Also required are a balloon tracking theodolite (manufactured by Breithaupt, West Germany)[4] and a Sharp 1500A[4] hand-held computer.

The transmitter is powered by a small 9 volt transistor radio type battery. The receiver and printer both contain (rechargeable) high capacity gel batteries that can operate the equipment for at least three days of normal operation. With a vehicle in which the equipment is housed and from which to properly operate it, upper air soundings can be taken within a mile of two of the prescribed burn site and at the time that is most appropriate for obtaining the necessary information. The balloon is inflated sufficiently to lift the transmitter at a rate of 180 m/min. The recording chart is driven at a constant speed and it is therefore easy to analyze the chart as a graph with temperature along the "x" axis and height as the "y" axis. The specially designed theodolite that is used for tracking the balloons is used to take readings of azmuth and elevation during each minute of the balloon's ascent. From these values and the known rate of ascent the upper winds are calculated.

APPLICATION

The information provided by the minisonde has its

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[4] The exclusion of certain manufactured products does not imply rejection nor does the mention of other products imply endorsement by the Canadian Forestry Service.

best application when it can be used as a management tool in the decision-making process for a prescribed burn. A Fire Boss must provide answers or make decisions concerning many questions prior to a prescribed burn being conducted. Some of these questions are answered only after an analysis of the upper air data in terms of stability and wind profile in a time frame of one hour or less before the time of ignition. Some of the questions are as follows.

(1) Can the prescribed burn be conducted effectively and safely under the present and forecasted weather conditions?
(2) How will the smoke affect the air support operations around the fire during ignition and later during possible suppression operations?
(3) Will local smoke affect sensitive areas such as airports, and cities?
(4) What will the spotting potential be as a result of the upper level wind speed and direction?
(5) How vigorous will the convective column and the fire intensity be?
(6) Will the convective column be conducive to extreme fire whirl generation?

The minisonde is very useful with respect to prescribed burns, however it also has some importance in wildfire situations. This is especially true in providing the fire crews and base camp personnel with information which would ensure the highest possible degree of safety while they are performing their duties.

SOME PRELIMINARY FINDINGS

The method of using this data in problem solving in OMNR operations is still quite subjective, and possibly to some extent, intuitive as a consequence of previous experiences. The relationship of fire behavior and associated wind profiles from work by Byram (1954) is used presently as a basis for some predictions but it is undergoing constant scrutiny as part of the OMNR minisonde program.

As far as stability is concerned, it has been found that severe whirlwinds occur most often when winds are 15 km/h or less through the lower 1000 to 1500 m of the atmosphere with a lapse rate close to or greater than 1°C per 100 m through that same depth. This layer is usually capped by a stable layer of at least 500 m.

For centre fire ignition, an unstable layer from the surface to at least 600 m is required, with a shallow layer next to the surface having a lapse rate greater than 1°C per 100 m. This lower layer is usually in the order of 15 to 20 m in depth. The winds are 15 to 20 km/h or less below 600 m dropping to less than 10 km/h at the surface.

It has also been found that a temperature change of as small a magnitude of 3°C at the surface can significantly alter the smoke column and consequently fire intensity in small fires where smoke column tops are below 2000 m.

Concluding Remarks

I feel that the experience gained from this program will enhance the mathematical models now present, and those yet to be written, to further describe fire behavior in more detailed terms than has previously been possible, when less accurate upper air data was used.

References Cited

Byram, G.M. 1954. Atmospheric conditions related to blow-up fires. U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, Ashville, North Carolina. Station Paper No. 35. 34 p.

RECENT DEVELOPMENTS IN THE CANADIAN FOREST FIRE DANGER RATING SYSTEM[1]

by

Robert S. McAlpine and Martin E. Alexander[2]

Introduction

Fire danger is "a general term used to express an assessment of both fixed and variable factors of the fire environment which determine the ease of ignition, rate of spread, difficulty of control, and fire impact" (Merrill and Alexander 1987). Fixed fire danger factors more or less vary from place-to-place at a given time (e.g., topography, values-at risk, fire climate, fuel types). It is the object of presuppression planning to take these constant elements into account in permanent fire management plans as part of an assessment of "total fire danger". Variable fire danger factors on the other hand vary from time to time (throughout the day and from day to day) at any given place (e.g., temperature, relative humidity, wind, precipitation, condition of herbaceous vegetation, fuel moisture). The purpose of a fire danger rating system is to properly integrate the individual and combined effects of these factors on fire potential into one or more qualitative and/or numerical indices as a guide in various fire management activities. However, both practical and scientific considerations limit the number of variables that can be accounted for in a fire danger rating system. It is common human experience that not more than three factors can be kept in mind at any one time. Consequently, the use of objective devices to simplify the mental process of bringing together all the significant factors affecting fire danger is sound. A further, stronger supporting argument, which is often overlooked, is the advantage of substituting an objective method for the opinions of individuals in justifying requested fire expenditures.

The historical basis for the present system of forest fire danger rating or measurement in Canada can be traced back to at least 1925 when J.G. Wright (considered the "father" of Canadian fire research) published a paper entitled "Relative Humidity and Fire Weather". The initial fire danger index system was produced by Wright in 1933. Wright was soon joined in the research and development

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[1] Summary of a presentation made by the first author at the Fourth Central Region Fire Weather Committee Scientific and Technical Seminar, April 2, 1987, Winnipeg, Manitoba.

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

work by H.W. Beall and eventually others (Van Wagner 1987c). Successive systems were gradually produced -- these became progressively more sophisticated while still retaining the very essential element of simplicity. The present system of forest fire danger rating in Canada -- the Canadian Forest Fire Danger Rating System (abbreviated CFFDRS) -- represents the fifth generation of such systems. The purpose of this paper is to review the current status and future outlook of the various modules or sub-systems of the CFFDRS. A similar report was presented at the first Central Region Fire Weather Committee scientific and technical seminar in 1984 (Alexander 1985a).

Current System Structure and Composition

The Canadian Forest Fire Danger Rating System (Stocks 1986) has been under development in its present form since 1968 when the Canadian Forestry Service (CFS) adopted a "modular" approach to a new national system of fire danger rating (Fig. 1)[3]. The CFFDRS is one of the few nationally applied systems in Canadian forestry. In fact, the CFFDRS represents the only "true" national system of fire danger rating in the world. The CFFDRS will ultimately form the basic building block for many other systems or schemes (Fig. 2) developed by fire management agencies (e.g., Anon. 1983; Gray and Janz 1985; Lanoville 1986 -- a highly attractive color poster has also been recently produced by NWT Fire Management) and fire research (e.g., Stechishen et al. 1982; Kourtz 1984, 1987; Martell et al. 1984a, 1984b; De Groot 1988b; Feunekes and Methven 1988). Concept-

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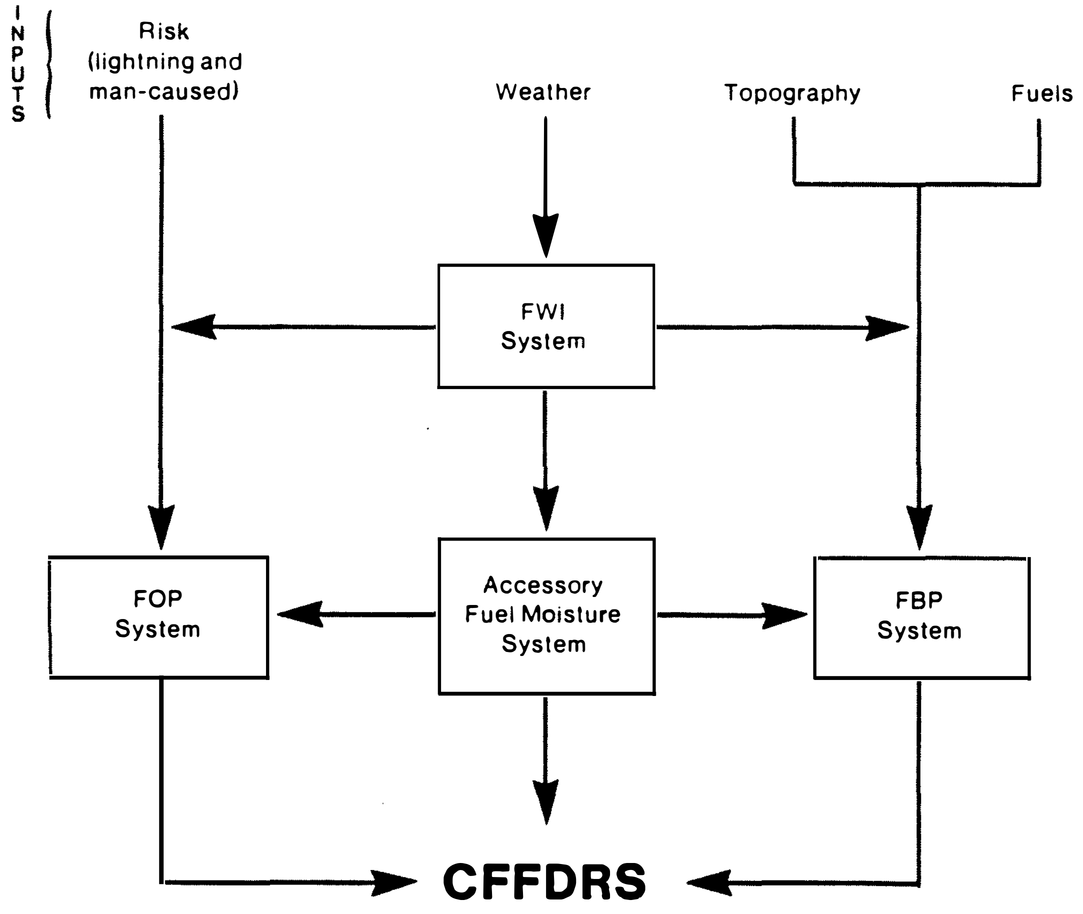
[3] Since its inception, the responsibility for continued development of the CFFDRS has rested with what has traditionally been referred to as the "CFS Fire Danger Group". The CFS Fire Danger Group presently consists of at least one representative from each of the three regional forestry centres maintaining an in-house fire research programme (i.e., Northern, Great Lakes, and Pacific) and the Petawawa National Forestry Institute. This group maintains liaison with regional, national, and international fire organizations, committees and agencies including annual reporting to the Canadian Committee on Forest Fire Management (the national body responsible for advising the federal government on fire research needs), to ensure research, development and application of the CFFDRS continues in a timely and relevant manner. This former *ad hoc* group of CFS fire researchers was officially recognized as a formal national CFS Working Group in February 1987. As a result this group has prepared "A Strategic and Operational Plan for Forest Fire Danger Rating Research and Development in Canada, 1987-1992" (Stocks and others 1987) which in effects an earlier (1982) document entitled "Proposed Extension of the Canadian Forest Fire Danger Rating System".

STRUCTURE OF THE CANADIAN FOREST FIRE DANGER RATING SYSTEM (CFFDRS)



CFFDRS subsystems	Status
Canadian Forest Fire Weather Index (FWI) System	4th edition published in 1984.
Canadian Forest Fire Behavior Prediction (FBP) System	Interim edition released in 1984. First complete version planned in 1987-8.
Canadian Forest Fire Occurrence Prediction (FOP) System	Under consideration. Several regional schemes in place.
Accessory Fuel Moisture System	In various stages of development.

Figure 1. Simplistic structure diagram of the Canadian Forest Fire Danger Rating System (CFFDRS) as currently envisioned by the Canadian Forestry Service Fire Danger Group (from Canadian Forestry Service 1987).

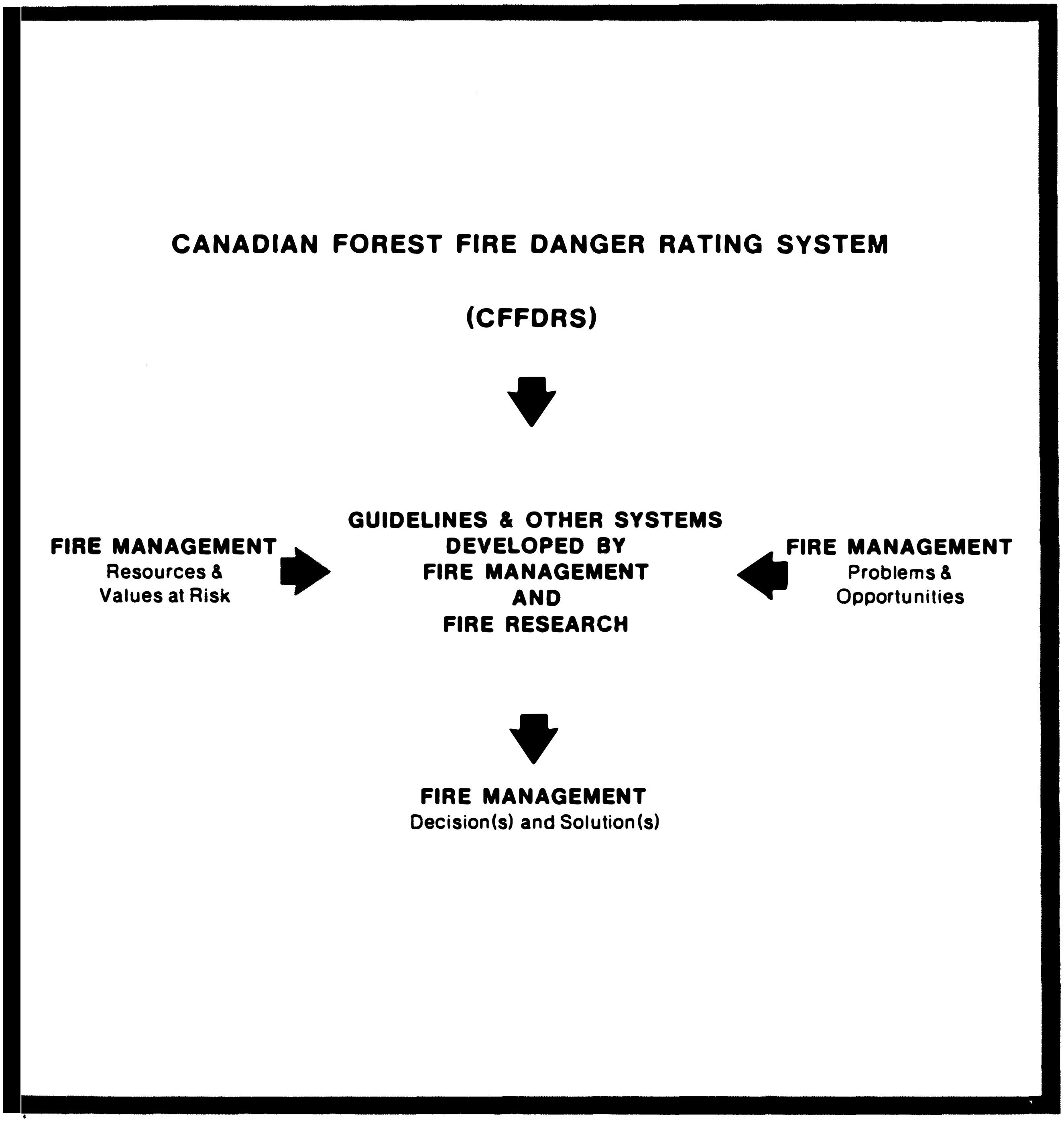


Figure 2. Conceptual framework illustrating the integral role of the Canadian Forest Fire Danger Rating System (CFFDRS) in fire management actions as envisioned by the Canadian Foresty Service Fire Danger Group (from Canadian Forestry Service 1987).

Conceptually, the CFFDRS will consist of a series of Forestry Technical Reports (FTR) published by CFS Headquarters (e.g., Canadian Forestry Service 1984; Van Wagner and Pickett 1985; Van Wagner 1987a) in both English and French. All such "national" publications will collectively form the CFFDRS. A CFFDRS users' guide consisting of a 3-ring binder, which will house all of these reports (which will eventually appear as FTRs) and related materials (e.g., Turner and Lawson 1978; Alexander and others 1984; Alexander 1986a) is currently being prepared for distribution (Canadian Forestry Service 1987). Provision has also been made for additional publications related to the CFFDRS produced at the regional level (e.g., DeGroot 1987a, 1987b, 1988a, 1988b; Hirsch 1987a, 1987b, 1988a, 1988b).

Canadian Forest Fire Weather Index (FWI) System

The first major module or sub-system of the CFFDRS, the Canadian Forest Fire Weather Index (FWI) System (Van Wagner 1987a), was initially released in provisional form in 1969. The first edition appeared in 1970 with subsequent editions appearing in 1976 (first metric version), 1978 and 1984. In many ways, the FWI System represents the culmination of Canadian fire danger rating research dating back to 1925. The system is based largely on field experimentation and observation with predictive components prepared from empirical correlations between fire weather elements, fuel moisture and fire behavior (i.e., 15,000 2-minute outdoor test fires plus 21 larger ones and a great mass of fuel moisture data linked to weather readings). A liberal amount of simple theory and philosophy was applied where necessary (Van Wagner 1987a).

The FWI System consists of six components that account for the effects of fuel moisture and wind on fire behavior. The three fuel moisture codes are the Fine Fuel Moisture Code (FFMC), Duff Moisture Code (DMC), and Drought Code (DC) and they are numerical ratings of the fuel moisture content of the fine surface litter, loosely compacted duff of moderate depth, and deep compact organic matter. The three fire behavior indexes, namely, the Initial Spread Index (ISI), Buildup Index (BUI), and Fire Weather Index (FWI) component itself, are intended to represent the rate of fire spread, fuel available for combustion, and frontal fire intensity.

Several computer programs (Van Wagner and Pickett 1985; McAlpine 1986b, 1987a, 1987b)[4] are available for

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[4] A user-friendly program (written in BASIC) for calculating FWI System components and archiving daily fire weather observations has been developed for the IBM-PC (Bryan S. Lee, Fire Research Officer, Canadian Forestry Service, Western and Northern Region, Northern Forestry Centre, Edmonton, Alberta, personal communication).

calculating the six components comprising the FWI System based on daily 1200 h LST observations of dry-bulb temperature, relative humidity, 10-m open wind speed, and 24-h accumulated rainfall in lieu of using the FWI System tables (Canadian Forestry Service 1984). FWI System components provide numerical ratings of relative fire potential in a standard fuel type (i.e., a mature pine stand) on level terrain based on the effects of past and current weather on fuel flammability (Alexander and DeGroot 1988). Since its introduction, the FWI System has been used with increasing confidence as a guide to planning and preparing for fire management activities (Kiil et al. 1986). The FWI component is still widely used as a general index to fire danger throughout the forested areas of Canada (Table 1). Harvey and others (1986) offer an overview of FWI severity rating and its application.

Canadian Forest Fire Behavior Prediction (FBP) System

Because the FWI System was developed to portray the influence of weather on fire behavior in a stylized fuel complex, on level ground, the same component value will obviously have different meanings among fuel types. The second major subsystem of the CFFDRS was conceived, in the original modular approach (Muraro 1969), as a series of regionally developed guides to actual (rather than relative) fire behavior characteristics in specific fuel types. Quantitative models for predicting fire behavior in absolute terms for specific fuel types have been under development for a number of years in Canada and are intended to form an integral part of the CFFDRS. The procedure for gathering fire behavior data has been to conduct a series of relatively small-scale experimental fires in the fuel type of interest over as wide a range in burning conditions (as reflected by the FWI System components) as possible (e.g., Stocks 1987b). The experimental data would then be supplemented with information obtained from well-documented wildfires and prescribed fires; particularly for the high to extreme end of the fire behavior scale. Although the approach to the development of such guides was coordinated nationally (e.g., uniform methodology), the preparation and publication of guidelines for wildfire and prescribed fire management in key fuel types regionally was deemed to be the responsibility of each CFS regional fire research unit. Work began in 1981 on a slightly revised approach to such a scheme, but on a national basis. Towards this end, an interim edition of the Canadian Forest Fire Behavior Prediction (FBP) System was released in the summer of 1984. Thus, the regional emphasis on quantitative fire behavior prediction in the CFFDRS was replaced by the FBP System.

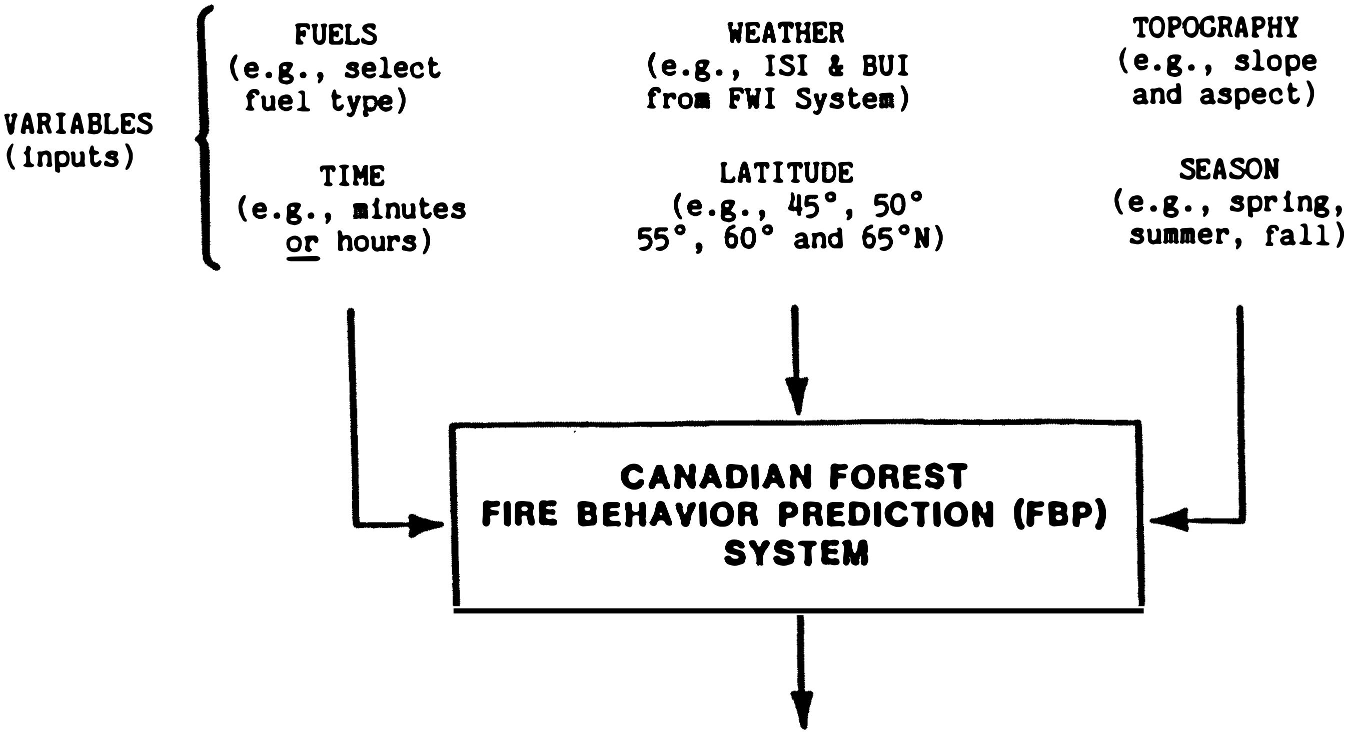
The FBP System consists of four primary and three secondary components (Fig. 3). An interim edition of the

Table 1. General progression of fire behavior characteristics which are likely to occur as the class of fire danger increases from **VERY LOW** to **EXTREME** (adapted from **Canadian Forestry Service 1970).** If 4 or 5 classes are desired, **LOW** may be combined with **VERY LOW** and **HIGH** may be combined with **VERY HIGH.** The descriptions given below would be appropriate for public interpretation of fire danger classes.

Fire Danger Class	Associated Fire Behavior Characteristcs
I *Very Low* Green	Fires are not likely to start. If started, they spread very slowly or may go out. There is little flaming combustion and generally only the upper portion of the litter is consumed.[1] Control is readily achieved and little or no mop-up is required.
II *Low* Green	Ignition may take place near prolonged heat sources (campfires, etc.); spread is slow in forests, moderate in open areas; these are light surface fires, with low flames; generally, the litter layer is consumed.[1] Control is readily achieved, and some light mop-up will be required.
III *Moderate* Blue	Flaming matches etc., may start fires; spread is moderate in forests, fast in open areas; fires burn on the surface with moderate flames; some of the duff may be consumed on dry sites. Control is not difficult and light to moderate mop-up will be necessary.
IV *High* Yellow	Flaming matches will probably start fires; spread may be fast in the forest though not for sustained periods; these are hot surface fires with some individual tree crowns being consumed; "short range" spotting may occur; much of the duff will be consumed on shallow and dry sites. Control may be difficult, and mop-up may require a moderate effort.
V *Very High* Orange	Ignition can occur readily; spread will be fast for sustained periods. Fires may be very hot, with local crowning and "medium range" spotting. Much of the duff will be consumed on moderately deep and normally moist sites. Control will be very difficult and mop-up may require an extended effort.
VI *Extreme* Red	Ignition can occur from sparks; rates of spread will be extremely fast for extended periods; fires will be extremely hot and there may be extensive crowning and "long range" spotting; much of the duff will be consumed on deep and normally wet sites.[2] Control may not be possible during the day and mop-up may be very extensive and difficult.

[1] It is important to note that with a high Drought Code (DC) & Buildup Index (BUI) there may be considerable smouldering throughout the entire organice layer despite a low Fire Weather Index (FWI) value.

[2] Assuming that the DC is high.



	Fire Behavior Element	Unit(s) or Output
Primary Components	RATE OF SPREAD (ROS)	m/min; km/h
	FUEL CONSUMPTION (FC)	kg/m^2; +/ha
	FRONTAL FIRE INTENSITY (FFI)	kW/m
	TYPE OF FIRE	surface <u>or</u> crown
Secondary Components	FIRE SPREAD DISTANCES (D)	m; km
	ELLIPTICAL FIRE AREA (A)	ha
	ELLIPTICAL FIRE PERIMETER LENGTH (P)	m; km

FIGURE 3. Proposed structure of the first edition of the Canadian Forest Fire Behavior Prediction (FBP) System as currently envisioned by the Canadian Forestry Service Fire Danger Group (prepared for distribution at the 1987 Annual Meeting of the Canadian Committee on Forest Fire Management held January 27-29 in Halifax, Nova Scotia.

system appeared in 1984 in the form of a user guide prepared by the CFS Fire Danger Group (Alexander and others 1984). An overview has also been published (Lawson et al. 1985). Both of these documents should be consulted for comprehensive treatments of the system. The FBP System was released in interim form to: (1) avoid any further delay in transmittal of the existing information on quantitative prediction of fire spread and growth and (2) for field testing and evaluation by fire management agencies prior to formal publication of the complete version of the FBP System.

The main emphasis in the 1984 interim edition of the FBP System was on "steady state" fire spread rates on level to gently undulating ground (Fig. 4). The principal input variable is the ISI component of the FWI System which combines the effects of wind and the FFMC on fire spread (Fig. 5). Head fire ROS/ISI relationships were developed for 14 major Canadian fuel types (Table 2) from a data base consisting of 245 experimental/operational prescribed fire and 45 wildfire observations. The ROS value from the FBP System can be adjusted for the effect of slope simply by multiplying the predicted value by the relative spread factor given by Van Wagner (1977b).

Fuel types in the FBP System, consisting of five major groups (i.e., Coniferous - C, Deciduous - D, Mixedwood - M, Slash - S, and Open - O), are described mainly in qualitative terms. Note that the fuel type names are to a certain degree simply labels. As indicated by Lawson et al. (1985), each of the fuel types will eventually be illustrated with representative color photographs and a composite wall poster. De Groot (1987a) and Hirsch (1988a) have produced earlier versions of the latter specifically for the provinces of Saskatchewan and Manitoba based on guidance received from the CFS Fire Danger Group. The number of fuel types currently recognized in the system simply reflects the amount of empirical fire behavior data available on fuel types in Canada. Eventually, other important fuel types will be added as further experimental burning projects are undertaken. However, one should not expect an enormous number of new ones to be added in the next several years. It's no secret that the boreal and "near-boreal" forest situations are quite adequately covered by the system's present series of fuel types. **It's worth emphasizing that proper application of the FBP System requires a thorough familiarization with the written descriptions of each fuel type.** It was recognized that these descriptions would be used by fire managers for equating FBP System fuel types to existing forest inventory/site classification schemes (e.g., De Groot 1988a), including the production of FBP System fuel type maps (e.g. Dixon et al. 1984; Gorley 1985).

The FBP System user guide (Alexander and others 1984)

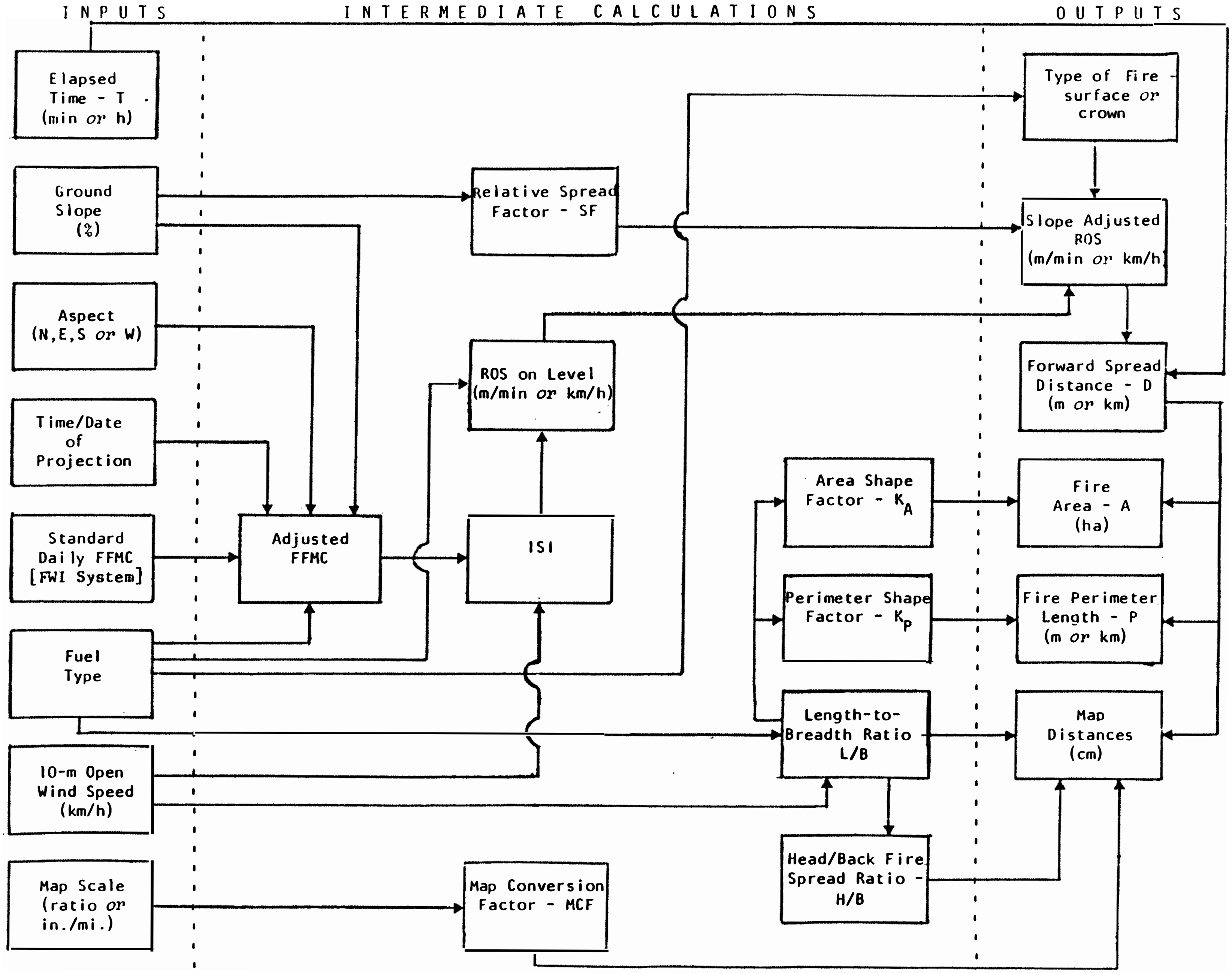


FIGURE 4. Flow chart of adjustments and proceedures in the 1984 interim edition of the Canadian Forest Fire Behavior Prediction (FBP) System (after Alexander and McAlpine 1987).

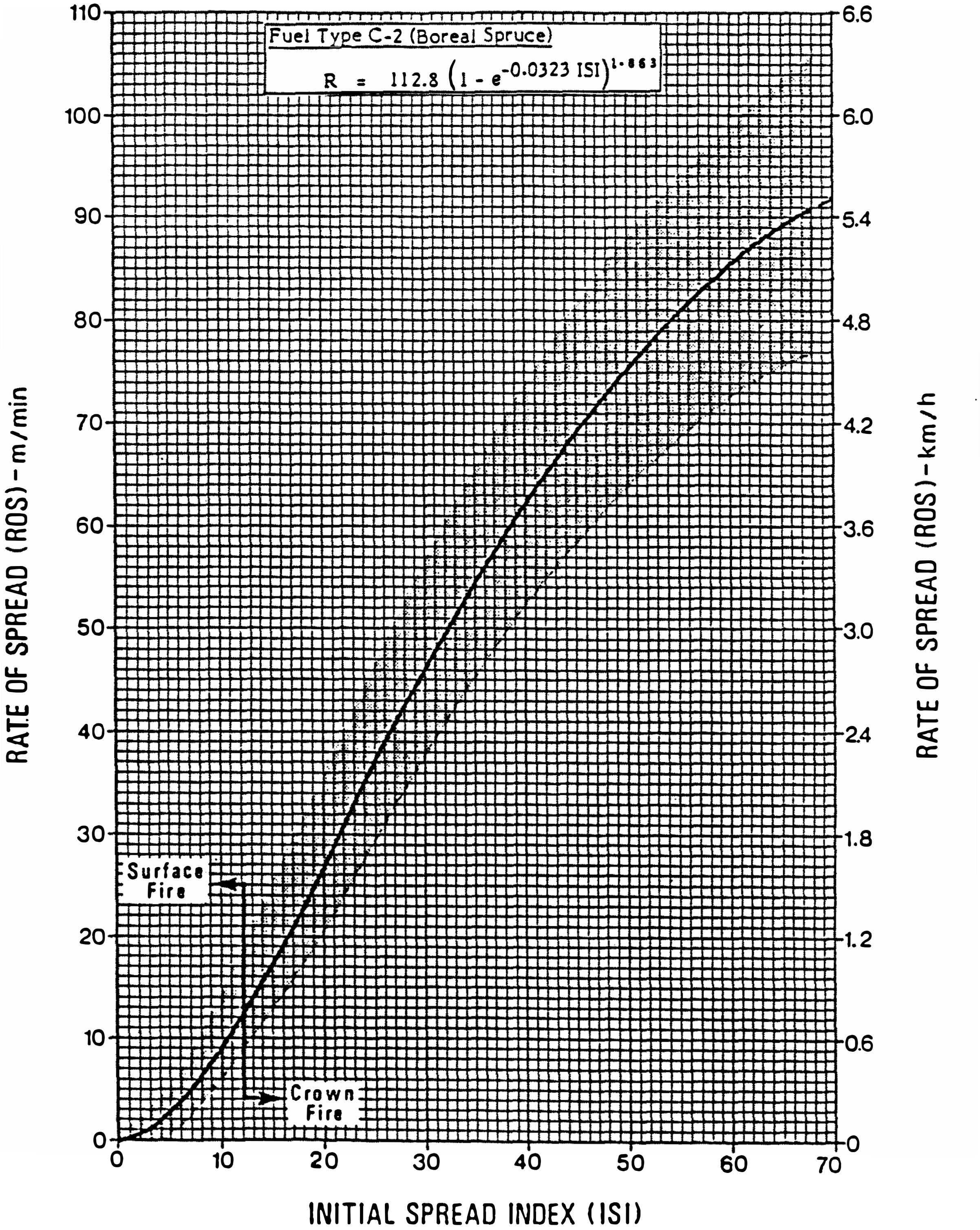


FIGURE 5. Example of a head fire rate of spread (ROS)/Initial Spread Index (ISI) graph and equation from the 1984 interim edition user guide to the Canadian Forest Fire Behavior Prediction (FBP) System for Fuel Type C-2 (Boreal Spruce) with 70% confidence limits (shaded area), crowning threshold, and limit of observed data (dashed line) indicated (from Alexander and others 1984).

TABLE 2. List of fuel types in the 1984 interim edition of the Canadian Forest Fire Behavior Prediction (FBP) System (from Lawson et al. 1985).

Group	Identifier	Descriptive Name
CONIFEROUS	C-1	SPRUCE - LICHEN WOODLAND
	C-2	BOREAL SPRUCE
	C-3	MATURE JACK or LODGEPOLE PINE
	C-4	IMMATURE JACK or LOGDEPOLE PINE
	C-5	RED AND WHITE PINE
	C-6	RED PINE PLANTATION[1]
	C-7	PONDEROSA PINE - DOUGLAS-FIR
DECIDUOUS	D-1	LEAFLESS ASPEN
MIXEDWOOD	M-1	BOREAL MIXEDWOOD - LEAFLESS[2]
	M-2	BOREAL MIXEDWOOD - SUMMER[2]
SLASH	S-1	JACK or LODGEPOLE PINE SLASH
	S-2	SPRUCE - BALSAM SLASH
	S-3	COASTAL CEDAR - HEMLOCK - DOUGLAS-FIR SLASH
OPEN	O-1	GRASS[3]

[1] Rate of Spread relationships available in the User Guide for three mean stand height ranges: <10m, 10-20m, and >20m.

[2] Must specify percent softwood (S) and hardwood (H) species composition. Three commonly accepted combinations have been included in the User Guide Rate of Spread and Graphs : 75S:25H, 50S:50H, and 25S:75H.

[3] Must specify percent cured or dead material. Standard fuel load is 3 t/ha. Variable fuel weight/rate of spread relationship available.

included graphs and tables produced for field use from the ROS component equations which were provided for computer users (e.g., Frech 1985; Pilling 1986). Threshold conditions for crown fire development, where applicable, were defined in terms of the ISI and the slope adjusted ROS (Table 3). Procedures for adjusting the FFMC for time of day and topography (i.e., % slope and aspect) were provided based on the best available "off-the-shelf" information. Guidelines for determining upslope or downslope spread rates relative to wind direction/slope and projecting fire spread/growth from an active perimeter source were also provided; computerized methods for the latter task are beyond (e.g., Kourtz 1984; Feunekes and Methven 1988). General guidelines for documenting wildfire observations (e.g., Alexander and Lanoville 1987) were also included in the user guide. The FBP System worksheet (Fig. 6) is designed to assist the user in performing the various required adjustments and computational procedures.

The 1984 interim edition of the FBP System also includes procedures for projecting fire growth from a point ignition (Figs. 7 and 8) based on a simple elliptical fire growth model (Van Wagner 1969). Fire shape and size calculations are described in detail by Alexander (1985b). Fire area and perimeter length tables have been prepared (Alexander 1986b) to assist in speeding-up manual computations. A slide-rule device called the **Fire Growth Calculator** or FGC, based on the FBP System (Alexander 1985b; Alexander and others 1984), has also been designed. It allows fire managers to make relatively quick estimates of fire growth (McAlpine 1986a). Instruction for plotting the projected area and perimeter length of the elliptical shaped fire were included in the user guide and supplementary material (Alexander and others 1984; Alexander 1986b; Alexander and McAlpine 1987).

The user guide to the 1984 interim edition of the FBP System was never intended to serve as a field reference **per se**. The aim was to provide the basic materials, recognizing each agency's needs would vary. For example, the Ontario Ministry of Natural Resources have incorporated the ROS graphs and tables into their basic field guide (Anon. 1984). The B.C. Ministry of Forests have condensed the pertinent features of the user guide to two plasticized summary sheets (4 pages in total)[5]. An FBP System field reference has recently been prepared (Alexander and McAlpine 1987).

All provincial and territorial fire management agencies west of Quebec have incorporated material from the FBP

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[5] M. Winder, Technician (Planning, Development and Research), B.C. Ministry of Forests, Forest Protection Branch, Victoria, B.C., personal written communication, 23 April 1985.

TABLE 3. Threshold conditions for crown fire development in the 1984 interim edition of the Canadian Forest Fire Behavior Prediction (FBP) System for fires burning on level to gently undulating ground or downslope in terms of the Initial Spread Index (ISI) **OR** for fires burning upslope in terms of the head fire rate of spread (ROS) adjusted for percent ground slope (from Lawson et al. 1985).

Threshold Conditions for Crown Fire Development

Fires burning on level or downslope - use Initial Spread Index (ISI)

Fires burning upslope - use Rate of Spread (ROS) adjusted for % Ground Slope

Fuel type		ISI	ROS	
			m/min	km/h
C-1		16	15	0.90
C-2		12	14	0.84
C-3		18	17	1.02
C-4		8	9	0.54
C-5		-------------crowning unlikely---------------		
C-6	<10m[1]	8	9	0.54
	10-20m	18	17	1.02
	>20m	-------------crowning unlikely---------------		
C-7		25	8	0.48
D-1		-------------crowning unlikely---------------		
M-1	75S:25H[2]	16	17	1.02
	50S:50H	20	17	1.02
	25S:75H	-------------crowning unlikely---------------		
M-2	75S:25H[2]	20	21	1.26
	50S:50H	27	21	1.26
	25S:75H	-------------crowning unlikely---------------		
S-1		N/A	N/A	N/A
S-2		N/A	N/A	N/A
S-3		N/A	N/A	N/A
0-1		N/A	N/A	N/A

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[1] Mean stand height.

[2] Percent softwood (S) and hardwood (H) species composition.

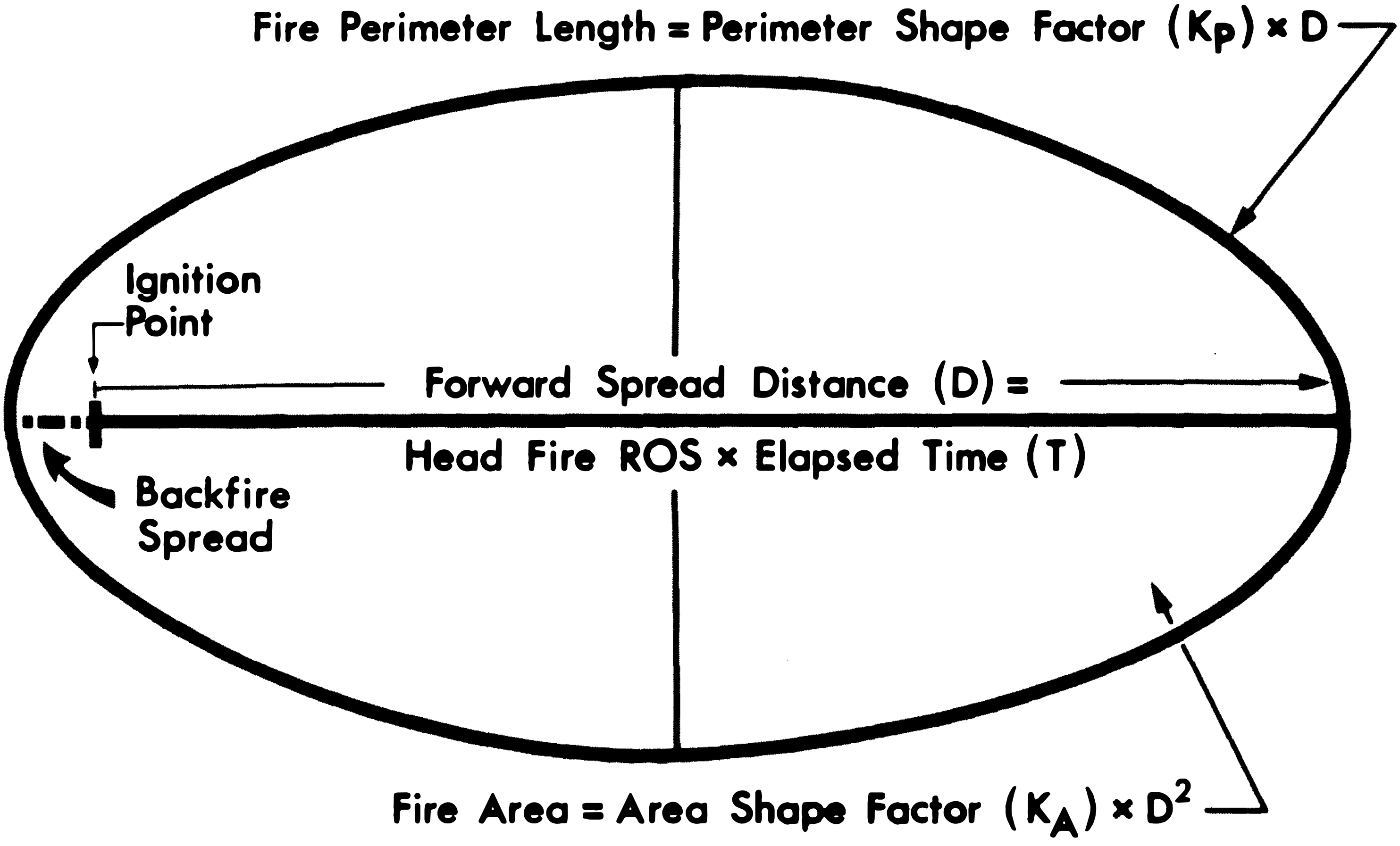
CANADIAN FOREST FIRE BEHAVIOR PREDICTION (FBP) SYSTEM WORKSHEET Page __ of __

Fire Number/Name ______________________ Date & Time ____________

Prediction Date & Time Interval ____________ from ________ to ________

1	Prediction Point					
	<u>Fuel Type Information</u>					
2	FBP System Fuel Type					
3	Softwood Species Composition (%)					
4	Hardwood Species Composition (%)					
5	Cured/Dead Grass (%)					
6	Grass Fuel Weight (t/ha)					
	<u>Fine Fuel Moisture Code (FFMC) Time & Slope/Aspect Adjustments</u>					
7	Standard Daily FFMC					
8	Time "T"					
9	FFMC at Time "T"					
10	Aspect (N, E, S, *or* W)					
11	Ground Slope (%)					
12	Adjusted FFMC					
	<u>Rate of Spread (ROS) Calculations</u>					
13	10-m Wind Speed (km/h)					
14	Initial Spread Index (ISI)					
15	Spread Factor (SF)					
16	ROS on Level (m/min *or* km/h)					
17	ROS[16] x SF[15] (m/min *or* km/h)					
	<u>Fire Size Calculations</u>					
18	Elapsed Time (min *or* h)					
19	Forward Spread Distance (m *or* km)					
20	Area Shape Factor (K_A)					
21	Area Burned (ha)					
22	Length/Breadth Ratio (L/B)					
23	Perimeter Shape Factor (Kp)					
24	Perimeter Length (m *or* km)					
	<u>Fire Area Plotting</u>					
25	Map Conversion Factor ( )					
26	Head Fire Spread Distance (cm)					
27	Wind Direction					
28	Head/Back Fire Spread Ratio (H/B)					
29	Backfire Spread Distance (cm)					
30	Total Fire Length (cm)					
31	Total Fire Breadth (cm)					

Figure 6. Worksheet associated with the 1984 interim edition of the Canadian Forest Fire Behavior Prediction (FBP) System (from Alexander and McAlpine 1987).



FIRE AREA (A) COMPUTATIONS; hectares (ha)

$$A\ (\text{ha}) = \frac{K_A \times [\text{ROS}\ (\text{m/min}) \times T\ (\text{min})]^2}{10{,}000} \quad \text{or} \quad A\ (\text{ha}) = [K_A \times (\text{ROS}\ (\text{km/h}) \times T\ (\text{h}))^2] \times 100$$

FIRE PERIMETER LENGTH (P) COMPUTATIONS; metres (m) *or* kilometres (km)

$$P\ (\text{m}) = K_p \times [\text{ROS}\ (\text{m/min}) \times T\ (\text{min})] \quad \text{or} \quad P\ (\text{km}) = K_p \times [\text{ROS}\ (\text{km/h}) \times T\ (\text{h})]$$

Figure 7. Schematic diagram illustrating the area and perimeter length calculations associated with free-burning elliptical shaped fires (ROS = Head Fire Rate of Spread and T = Elapsed Time Since Ignition) (from Alexander 1986b).

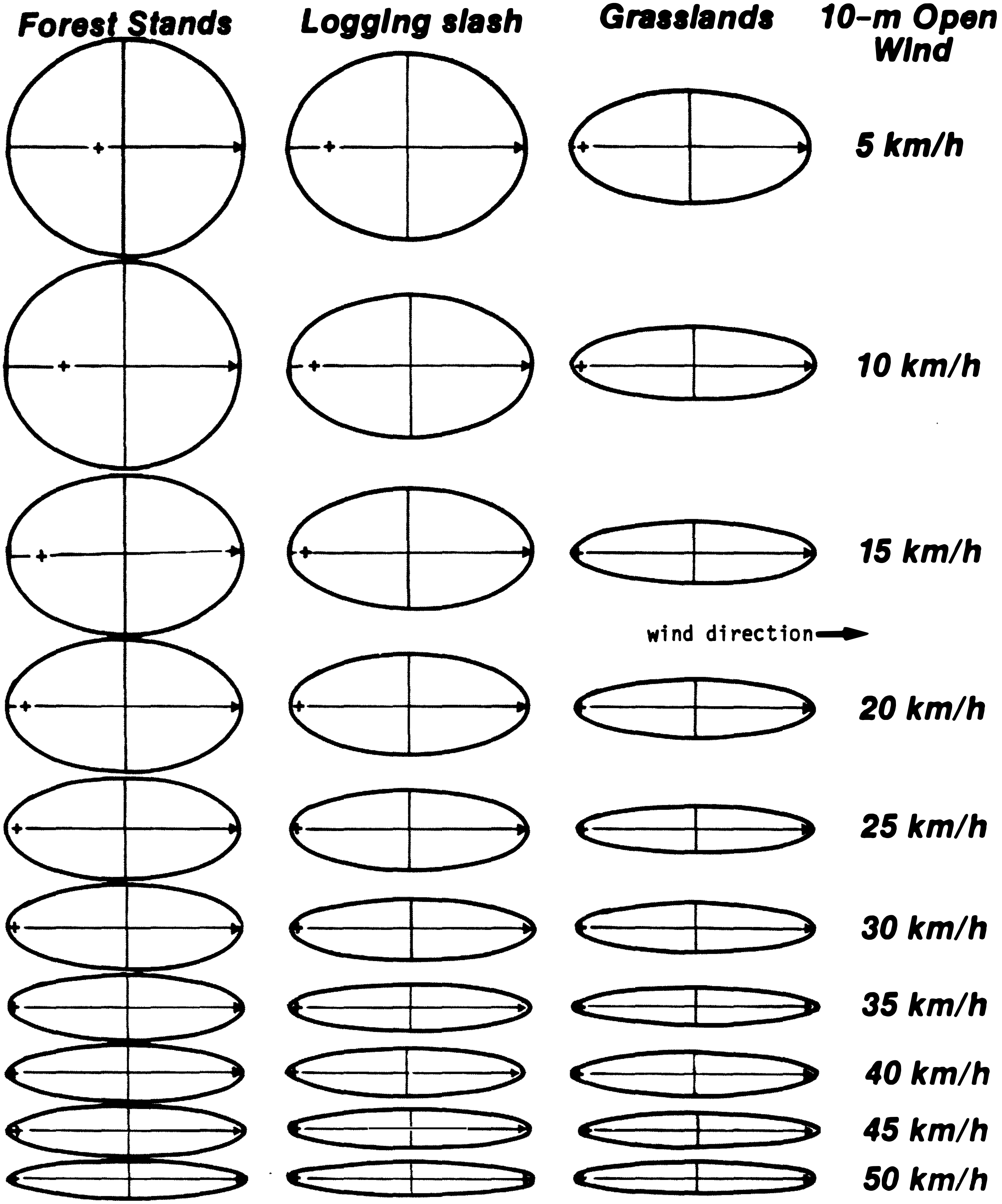


Figure 8. Elliptical fire shape guide associated with the 1984 interim edition of the Canadian Fire Behavior Prediction (FBP) System.

System into their fire behavior seminars and training courses (e.g., Ontario - M-100 Fire Behavior for Fire Managers and M-200 Fire Behavior Officer courses; Alberta - Advanced Fire Behavior Course). CFS fire research personnel have been involved to varying degrees in this regard; the Saskatchewan (**see** Forest Fire News No. 25, p. 29, Jan. 1988) and Manitoba[6] District Offices offered several courses in 1987[7]. Some of the universities and technical schools have also done the same in their fire management courses (e.g., Eiber 1985; Feller 1985).

Although no computer program was included in the 1984 edition of the FBP System, all of the necessary equations and tables were provided or available for anybody who wished to do so. Programs for the Sharp 1500A (Anon. 1984, 1985) and NEC PC-8201A portable computers (McAlpine 1986b, 1987a, 1987b) have been formulated. Programs have also been developed for the Apple III[8] (e.g., Frech 1985) and IBM-PC[9] microcomputers as well as for traditionally main-frame computers (e.g., Pilling 1986).

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[6] K.G. Hirsch, Fire Research Officer, Canadian Forestry Service, Manitoba District Office, Winnipeg, Man., personal communication.

[7] Forest fire danger rating system seminars were recently held in eastern Canada (NB, NS, NFLD, PEI, and QUE.). Total attendance at the five sessions was 133 and included, in addition to individuals from the provincial fire management agencies and organizations, representatives from the university forestry schools, Environment Canada-Parks, and the Atmospheric Environment Service (**see** Forest Fire News No. 25, p. 6, Jan. 1988). B. J. Stocks (Head-Fire Research Unit, Great Lakes Forestry Centre, Sault Ste. Marie, Ont.) and M.E. Alexander, both members of the CFS Fire Danger Group, made a dozen separate flights and travelled approximately 10 000 km during the 9-day period from March 31 to April 8. Logistical arrangements and funding for the seminars was coordinated by D.E. Dube, Fire Research Coordinator, CFS National Headquarters Unit. The seminars were warmly received as evident by the keen interest at each location and subsequent feedback. However, continual contact is obviously needed for optimum effectiveness. On a historical note, the trip to Charlottetown represents the first time that CFS fire researchers have ventured to Prince Edward Island on work travel status!

[8] N. Nimchuk, Meteorologist, Alberta Forest Service, Forest Protection Branch, Edmonton, Alta.

[9] D. Carnell, Sr. Park Warden, Jasper National Park, Jasper, Alta., personal communication.

A comment on the two principal methods of calculation associated with the 1984 interim edition of the FBP System -- i.e., manual and computer -- is in order at this time. The point to be emphasized is that the same equations are used in both methods. Thus, the predicted ROS should be identical given the same inputs, regardless of the calculation method (Andrews 1986). Any slight differences would be due to rounding or table construction. Each method offers certain advantages and disadvantages in terms of availability or access, costs, power requirements/failure potential, ease of use (i.e., computation time required, user-friendliness) as summarized in Table 4.

Table 4. Summary of the various methods of calculation involved with the Canadian Forest Fire Behavior Prediction (FBP) System.

Method of Calculation	Sample Reference(s)	Remarks
Manual		
Tables & Graphs	Alexander & others (1984) Alexander (1986b) Anon. (1984) Alexander & McAlpine (1987)	Simple, inexpensive (~ $2-5) calculator handy but not necessary. Inconvenient for novice users.
Fire Growth Calculator (FGC) slide-rule	McAlpine (1986a)	Cost: $10. Quick estimates of fire spread distance, area, and perimeter length possible.
Computer		
Portable or "Lap-top" (e.g., NEC PC-8201A, Sharp 1500A, HP-71B)	McAlpine (1986b, 1987a, 1987b) Anon. (1984, 1985)	Relatively inexpensive (~ $500-1000). Field portable (battery power). Ideal for fire behavior officers/ specialists.
Micro (e.g., Apple III, IBM-PC, Wang)	Frech (1985) Feunekes & Methven (1988) Methven & Feunekes (1987)	Moderately expensive (~ $1000-10 000). Office or field use, depending on power source.
Mini- or Main-frame (e.g., VAX)	Pilling (1986)	Extremely high purchase and operating costs (~ $50 000 - 500 000) restricted to office use.

The other two major components of the FBP System -- fuel consumption (Fig. 9) and frontal fire intensity -- are currently under development for inclusion in the first published version of the complete system. However, some initial work on the frontal fire intensity component has been released. The chart and accompanying guide presented in Figure 10 and Table 5 were prepared initially, by the second author (M.E.A.) on behalf of the CFS Fire Danger Group, for distribution at the 1986 Annual Meeting of the Canadian Committee on Forest Fire Management held January 21-23 in Ottawa, Ontario, in order to solicit comments, etc. on the concept. The protype example, which was prepared for illustration purposes only, is in this case deemed applicable to upland jack pine stands on level ground. The key conceptual point incorporated into the chart/table is that the frontal fire intensity (Alexander 1982), expressed in kilowatts per meter (kW/m), determines the difficulty of controlling a fire (i.e., what kind(s) of fire suppression resources would or would not be effective). What is **not** considered is the "containment capability" required (i.e., the forces required for constructing fireguard in order to exceed the rate of perimeter growth and/or resistance to fireguard construction due to fuel and site characteristics). The assumption is made that the fire has reached a 'steady-state condition'. The ISI and BUI inputs can be determined on the basis of the standard daily FWI System calculations at 1200 h LST or an updated FFMC and 10-m open wind speed.

How do you use the frontal fire intensity rank chart/table? Given the ISI and BUI, determine the Intensity Rank (e.g., ISI = 10 and BUI = 40, then Rank = 3) and then refer to the table for a descriptive explanation based on the numerical rating between 1 and 6 (e.g., Rank 3: low vigour to moderately to highly vigorous surface fire. Hand-constructed ... etc.). Note the corresponding intensities and approximate flame sizes, as well as the associated FWI values for upland jack pine.

Several possible applications of the Intensity Rank chart are foreseen. For example, actual or forecasted ISI and BUI values from an agency's fire weather station network could be plotted on a daily basis to assist in presuppression planning. The chart could also be used to evaluate the potential fire behavior of a going campaign fire. The fire danger indices associated with eight experimental fires documented during August 1986 in central Alberta (Murphy et al. 1987) have been plotted on the chart to illustrate its use; an additional experimental fire was completed in July 1987.[10] These fires were conducted to determine the "hotspotting" production rates of initial attack fire fighters (all nine fires were successfully controlled by the ground suppression crews, although the 1987 fire was noticeably more difficult to control[10]). The

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[10] D. Quintilio, Sr. Fire Control Instructor, Forest Technology School, Hinton, ALta., personal communication.

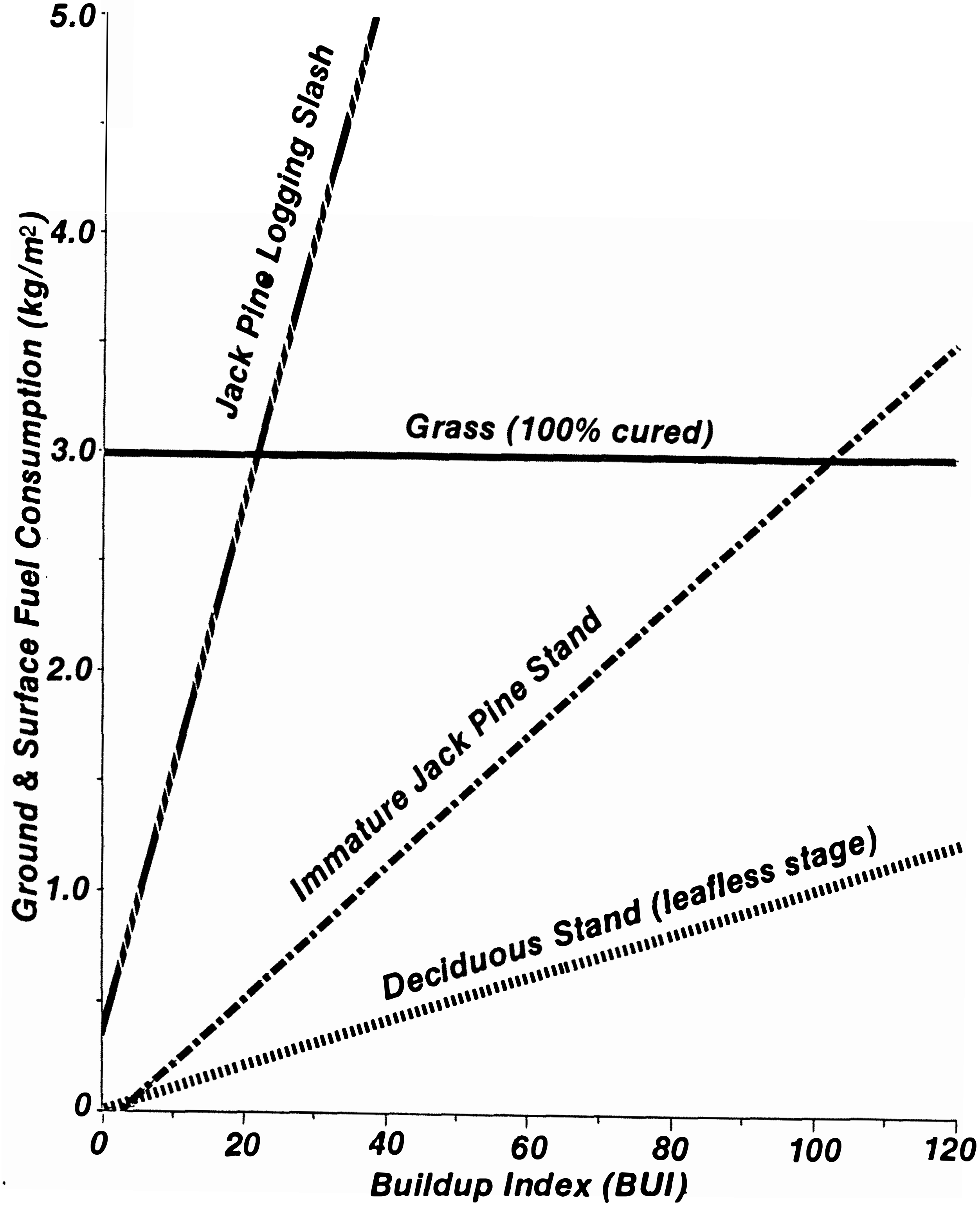

Figure 9. Total ground and surface fuel consumption as a function of the Buildup Index for four distinctly different fuel complexes (adapted from Stocks and Walker 1972; Alexander and others 1984; Martell et al. 1984a; Stocks 1987b).

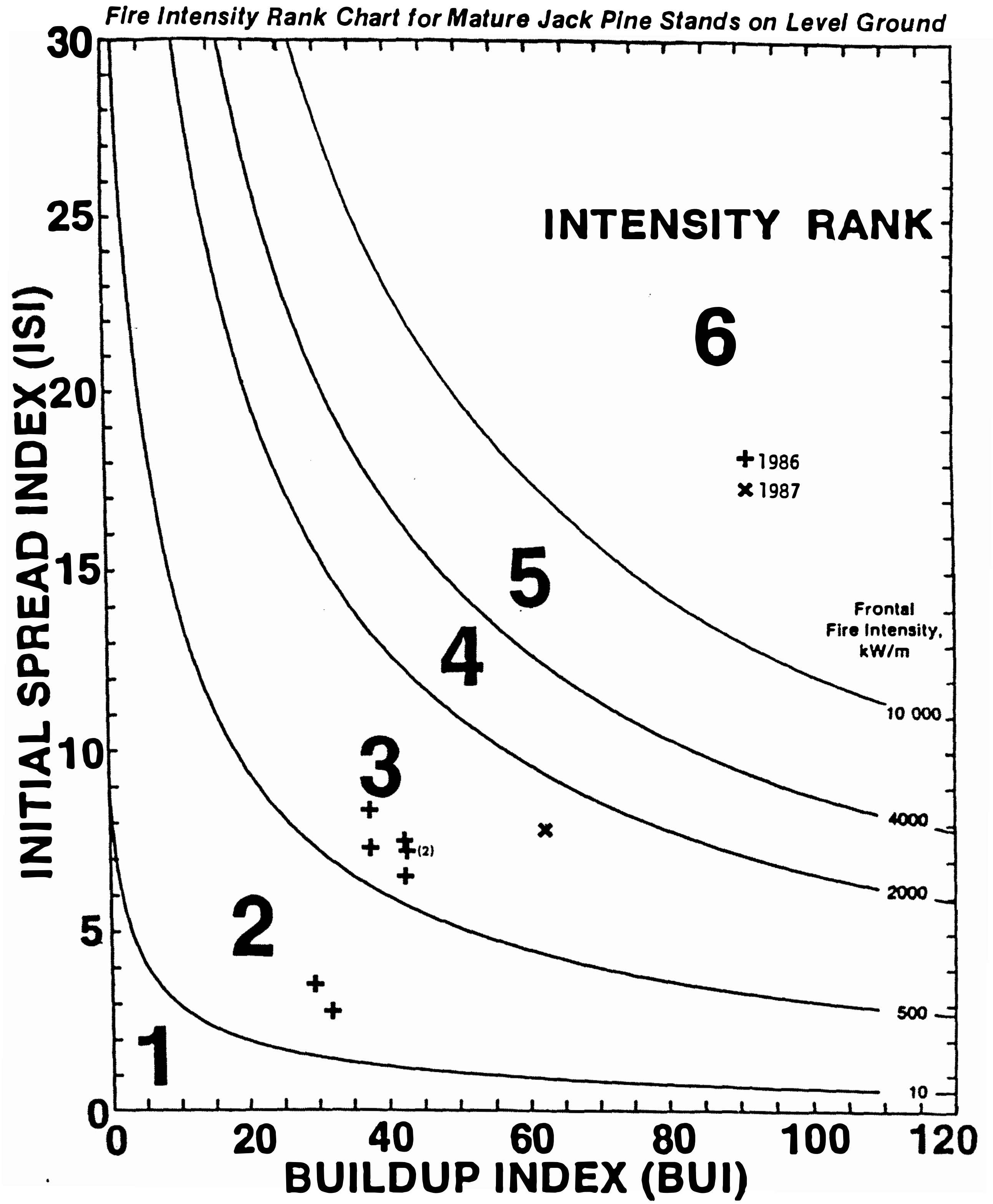

Figure 10. Sample of proposed frontal fire intensity rank chart. This particular example is for mature jack pine stands on level ground (after Alexander and De Groot 1988). Refer to Table 5 for fire control management applications. See text for explanation of the plotted value (+).

Table 5. Guide to fire behavior characteristics and fire suppression interpretations associated with the sample of the proposed frontal fire intensity rank chart (see Fig. 10) (after Alexander and De Groot 1988).

Chart Rank	Frontal Fire Intensity (kW/m)	Surface Head Fire[1] Flame Length (m)	Surface Head Fire[1] Flame Height (m)	Type of Fire and Fire Suppression Difficulty	Fire Weather Index[2] (FWI)
1	<10	<0.2	<0.1	Firebrands that cause an ignition to occur are self-extinquishing (i.e., fire fails to spread). Going fires reamin of the smouldering ground or subsurface variety, provided there is a forest floor layer of significant depth and a general level of dryness[3] Extensive mop-up is generally required.	0-3
2	10-500	0.2-1.4	0.1-1.0	Creeping or gentle surface fire. Direct manual attack at fire's head or flanks by firefighters with hand tools and water is possible. Constructed fireguard should hold.	4-13
3	500-2000	1.4-2.6	1.0-1.9	Low vigour to moderately or highly vigorous surface fire. Hand-constructed fireguards likely to be challenged. Heavy equipment (bulldozers, pumpers, retardant aircraft, skimmers, helicopter with bucket) generally successful in controlling fire.	14-23
4	2000-4000	2.6-3.5	1.9-2.5	Very vigorous to extremely intense surface fire (torching common). Control efforts at fire's head may fail.	24-28
5	4000-10 000	3.5-5.4	2.5-4.6	Intermittent crown fire[4] Very difficult to control. Suppression action is generally restricted to fire's flanks. Indirect attack with aerial ignition (i.e., helitorch and/or A.I.D. dispenser) may be effective.	29-35
6	> 10 000	> 5.4	> 4.6	"Blow-up" or "conflagration" type fire run; violent physical behavior probable. Suppression actions should not be attempted until burning conditions ameliorate.	> 36

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[1] Flame length based on relationship with fire intensity according to Byram (1959). Flame height based on flame length and a 45° flame angle (Alexander 1982).

[2] Applicalbe to mature jack pine stands on level ground. Based on the equation given in Alexander and De Groot (1988), except the upper and lower FWI values for Fire Intensity Ranks 1 and 2 were determined from Van Wagner (1987a) since none of the experimental fires on which the equation is based were conducted at the very low end of the intensity scale.

[3] Drought Code (DC) > 300 and/or Buildup Index (BUI) > 40.

[4] Synonymous with passive crown fire as described by Van Wagner (1977a) (Merrill and Alexander 1987).

proposed chart format is considered a convenient way of portraying the frontal fire intensity component of the FBP System for the generalist and would also serve as a quick reference for the fire behavior specialist as well. The approach does avoid the mathematical necessity of calculating frontal fire intensity using the I = Hwr (Byram 1959; Alexander 1982) formula. User agencies may wish to replace or supplement the numerical ratings of 1 to 6 on the chart with generalized symbols (e.g., back-pack pump, fire shovel/Pulaski, helicopter with bucket, airtanker, flying drip torch, towering or wind-driven convection column), agency specific symbols (e.g., rappel crews, CL-215), color codes (green, blue, yellow, orange, and red) and/or typical fire behavior illustrated with representative photographs (e.g., ground fire, surface fire, crown fire, "blow-up"). The Ontario Ministry of Natural Resources (Anon. 1984, Anon. 1985), Alberta Forest Service, (Lieskovsky et al. 1987) and B.C. Forest Service (Anon. 1987) have already incorporated the protype chart and table into their field handbooks (e.g., fire behavior officer and air attack manuals) and training guides. The present example of the chart/table is based on readily available information (e.g., intensive review of world literature). Note that the frontal fire intensity component chart is similar to the "hauling chart" used in the U.S. (Andrews and Rothermel 1982). The chart concept could also be extended to the prediction of certain fire impacts and effects (Table 6); prepared by the second author (M.E.A.) in March 1986 to satisfy a local request (McKinnon 1987).

The general response to the 1984 interim edition of the FBP System in British Columbia[11], Alberta[12] Northwest Territories[13], and Ontario[14] has been overwhelmingly positive. Excellent results with the system have been reported. Verifiable after-the-fact predictions have shown quite acceptable agreement between observed versus predicted values given the nature of the inputs (e.g., Lawson et al. 1985; De Groot and Alexander 1986; Stocks and Flannigan 1987; Hirsch 1988b; Stocks 1988).

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[11] Effa, C., Technical Forest Officer (fire weather), B.C. Forest Service, Forest Protection Branch, Victoria, B.C., personal written communciation, 2 December 1985.

[12] T.A. Van Nest, Fire Behavior Officer, Alberta Forest Service, Forest Protection Branch, Edmonton, Alta., personal communication.

[13] R.A. Lanoville, Fire Behavior Science Officer, GNWT Department of Renewable Resources, Territorial Forest Fire Centre, Fort Smith, N.W.T., personal communication.

[14] R.A. White, Manager - Fire Environment Program, Ontario Ministry of Natural Resources, Aviation and Fire Management Centre, Sault Ste. Marie, Ont., personal communication.

Table 6. Guide to fire impacts/effects on trees and understory flora associated with the example of the proposed frontal fire intensity rank chart (see Fig. 10).

Intensity Rank	Frontal Fire Intensity (kW/m)	Stem-Bark Char Height[1] (m)	Lethal Scorch Height[2] (m)	Description of Impacts and Direct Effects of Fire on Aboveground Vegetation
1	<10	<0.1	<0.7	None to minimal provided there is no persistent ground fire activity. (The subsurface impacts and effects of fire are largely dependent on the 'Depth of Burn' and woody fuel consumption which are in turn a function of the Buildup Index (BUI) or Duff Moisture Code (DMC), depending on the fuel type.)
2	10-500	0.1-1.0	0.7-9.3	Fires are so gentle that the overstory canopy sustains very little or no visible damage. However, advanced regeneration is generally kill and a portion or all of the surface component of lesser plants are normally consumed in the flaming front.
3	500-2000	1.0-1.9	9.3-23.5	Fires are vigorous enough to induce stem bole scarring and/or tree mortality in some forest stands.
4	2000-4000	1.9-2.5	23.5-37.4	Fires sufficiently intense enough to cause complete tree mortality over relatively large areas.
5	4000-8000	2.5-3.4	37.4-59.3	Represents a level of fire behavior that very little of the Canadian forest could survive.
6	>8000	>3.4	>59.3	Same remarks as for Intensity Rank 5 — stand-replacing crown fire.

[1] Based on the estimated flame height of a surface fire.

[2] Based on Van Wagner's (1973b) height of crown scorch - frontal fire intensity relation.

An example of the reliability of the FBP System to provide realistic estimates of fire behavior is offered by hindsight analysis of the 1985 Butte Fire which occurred on the Salmon National Forest in central Idaho (Mutch and Rothermel 1986). The fire's behavior has been described by Rothermel and Mutch 1986). On August 29th, the Butte Fire made a "run" of about 2.22 km between 1430 and 1610 h MDT (elapsed time: 100 min). This corresponds to a head fire ROS of 22.2 m/min or 1.33 km/h. This wildfire was deemed to be of the active/independent crown fire variety. The prevailing fuel type in the run area was mature lodgepole pine-subalpine fir forests. Elevations from the start to the termination of the run varied from 2146 m to 2341 m MSL. This corresponds to a 9% ground slope or a relative spread factor (SF) of 1.22 according to Van Wagner (1977b). The 1300 h MDT fire weather observations as recorded at the Skull Creek remote automatic weather station (RAWS), located 14 km southwest of the fire area (elevation: 1554 m MSL), were as follows (the quoted wind speed is actually the mean of the three 10-min averages as recorded at 1400, 1500, and 1600 h MDT):

Dry-bulb Temperature - 25.6°C
Relative Humidity - 18%
10-m Open Wind - SE 17 km/h
Days Since Rain (>0.6 mm) - 26

The associated FWI System components at the Skull Creek RAWS, which were historically calculated, were as follows:

Fine Fuel Moisture Code (FFMC) - 94.7
Duff Moisture Code (DMC) - 173
Drought Code (DC) - 744

Initial Spread Index (ISI) - 19.6
Buildup Index (BUI) - 219
Fire Weather Index (FWI) - 60

The predicted head fire ROS on level ground for FBP System Fuel Type C-3 (Mature Jack or Lodgepole Pine) based on an ISI = 19.6 would be 19.77 m/min or 1.19 km/h. The slope adjusted head ROS would be 24.1 m/min (i.e., 19.77 x [SF=] 1.22) or 1.45 km/h. Note that the frontal fire intensity rank would according to Figure 10, equal 6.

Other verified examples of reasonably accurate predictions of fire spread in British Columbia are given by Lawson (1986), including a quite well-documented fire which occurred near Cranbook, B.C. in 1985 that spread at 16.5 m/min[15]. The predicted ROS for FBP System Fuel Type C-7 (Ponderosa Pine-Douglas-fir) was 14.5 m/min.

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[15] B.D. Lawson, Head - Forest Fire Research Unit, Canadian Forestry Sevice, Pacific Forestry Centre, Victoria, B.C., personal written communication, 16 October 1986.

In addition to the present ongoing work associated with the revision of the ISI/ROS equations (based on additional data since 1984) and development of the fuel consumption and frontal fire intensity components, including estimates of flame length (e.g., Nelson and Adkins 1986), the following items are also being addressed for the first published edition of the FBP System:

(1) A more rigorous, equation-based approach to the time of day and topographic (slope, aspect, and elevation) adjustments to the FFMC, including variation with latitude, than the present "off-the-shelf" procedures.

(2) The addition of Fuel Type C-8 (Spruce Budworm-killed Balsam Fir) based on the best available information (i.e., Stocks 1987a). The extraordinary fire hazard associated with this fuel type warrants this "best guess" approach. In fact, interim guidelines are already in place (**see** Anon. 1984). Separate ISI/ROS relationships are available for spring (prior to "green-up" and summer (after "green-up") conditions. Work is continuing on the refinement/verification of Fuel Type C-2 (Boreal Spruce) at the Big Fish Lake experimental burning project study area in north-central Alberta.

(3) The inclusion of a BUI adjustment to rate of spread (**see** Van Wagner 1973a). A fire's ROS is mainly dependent on wind speed and fine fuel moisture content as currently exemplified by the ISI. However, it is undoubtedly true that the spread rate of an established fire can also be influenced to a certain degree by the amount of available heavy fuel.

(4) Re-designing the criteria for determining the type of fire rather the present simplistic scheme (i.e., crown fire? -- no, yes, N/A) based on the ISI or the slope adjusted ROS. This would involve the calculating of threshold conditions for crown fire development (Van Wagner 1977a; Alexander 1988), including the incorporation of the effects of foliar moisture content on crowning potential (some sort of latitude-longitude/elevation scheme is planned based on presently available information).

(5) Allowance for the initial acceleration pattern from the time of ignition to equilibrium "steady-state" conditions (Cheney 1981, 1985) in the simple elliptical fire growth computations. This should also make it possible to determine the elapsed time since ignition until if appropriate, crowning commences. In the 1984 interim edition of the FBP System, a simplyfing assumption was deemed appropriate for the time being (Alexander and others 1984). Consideration of backfire spread has already been incorporated into the simple elliptical fire growth model (Alexander 1985b).

(6) The ability to calculate frontal fire intensity at the head, flanks and rear of an elliptical shaped fire and at any point along the perimeter (Catchpole et al. 1982). This should make it possible to calculate the amount of perimeter above a certain "critical" intensity value(s) and in turn determine by simulation, for different combinations of suppression resources and various burning conditions, the elapsed time since ignition that initial attack would be successful (or fail to) at containing a potential fire.

It's presently envisioned that the first complete edition of the FBP System will be documented in two CFS Forestry Technical Reports -- i.e., a "technical guide" which will include the scientific details on equation derivation and a computer program and perhaps a "field reference" which would be designed exclusively for manual computation of FBP System components.

Canadian Forest Fire Occcurrence Prediction (FOP) System

Development of the Canadian Forest Fire Occurrence Prediction (FOP) System shown in Figure 1 is currently under consideration. The fire occurrence prediction module to the CFFDRS is envisioned as a single, national system, consisting of both lightning and man-caused fire components, rather than various regional versions. Several approaches to predicting the number of lightning and man-caused fires, which rely in one way or another on the FWI System components, are being used on an operational and/or experimental basis in Ontario, Quebec, and British Columbia. (e.g.,Kourtz 1984, 1987; Martell 1986; Martell and Bevilacqua 1987; Martell et al. 1987).

Accessory Fuel Moisture System in the CFFDRS

The 'Accessory Fuel Moisture System' (name still tentative) shown in Figure 1 is currently in various stages of completion and likely to remain so for some time given the immense variety of fuel situations and fire danger rating requirements in Canada. This system is intended to include: (1) fuel-specific moisture codes not represented by the three standard fuel moisture codes in the FWI System (i.e., for shaded needle litter, loosely compact duff of moderate depth and deep compact organic matter) for such fuels as cured grass, exposed ground lichen (e.g., Pech 1987) and roundwood slash (e.g., Van Wagner 1987b), and (2) corrections/adjustments for elevation, topography, latitude, season (e.g., green surface fuel effect), time of day, (Van Wagner 1972, 1977c; Alexander et al. 1984), etc. The primary role of the Accessory Fuel Moisture System in the CFFDRS is to supplement or support special applications/requirements of the other three major systems.

Concluding Remarks

There is a great tendency in fire management to rely quite heavily on computerized fire behavior systems. However, Cheney (1985) makes the following points:

> The advent of computers allows access to large data bases of fuel and terrain information and the rapid computation of complex equations. However, a mathematical description of how a fire spreads is still inadequate. Certain assumptions must be made and practical restrictions placed on the model and on the confidence limit of the answer.

The reality of fire behavior predictions is that overestimates can be easily readjusted without serious consequences (Cheney 1981); under-estimates of fire behavior can be disastrous both to the operations of the fire manager and the credibility of the person making the prediction. A precise prediction of fire behavior for a specific location requires precise fire weather forecasts and knowledge of fuel types and topography. Van Wagner (1971) points out some of the realities of fire behavior prediction:

> The goal of research on the behavior of forest fires is presumably to be able to predict with reasonable assurance how a fire will behave in any stated weather and forest fuel. This goal does not, of course, have an absolute form since the prediction of forest fire behavior can never be an exact process. Performance may some day approach a generally acceptable level of accuracy, but error due to the infinite variety of weather, fuel, and topography will always be present.
>
> The job to be done is to place the required useful information in the hands of people charged with controlling and using fire, in the shortest possible time. To be useful, the information must be well organized and relatively uncomplicated - or, if it is complicated, then the complexity should be buried out of sight, as in prepared tables or computer programs.

There is little doubt about the "art and science" of fire behavior prediction. Van Wagner (1985) made the following comment in this regard.

> If one could boil down the whole science of fire behavior to its practical essence, it might just be to put in the hands of the fire boss a decent estimate how fast his newly-reported fire will advance. Fire behavior predictions may not be infinitely valuable;

> but as long as the forest fire people continue to want better ones, and there are researchers to work on them, it is safe to say that next year's predictions will be better than last year's. And because in a subject as complex as fire science, pure scientific logic just doesn't seem to be enough, the researcher had better be something of an artist as well as a scientist.

It's probably safe to say that a fire manager or practicing fire behavior officer must be something of a scientist as well as an artist.

Although the key factors determining fire behavior have or are being incorporated into the CFFDRS, the fire manager must at least be familiar with the system's structure and technical development in order to properly apply it. The CFFDRS is not complete at this stage nor can one expect a perfect evaluation or prediction. However, this should not discourage the user from becoming familiar with all the information the system has to offer. Further additions and improvements to the system will require not only continued research and testing, but a lot of feedback from the field people making day-to-day fire management decisions.

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CLIMATIC CHANGE: A REVIEW OF CAUSES[1]

by

James B. Harrington[2]

Abstract[3]

The earth's climate is constantly changing. Climatic change is effected by many factors: the influence of continental drift, variations in solar intensity, volcanism, the impact of meteors and comets, changes in the earth's orbital parameters, ice accumulation and depletion, variations in oceanic circulations and chemistry, changes in terrestrial and aquatic life, and changes in atmospheric composition and circulation. Despite these influences, many of them large, and despite changes in the sun's radiant intensity over the past 4.5 billion years, the average temperature of the earth's surface has remained remarkably constant, hovering near 15°C. This implies the presence of strong negative feedbacks reacting to any major environmental change. During the past century, man's influence on his environment has been increasing at an unprecedent rate. Under this influence, and particularly because of the effect of the so-called 'greenhouse gases', the global mean temperature is expected to rise approximately 2.5° by the middle of the 21st century. There remains a degree of uncertainty in this prediction because of unresolved problems in estimating various positive and negative feedback mechanisms in air, earth, ocean, ice, and vegetation interaction and in the unknown magnitude of volcanic activity. The finest numerical models and the fastest computers are, at present, inadequate to resolve all of the problems. However, the best scientific evidence points to a return by the middle of the 21st century to a climate similar to that of the climatic optimum 5000-6000 years ago. The degree of confidence in the direction, speed, and magnitude of the impending climatic change is sufficient that affected agencies should be actively mapping strategies to respond most advantageously to the expected

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[1] Summary of a presentation made at the Fourth Central Region Fire Weather Committee Scientific and Technical Seminar, April 2, 1987, Winnipeg, Manitoba.

[2] Research Scientist, Petawawa National Forestry Institute, Canadian Forestry Service, Chalk River, Ontario, KOJ 1J0.

[3] Editor's note: Due to the extensive nature of this paper only the abstract is presented in these proceedings. However the complete paper was recently published in the Canadian Journal of Forest Research **17**: 1313-1339.

changes. This is particularly true of forestry in Canada where climatic changes are expected to be large and the lifetime of current plantings will extend well into the period of anticipated change.

LIST OF SEMINAR ATTENDEES

NAME	TITLE	AFFILIATION[1]
Blair, Dan	Lecturer	Univ. of Man., Geography Dept.
Briggs, Art	Chief - Fire Programs	MNR, Winnipeg
Cameron, Don	Operations Officer	CIFFC, Winnipeg
Cataldo, Nello	Ren. & Intensive Mgmt. Coord.	CFS, MDO, Winnipeg
Charest, Jean	Met. Instructor	CFWS, Winnipeg
DeGroot, Bill	Fire Research Officer	CFS, SDO, Prince Albert
Dmytriw, John	Sr. Staff Officer - Met.	DND, ACHQ, Winnipeg
Durnin, Jim	Res. Con.	CPS, Winnipeg
Fluto, Ken	Chief - Forecast Services	AES Central Region, Winnipeg
Gauthier, Tim	Helitac Officer	MNR, Eastern Region, Beausejour
Harrington, James	Research Scientist	CFS, PNFI, Chalk River, Ontario
Held, I.E.	Forecaster	AES, PRWC, Winnipeg
Henry, Dale	Chief, Weather Services	AES, Central Region, Winnipeg
Hirsch, Kelvin	Fire Research Officer	CFS, MDO, Winnipeg
Jacobs, Robert	Fire Meteorologist	SPRC, FMB, Prince Albert
Klaponski, Carol	Chief Meteorologist	AES, PRWC, Winnipeg
Kluth, Terry	Meteorological Technician	MNR, Winnipeg
LaDochy, Steve	Assistant Professor	Univ. of Wpg, Geography Dept.
Larmard, Dennis	Fire Intelligence Officer	OMNR, NW Region, Dryden
Mason, Jerry	Sup. Air Operations	MNR, Winnipeg
McAlpine, Rob	Fire Control Officer	MNR, Eastern Region, Beausejour
Ostry, Tom	Sr. Develop. Meteorologist	AES, PRWC, Winnipeg
Quinn, Doris	Staff Officer - Met.	DND, ACHQ, Winnipeg
Raddatz, Rick	Sci. Serv. Meteorologist	AES, Central Region, Winnipeg
Schaefer, David	Fire Ranger	MNR, Eastern Regn. Lac Du Bonnet
Shipley, Bill	Fire Management Officer	MNR, Winnipeg
Silver, Spencer	Met. Instructor	CFWS, Winnipeg
Vandevyvere, Dan	Meteorologist	AES, PRWC, Winnipeg
Wailes, Howard	Meteorological Technician	OMNR, Timmins Region, Timmins
White, Dick	Program Manager	OMNR, Sault Ste. Marie
Young, Debbie	Fire Data Analyst	MNR, Winnipeg

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[1] Abbreviations: ACHQ = Air Command Headquarters; AES = Atmospheric Environment Service; CFS = Canadian Forestry Service; CFWS = Canadian Forces Weather Service; CIFFC = Canadian Interagency Forest Fire Centre; CPS = Canadian Parks Service; DND = Department of National Defence; FMB = Fire Management Branch; MDO = Manitoba District Office; MNR = Manitoba Natural Resources; NoFC = Northern Forestry Centre; OMNR = Ontario Ministry of Natural Resources; PNFI = Petawawa National Forestry Institute; PRWC = Prairie Weather Centre; SPRC = Saskatchewan Parks, Recreation and Culture; SDO = Saskatchewan District Office

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

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- Review of Operational Weather Forecast Procedures for the 1984 Fire Season -- Daniel A. Vandervyvere
- Day-1 Forecasting in Forest Fire Danger Rating -- Peter M. Paul
- Synoptic Fire Weather Climatology -- Roger B. Street
- Canadian Forest Fire Danger Rating System: an update -- Martin E. Alexander
- The Ash Wednesday Bushfires of 16 February 1983 in south-eastern Australia: video tape -- overview by Martin E. Alexander

Alexander, M.E. (compiler & editor). 1985b. Proceedings of the Second Central Region Fire Weather Committee Scientific and Technical Seminar (Apr. 17, Winnipeg, Man.). Government of Canada, Canadian Forestry Service, Northern Forest Research Centre, Edmonton, Alta. Study NOR-5-05 (NOR-5-191) File Report No. 11. 31 p.

- Daily People-Caused Forest Fire Occurrence Prediction -- David L. Martell, Samuel Otukal and Brian J. Stocks
- The Lightning Location & Protection (LLP) System: Alberta's operational experience -- Nicholas Nimchuk
- Operational Lightning Fire Occurrence Prediction in 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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- A Weather Network Design for Forest Fire Management in Saskatchewan -- R. L. Raddatz
- Forest Fire Monitoring Using the NOAA Satellite Series -- Michael D. Flannigan
- Wildlife Behavior on the Canadian Shield: A Case Study of the 1980 Chachukew Fire, East-central Saskatchewan -- William J. De Groot and Martin E. Alexander
- Wildfire Activity in Relation to Fire Weather and Fire Danger in Northwestern Manitoba . . . An Interim Report -- Kelvin G. Hirsch