A Primer on the Canadian Forest Fire Danger Rating System (CFFDRS)

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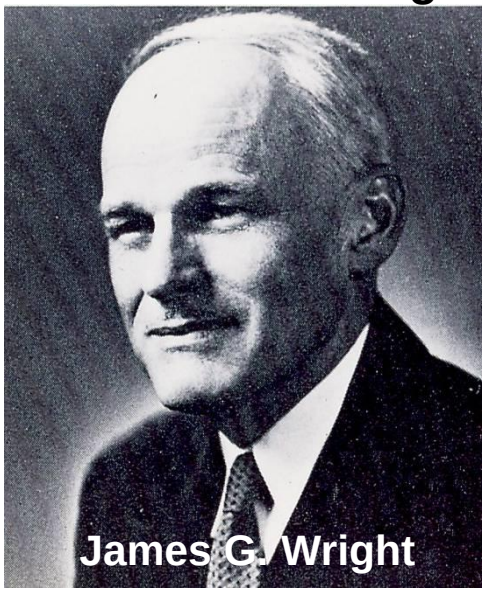
Objectives

- **Review the philosophy and structure behind the Canadian Forest Fire Danger Rating System (CFFDRS).**

- **Develop an appreciation for the similarities and differences between the systems used for rating fire danger and predicting fire behavior used in Canada and the U.S.**

Canadian Pioneers in Forest Fire Danger Rating Research

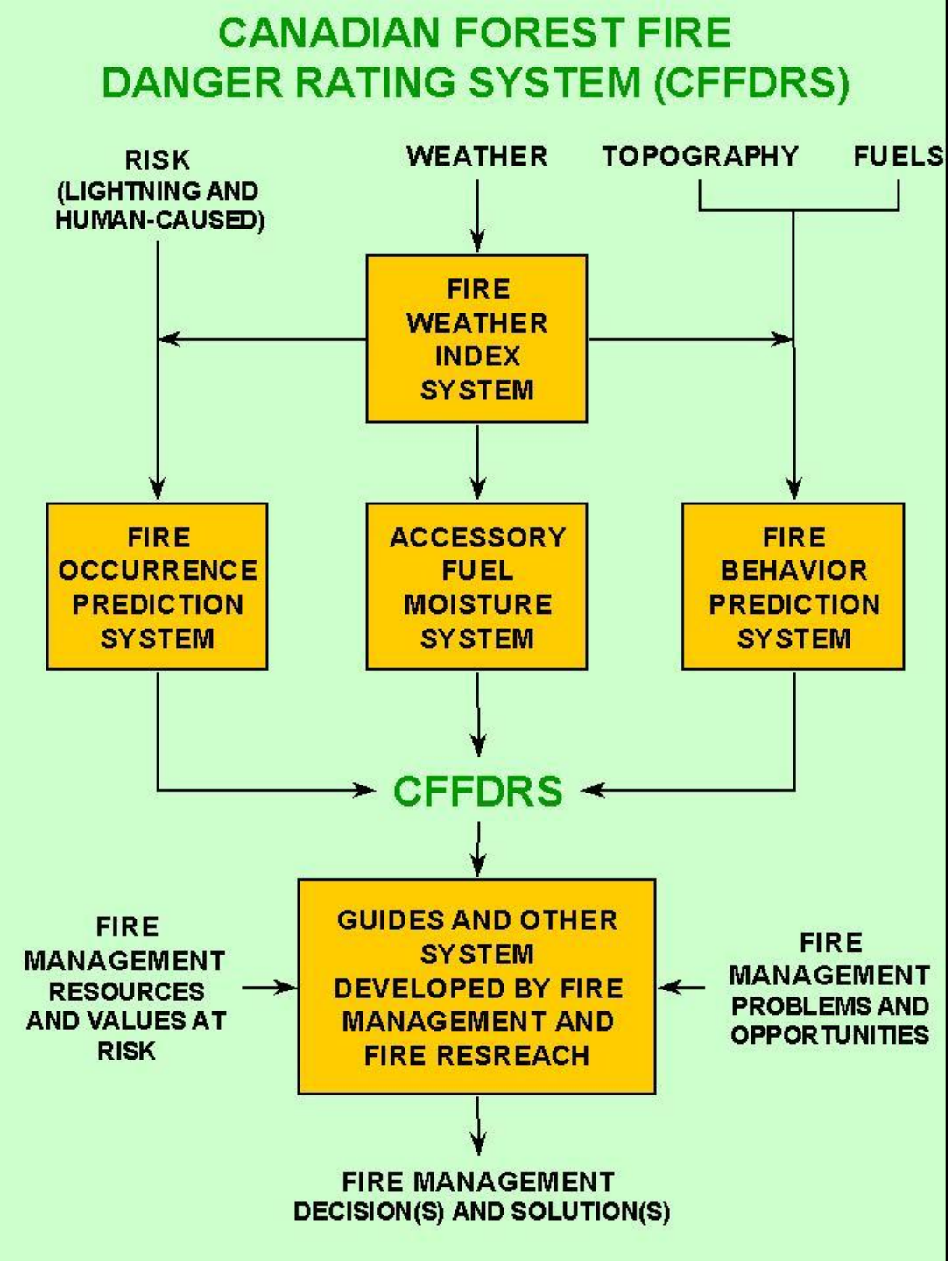

James G. Wright

Herbert W. Beall

CFFDRS Structure

The Canadian Forest Fire Danger Rating System (CFFDRS) is the national system of rating fire danger used in Canada. The CFFDRS includes all the guides to the evaluation of fire danger and the prediction of fire behavior.

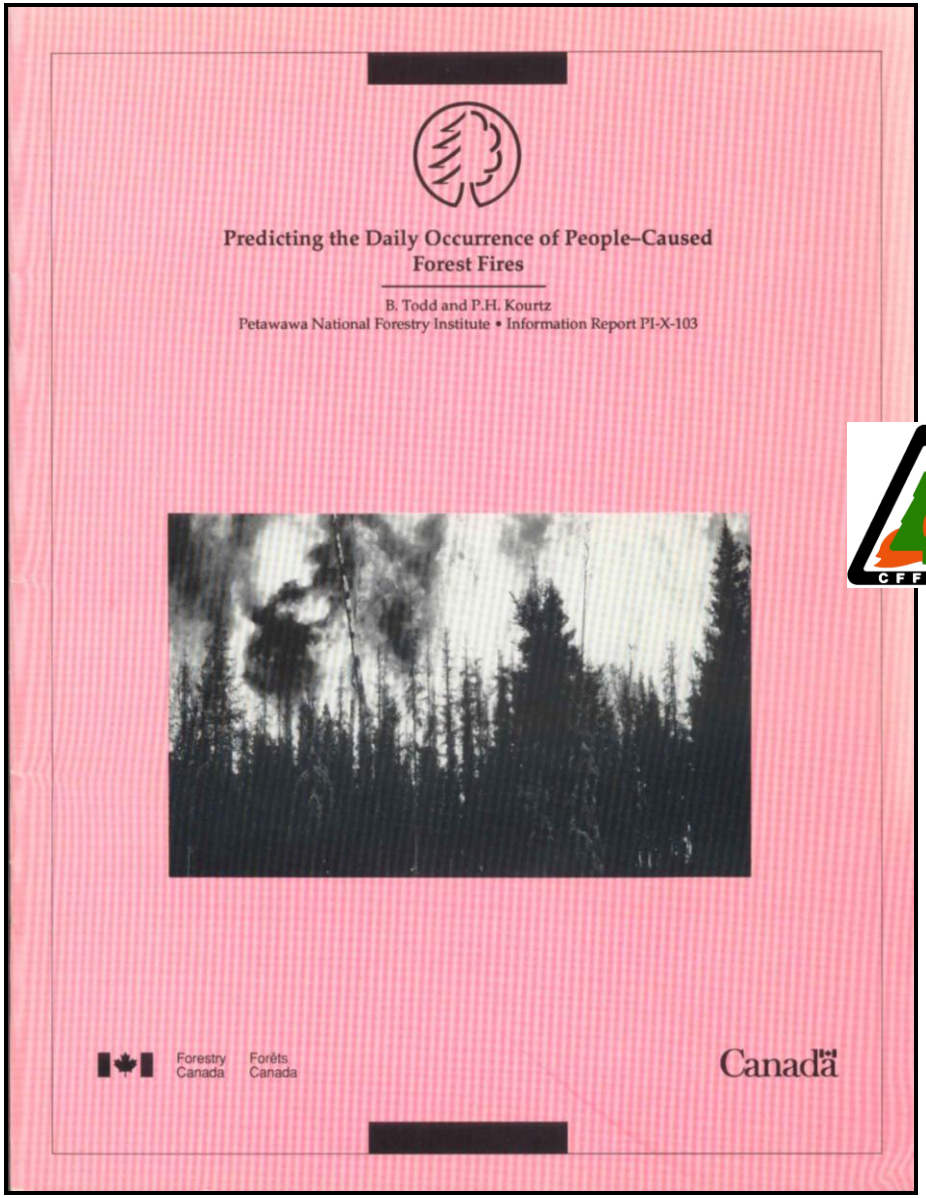
The CFFDRS represents the fifth generation of fire danger rating methods developed in Canada by the federal forestry service.

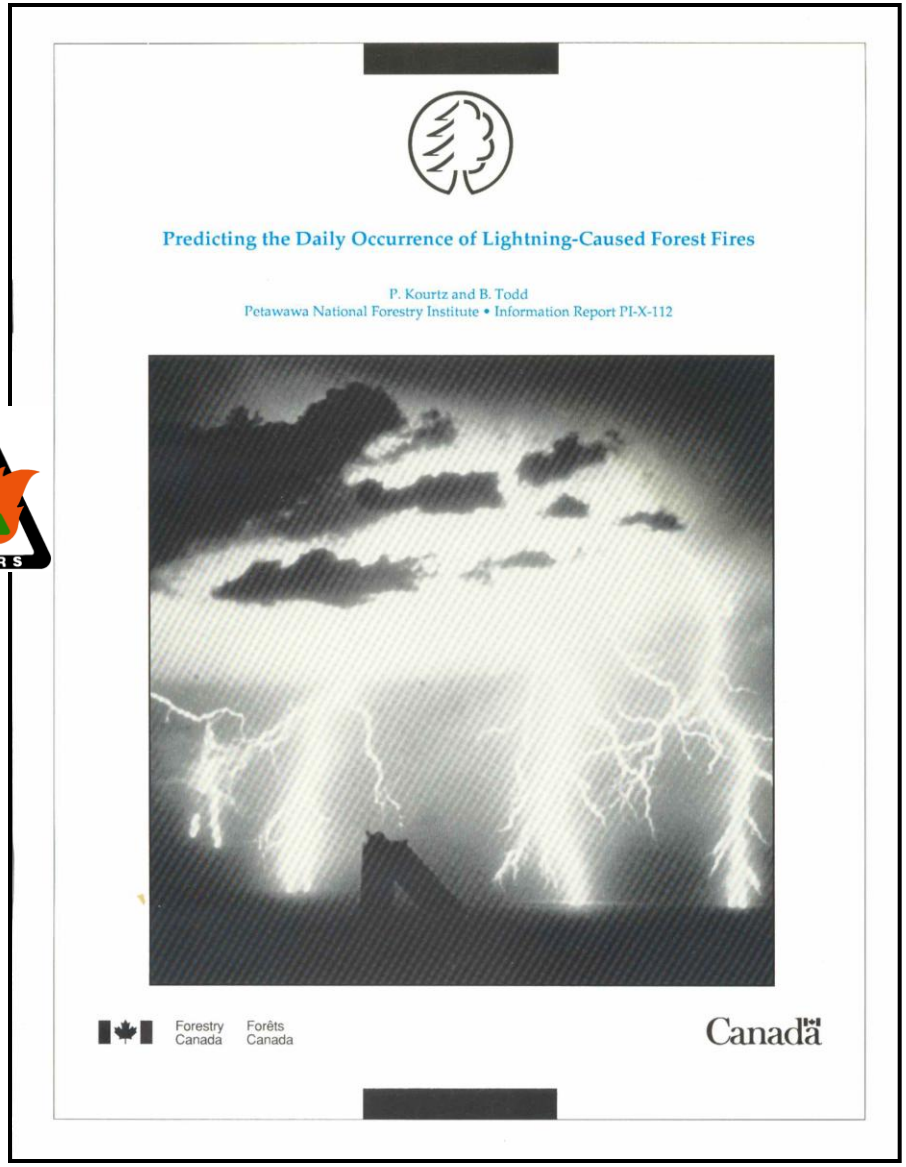


Simplified CFFDRS structure diagram illustrating the linkage to fire management actions

CFFDRS

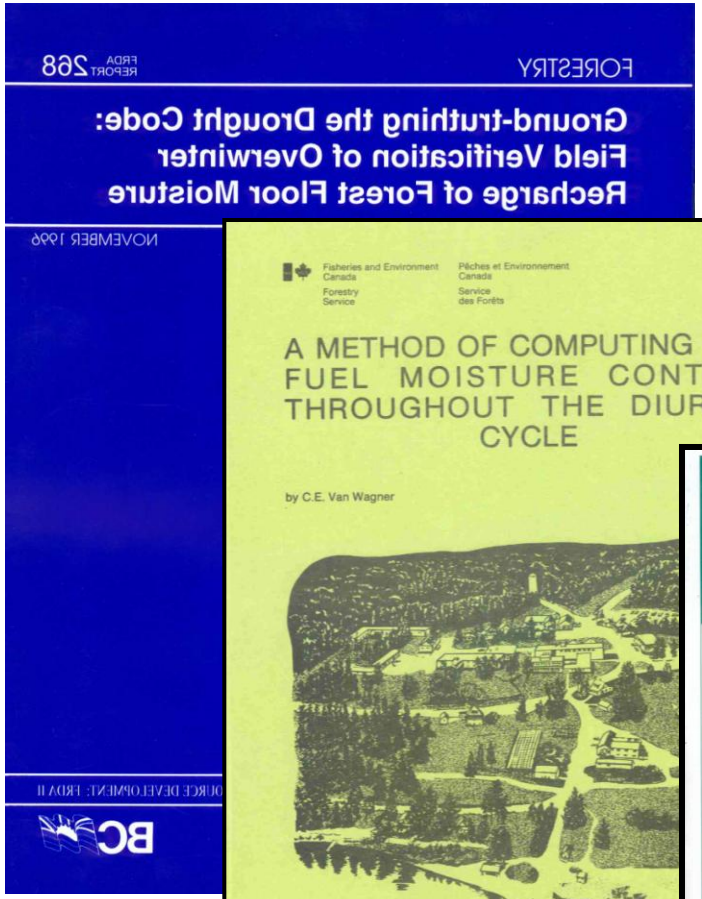
Canadian Forest Fire Occurrence Prediction System

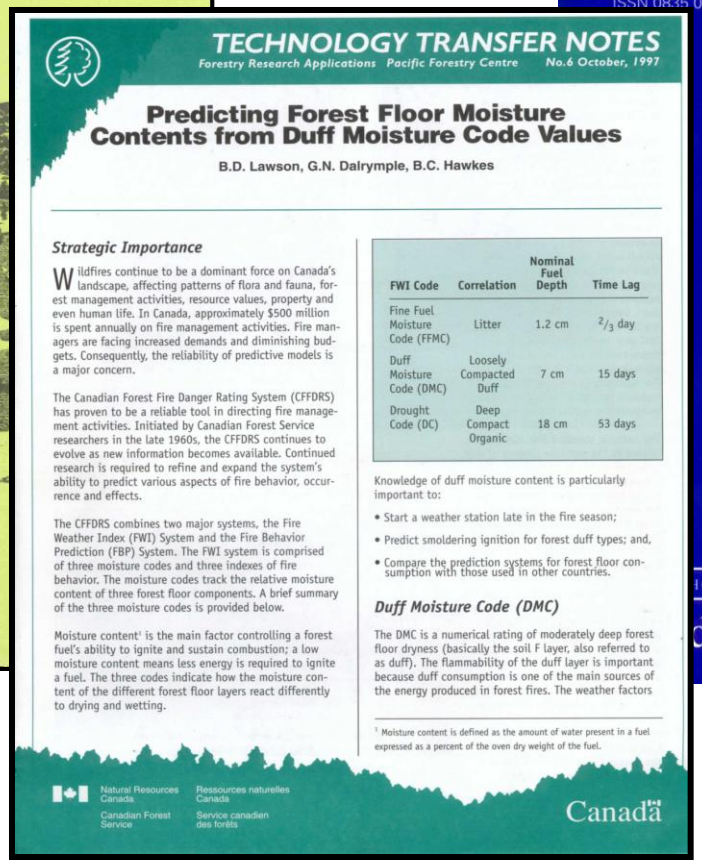




Accessory Fuel Moisture System

Purpose: to support applications of other CFFDRS subsystems





TECHNOLOGY TRANSFER NOTES

Forestry Research Applications Pacific Forestry Centre No.6 October, 1997

Predicting Forest Floor Moisture Contents from Duff Moisture Code Values

B.D. Lawson, G.N. Dalrymple, B.C. Hawkes

Strategic Importance

Wildfires continue to be a dominant force on Canada's landscape, affecting patterns of flora and fauna, forest management activities, resource values, property and even human life. In Canada, approximately $500 million is spent annually on fire management activities. Fire managers are facing increased demands and diminishing budgets. Consequently, the reliability of predictive models is a major concern.

The Canadian Forest Fire Danger Rating System (CFFDRS) has proven to be a reliable tool in directing fire management activities. Initiated by Canadian Forest Service researchers in the late 1960s, the CFFDRS continues to evolve as new information becomes available. Continued research is required to refine and expand the system's ability to predict various aspects of fire behavior, occurrence and effects.

The CFFDRS combines two major systems, the Fire Weather Index (FWI) System and the Fire Behavior Prediction (FBP) System. The FWI system is comprised of three moisture codes and three indexes of fire behavior. The moisture codes track the relative moisture content of three forest floor components. A brief summary of the three moisture codes is provided below.

Moisture content[1] is the main factor controlling a forest fuel's ability to ignite and sustain combustion; a low moisture content means less energy is required to ignite a fuel. The three codes indicate how the moisture content of the different forest floor layers react differently to drying and wetting.

FWI Code	Correlation	Nominal Fuel Depth	Time Lag
Fine Fuel Moisture Code (FFMC)	Litter	1.2 cm	$^2/_3$ day
Duff Moisture Code (DMC)	Loosely Compacted Duff	7 cm	15 days
Drought Code (DC)	Deep Compact Organic	18 cm	53 days

Knowledge of duff moisture content is particularly important to:

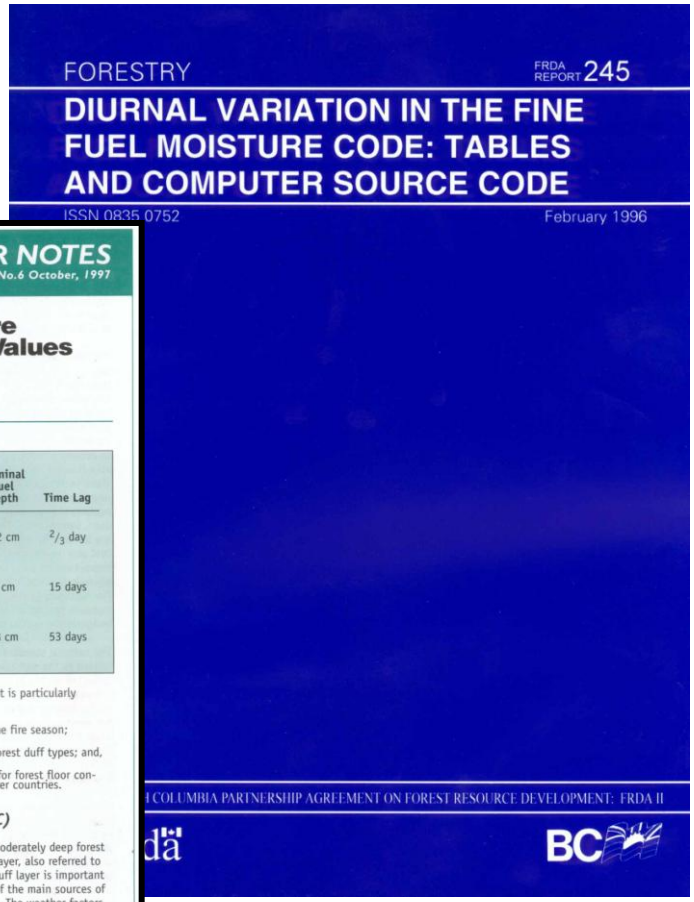
- Start a weather station late in the fire season;
- Predict smoldering ignition for forest duff types; and,
- Compare the prediction systems for forest floor consumption with those used in other countries.

Duff Moisture Code (DMC)

The DMC is a numerical rating of moderately deep forest floor dryness (basically the soil F layer, also referred to as duff). The flammability of the duff layer is important because duff consumption is one of the main sources of the energy produced in forest fires. The weather factors

[1] Moisture content is defined as the amount of water present in a fuel expressed as a percent of the oven dry weight of the fuel.

Natural Resources Canada / Ressources naturelles Canada
Canadian Forest Service / Service canadien des forêts
Canada



CFFDRS

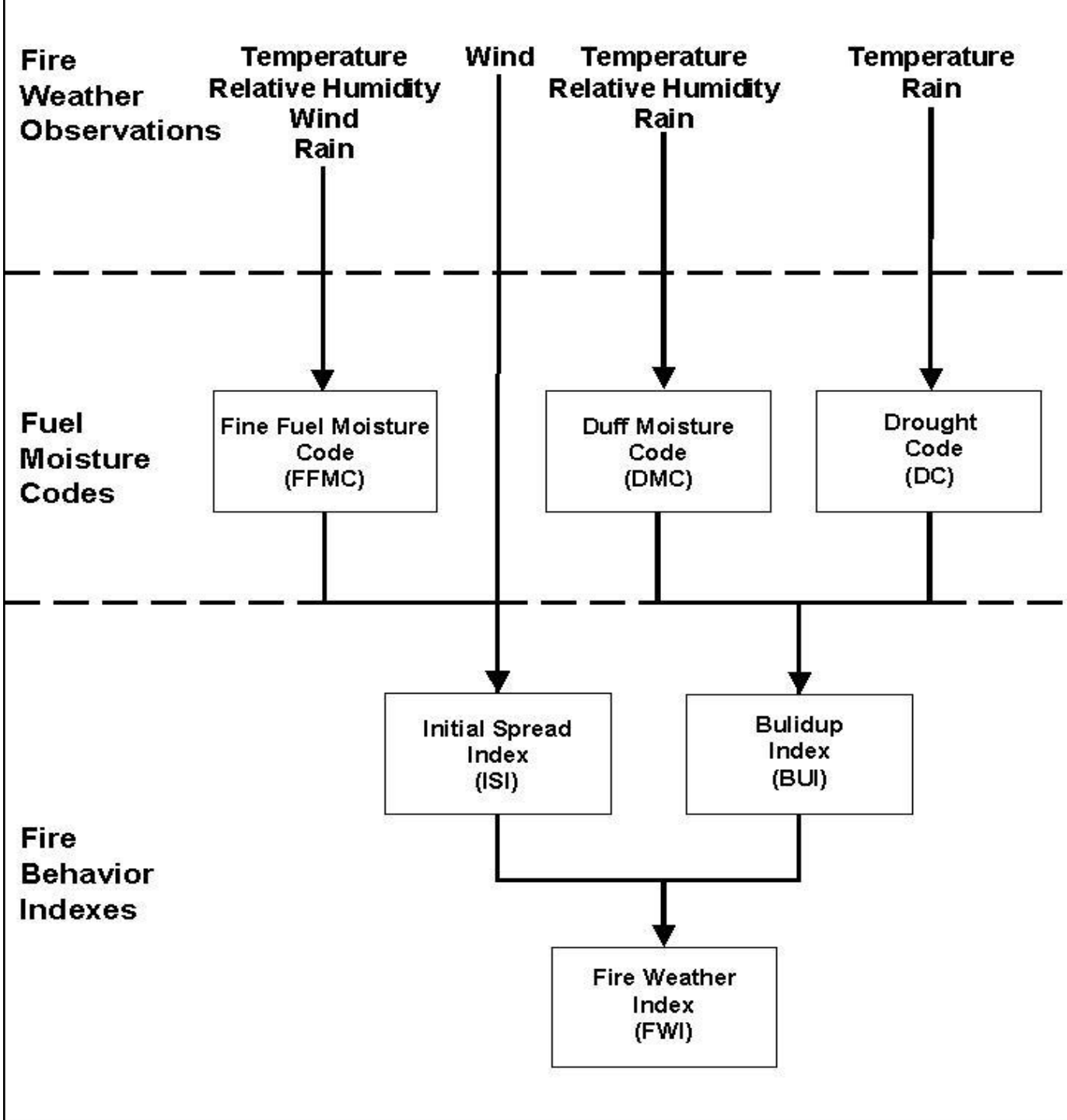
Fire Weather Index Module or Subsystem

The FWI System provides relative numerical ratings of fire potential in a standard fuel type (i.e., mature pine stand) on level terrain.

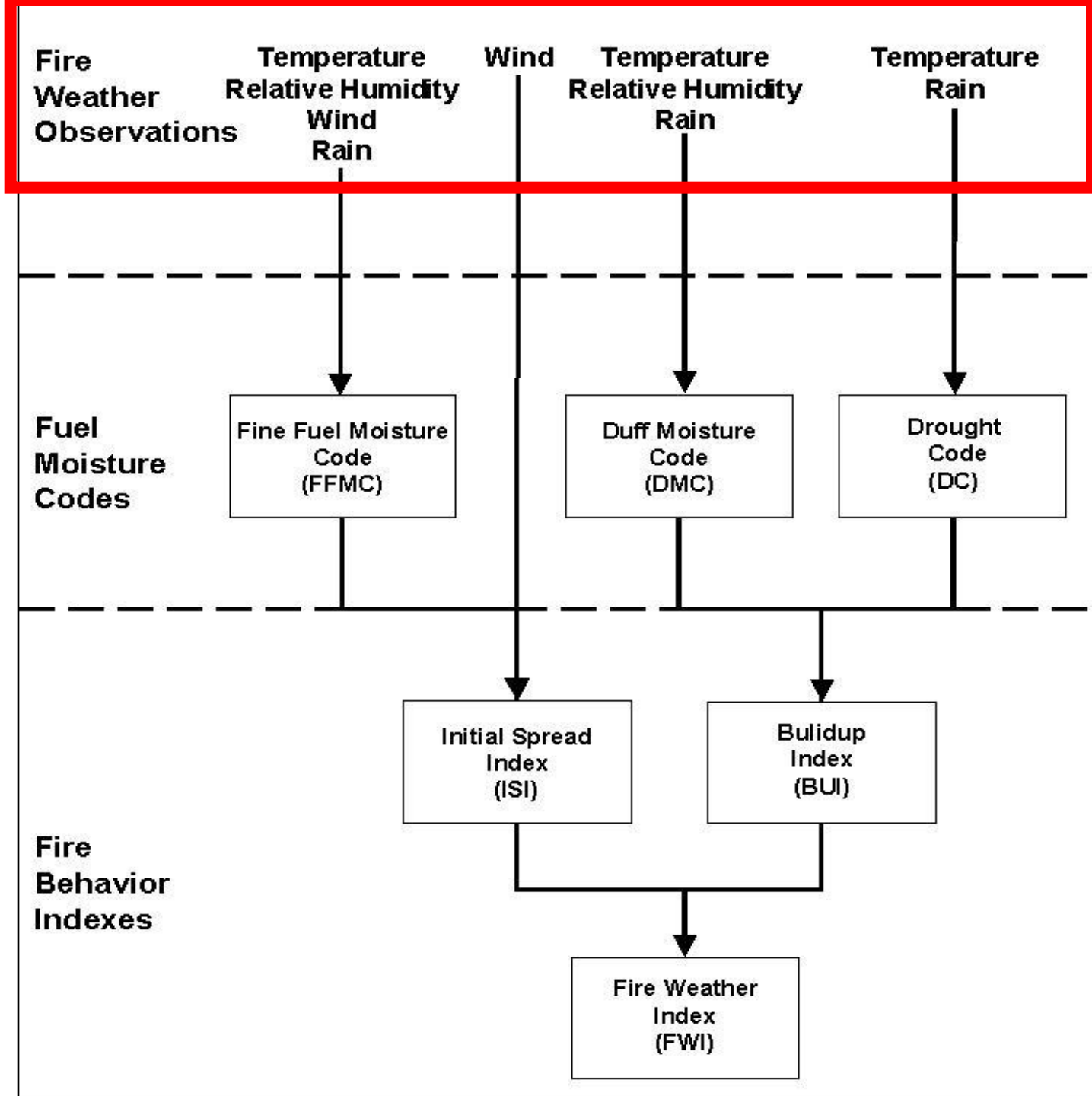
CFFDRS

Jack pine and lodgepole pine forests have continental distribution across Canada.

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



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

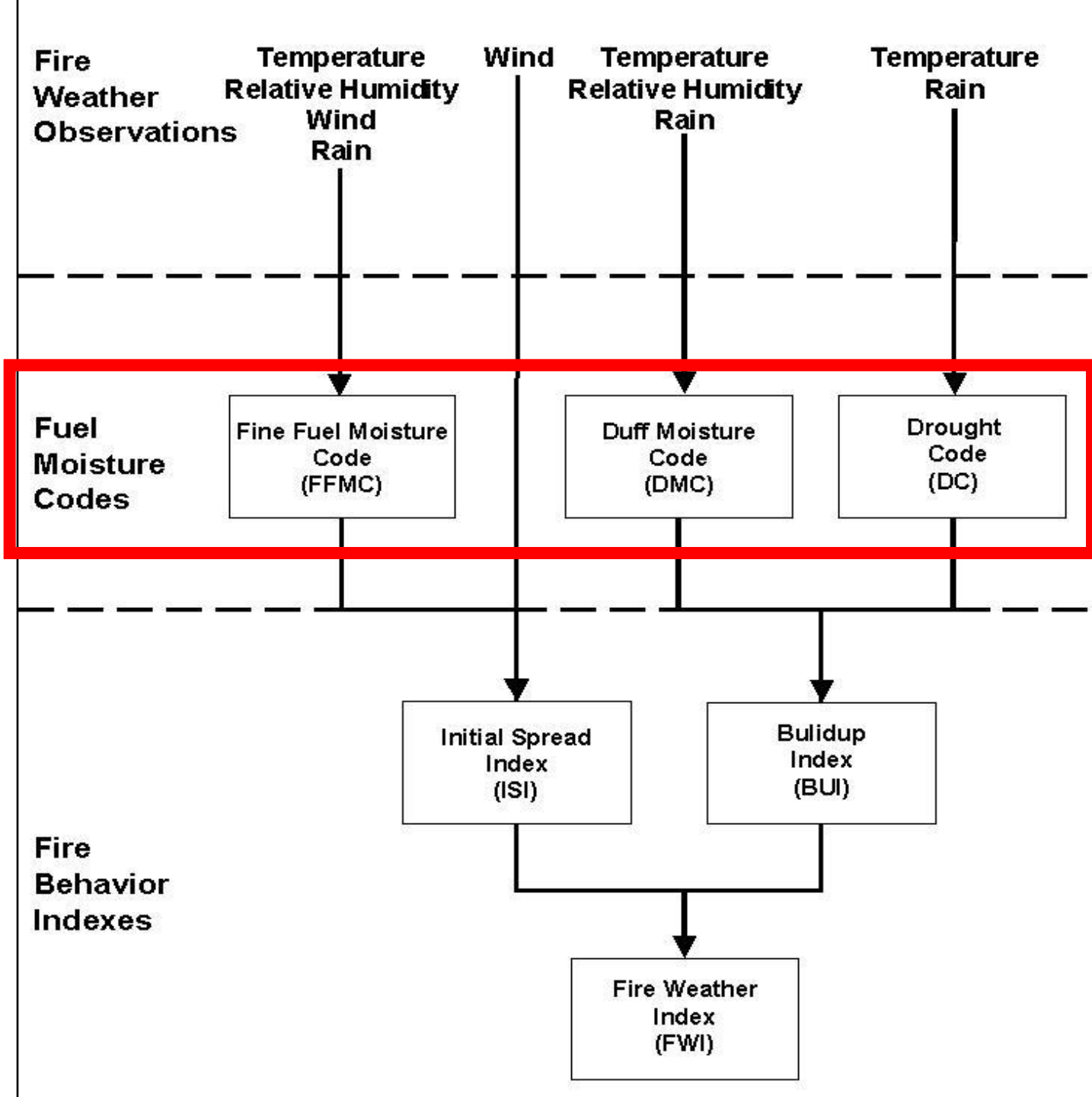


Fire Weather Observations

Dry-bulb Temperature
Relative Humidity
33-ft Open Wind Speed
24-hr Accumulated Rainfall

Calculation of the FWI System components is based on consecutive daily fire weather observations. Therefore, an unbroken daily weather record is required.

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

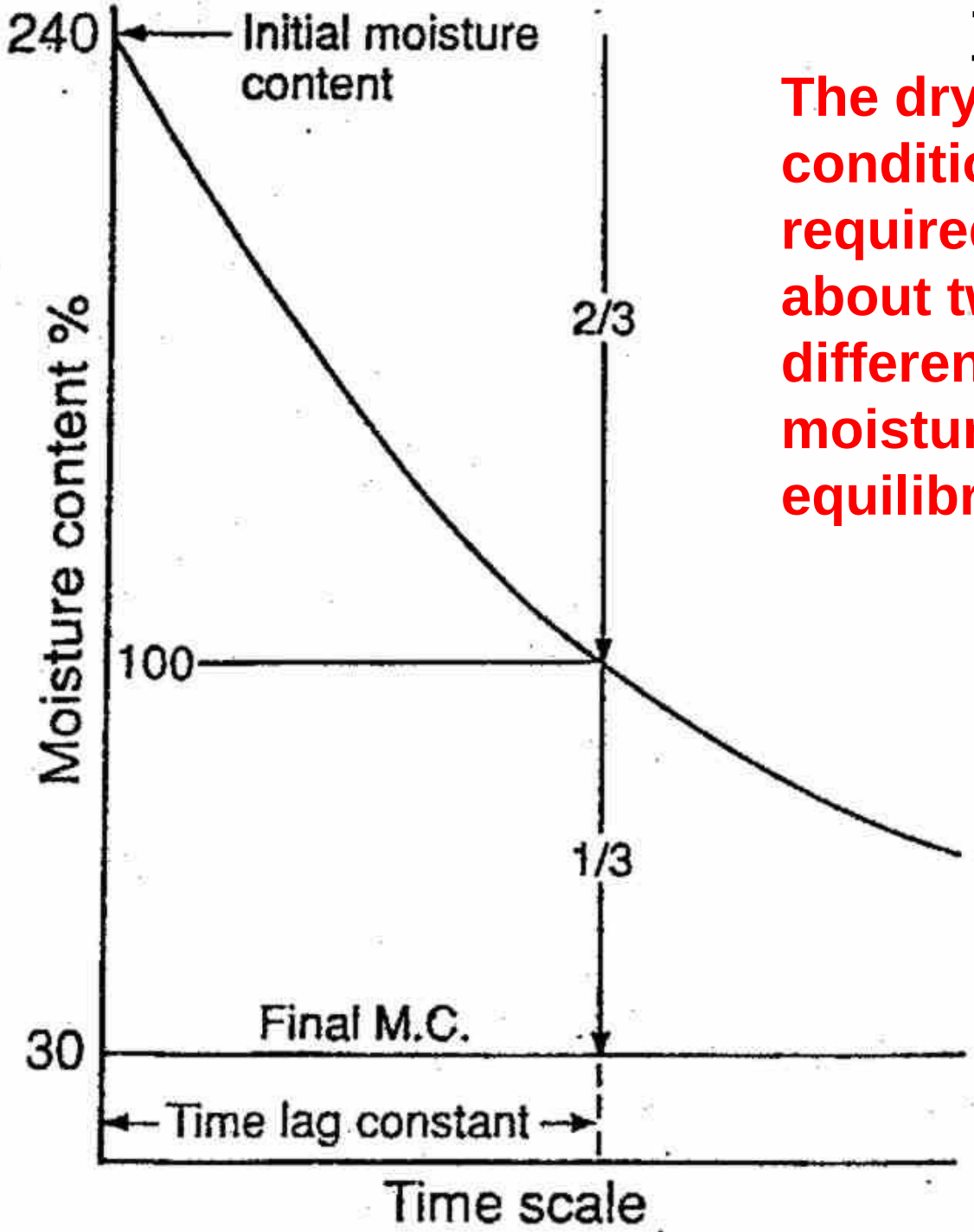


The FWI System fuel moisture codes are dynamic "bookkeeping" systems that account for each day's wetting and drying effects.

- **Fine Fuel Moisture Code (FFMC)**
- **Duff Moisture Code (DMC)**
- **Drought Code (DC)**

Higher values represent lower moisture contents and hence greater flammability

CFFDRS



Timelag Concept

The drying time, under stated conditions and time of year, required for dead fuels to lose about two-thirds of the difference between their initial moisture content and their equilibrium moisture content.

Stated Conditions

Dry-bulb Temperature:
21.1 °C (70 °F)
Relative Humidity:
45%
Wind Speed:
13 km/h (8.1 mph)
Time of Year:
July

Fine Fuel Moisture Code (FFMC)

A numerical rating of the moisture content of litter and other cured fine fuels. This code is an indicator of the relative ease of ignition and flammability of fine fuel.

<u>Weather inputs:</u> Temp, RH, Wind, Rain

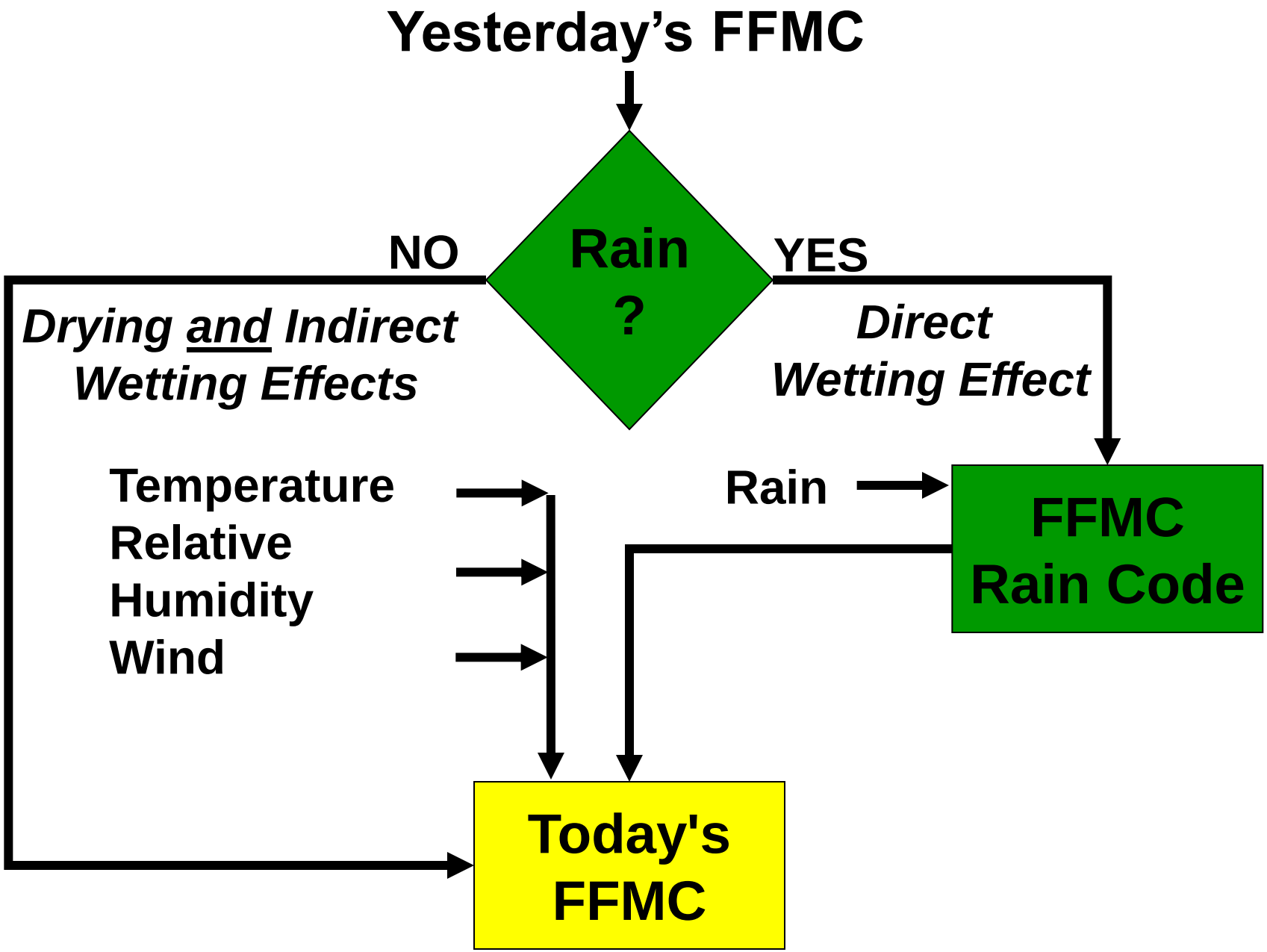
<u>Scale:</u> 0-101 (higher numbers mean lower MC)

<u>Rainfall threshold:</u> 0.02 in.

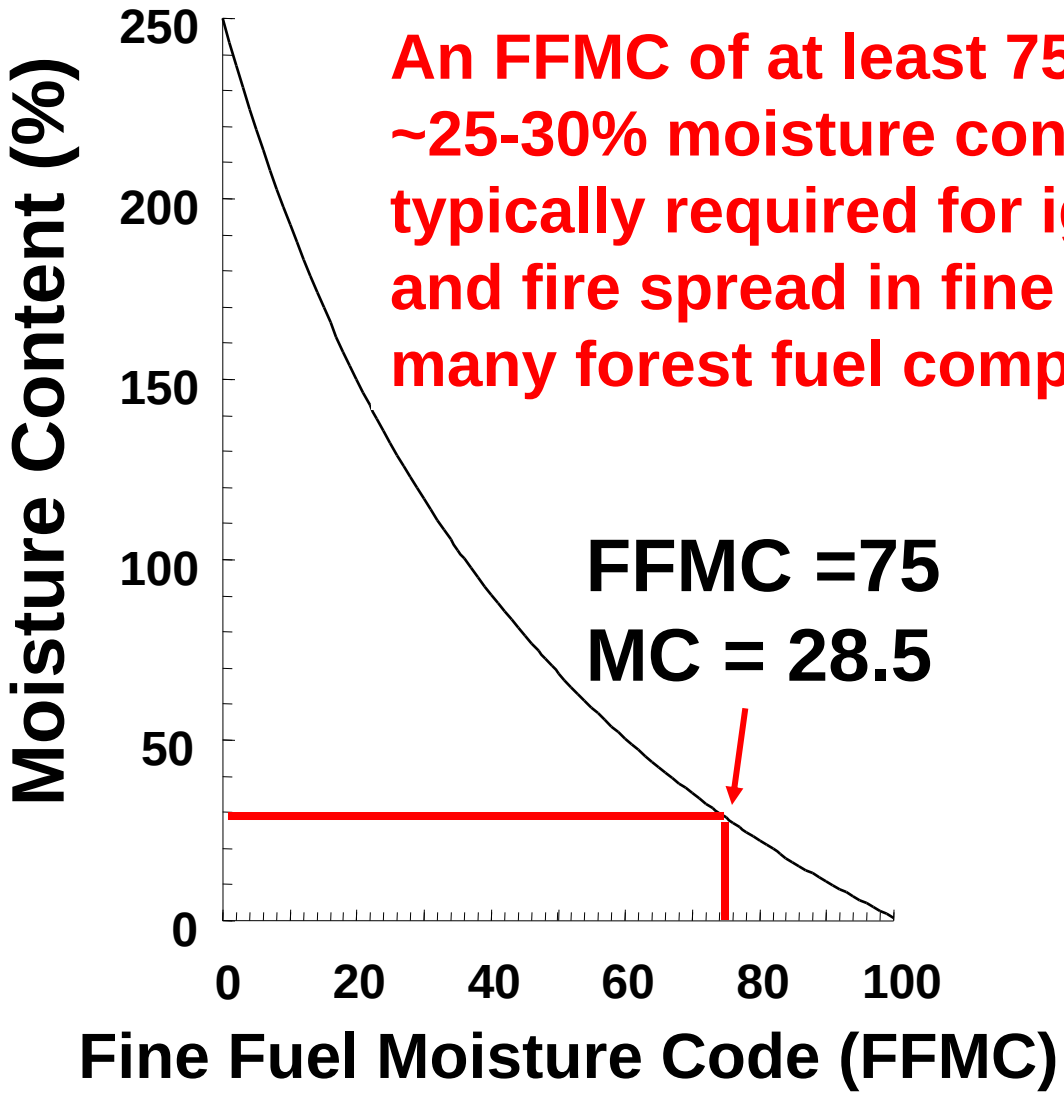
<u>Timelag or response time:</u> 2/3 day or 16 hours

<u>Nominal depth & load:</u> 0.5 in. & 1.1 T/ac

Calculation of the Fine Fuel Moisture Code (FFMC)



Fine Fuel Moisture Code (FFMC) "rough rule of thumb"



An FFMC of at least 75 (i.e., ~25-30% moisture content) is typically required for ignition and fire spread in fine fuels in many forest fuel complexes.

Spot fire ignition begins to approach certainty at FFMC 90

Duff Moisture Code (DMC)

A numerical rating of the average moisture content of loosely compacted organic layers of moderate depth. This code gives an indication of fuel consumption in moderate duff layers and medium-sized woody material.

<u>Weather inputs:</u> Temp, RH, Rain (+ Month)

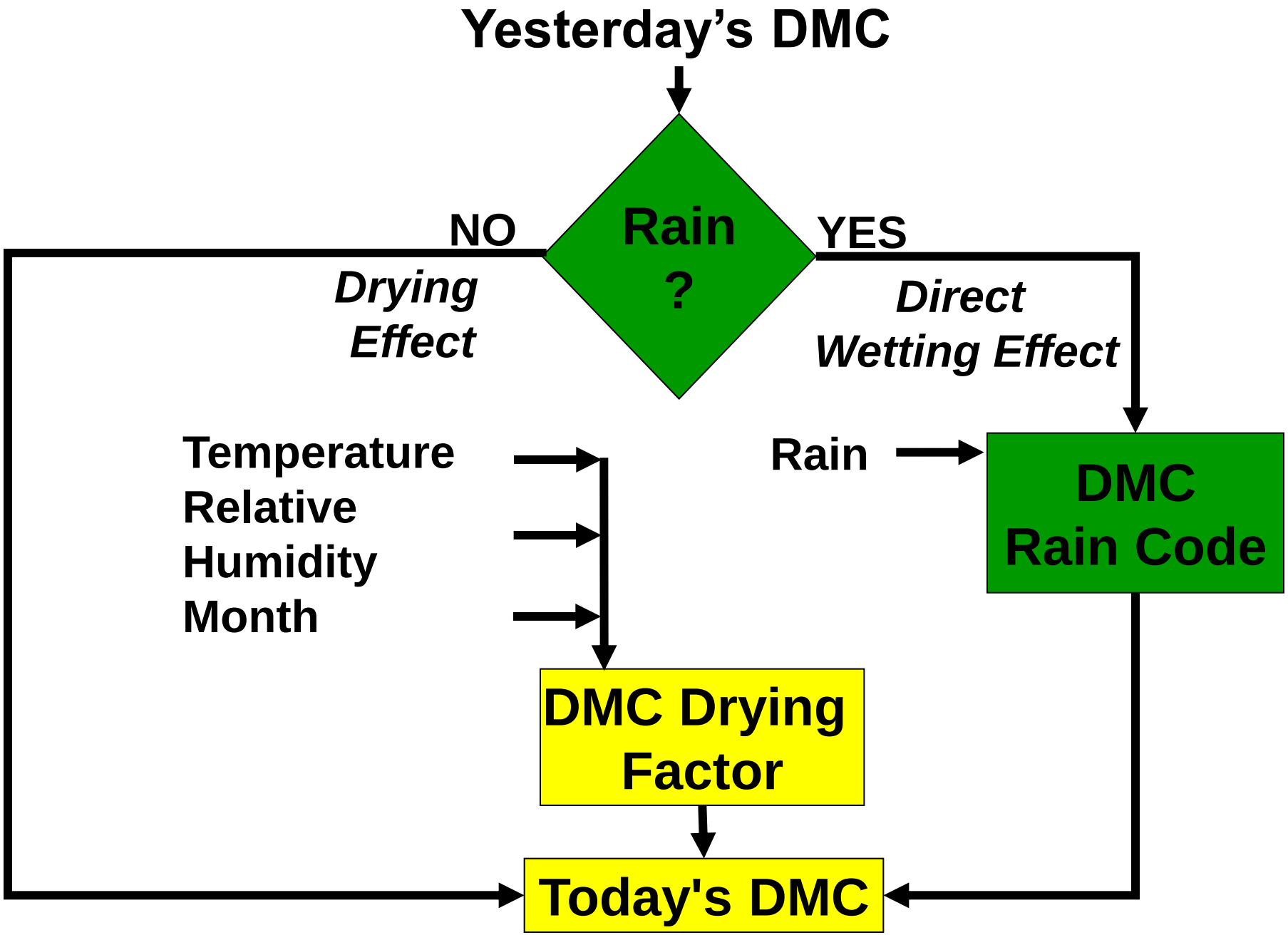
<u>Scale:</u> 0 (saturation) to "open ended"

<u>Rainfall threshold:</u> 0.06 in.

<u>Timelag or response time:</u> 15 days

<u>Nominal depth & load:</u> 2.8 in. & 22 T/ac

Calculation of the Duff Moisture Code (DMC)



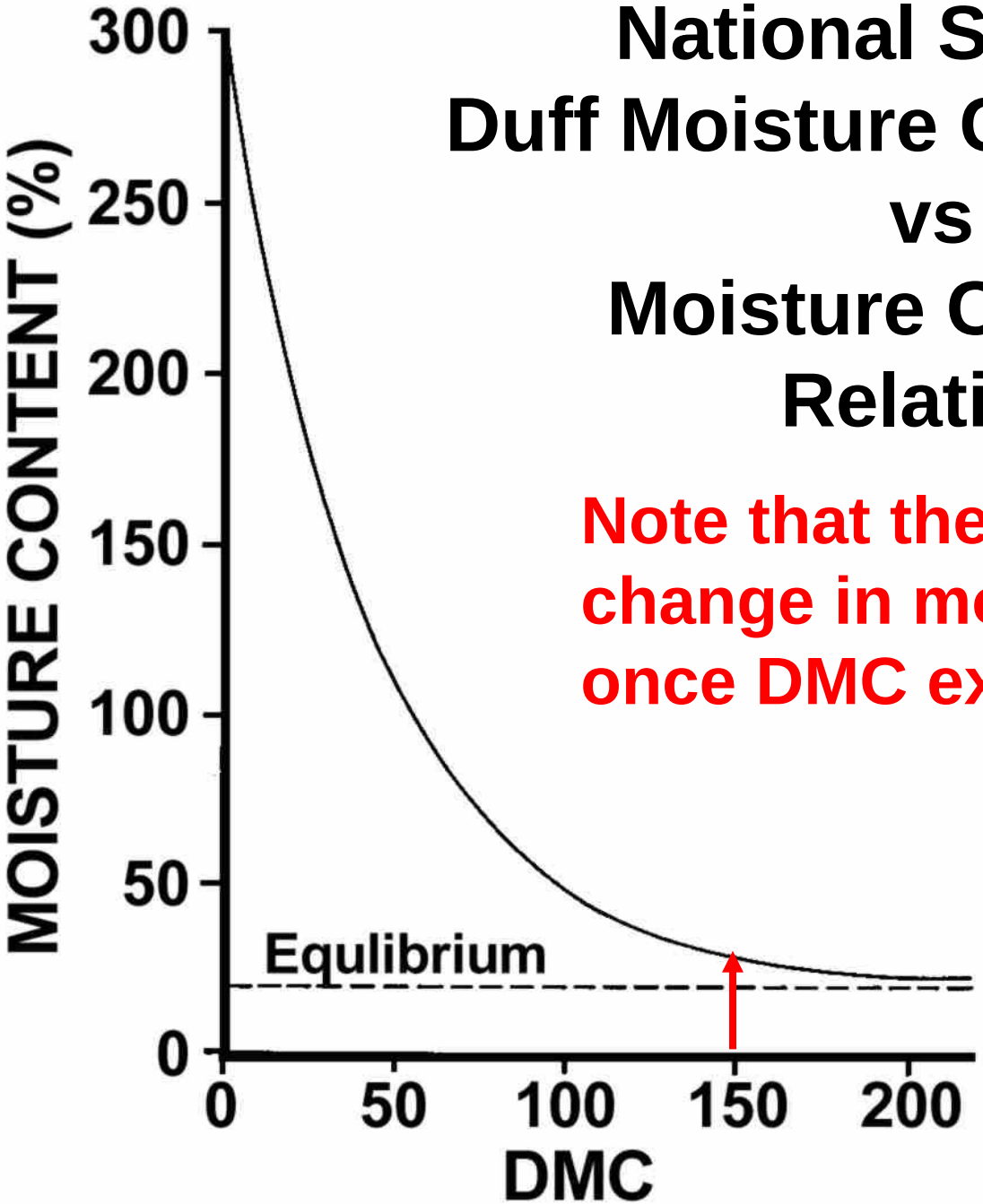
Seasonal Variation in DMC Drying

DUFF MOISTURE CODE — DMC — TABLE 4

Temperature (°C)	RH (%)	Month									
		February	March	April	May	June	July	August	September	October	November
		Drying Factor									
20.5–25	0–32	3	3	5	5	5	4	4	3	3	2
	33–52	2	2	3	4	4	3	3	2	2	2
	53–73	1	2	2	2	2	2	2	2	1	1
	74–100	1	1	1	1	1	1	1	1	1	1
25.5–30	0–27	3	4	6	6	6	5	5	4	3	3
	28–42	3	3	5	5	5	4	4	3	3	2
	43–58	2	2	3	4	4	3	3	3	2	2
	59–73	1	2	2	3	3	2	2	2	1	1
	74–100	1	1							1	1
30.5–35	0–22	4	5							4	4
	23–37	3	4							4	3
	38–53	3	3							3	2
	54–68	2	2							2	2
	69–100	1	1							1	1
≥35.5	0–17	5	6	8	9	9	8	7	6	5	5
	18–29	4	5	7	8	8	7	6	5	4	4
	30–41	4	4	6	7	7	6	5	4	4	3
	42–53	3	3	5	5	5	5	4	4	3	3
	54–65	2	3	4	4	4	4	3	3	2	2
	66–100	2	2	3	3	3	3	2	2	2	2

The length of the day influences the duration of drying

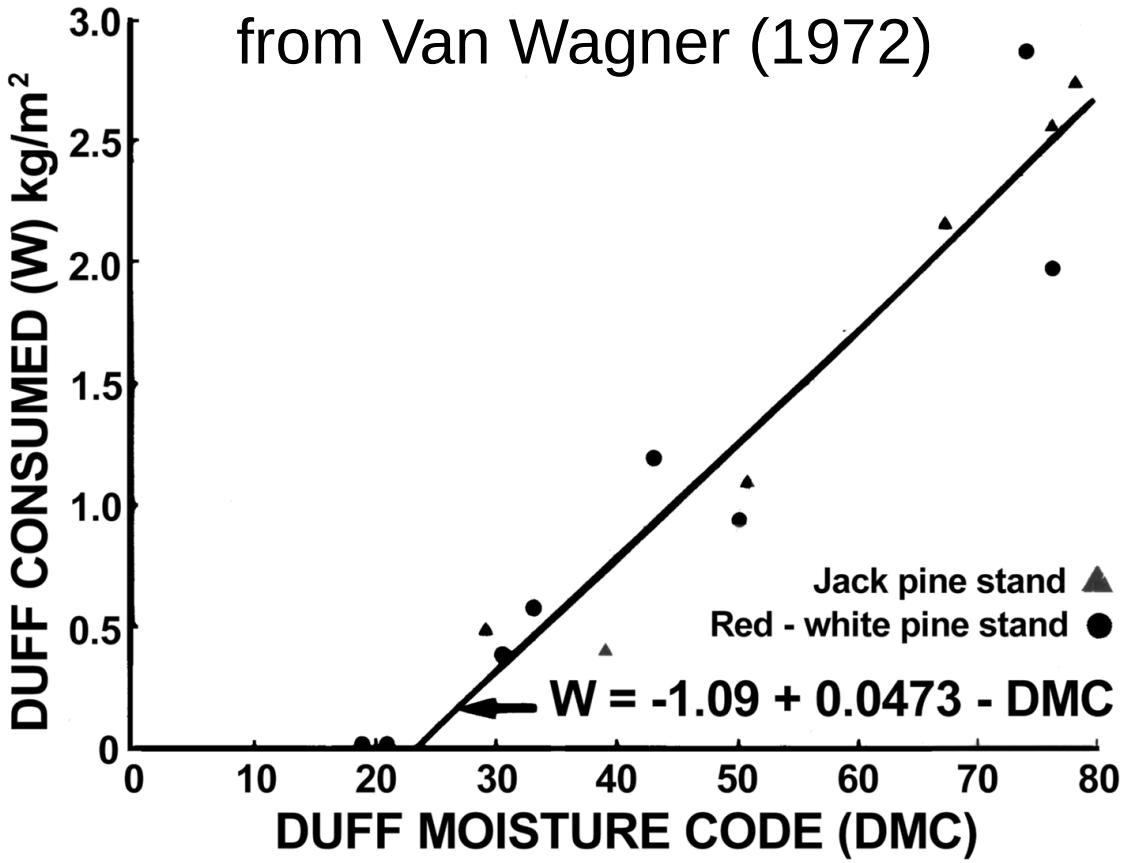
National Standard Duff Moisture Code (DMC) vs Moisture Content Relation



Note that there is very little change in moisture content once DMC exceeds ~ 150

Other duff specific relations exist

Duff Moisture Code (DMC) "rough rule of thumb"



Duff doesn't normally become involved in combustion until the DMC reaches ~ 20.

A DMC of 20 is also regarded as a threshold for lightning fire starts.

Drought Code (DC)

A numerical rating of the average moisture content of deep,compact, organic layers. This code is a useful indicator of seasonal drought effects on forest fuels, and amount of smoldering in deep duff layers and large logs.

<u>Weather inputs:</u> Temp, Rain (+ Month)

<u>Scale:</u> 0 (saturation) to "open ended"

<u>Rainfall threshold:</u> 0.11 in.

<u>Timelag or response time:</u> 53 days

<u>Nominal depth & load:</u> 7.1 in. & 112 T/ac

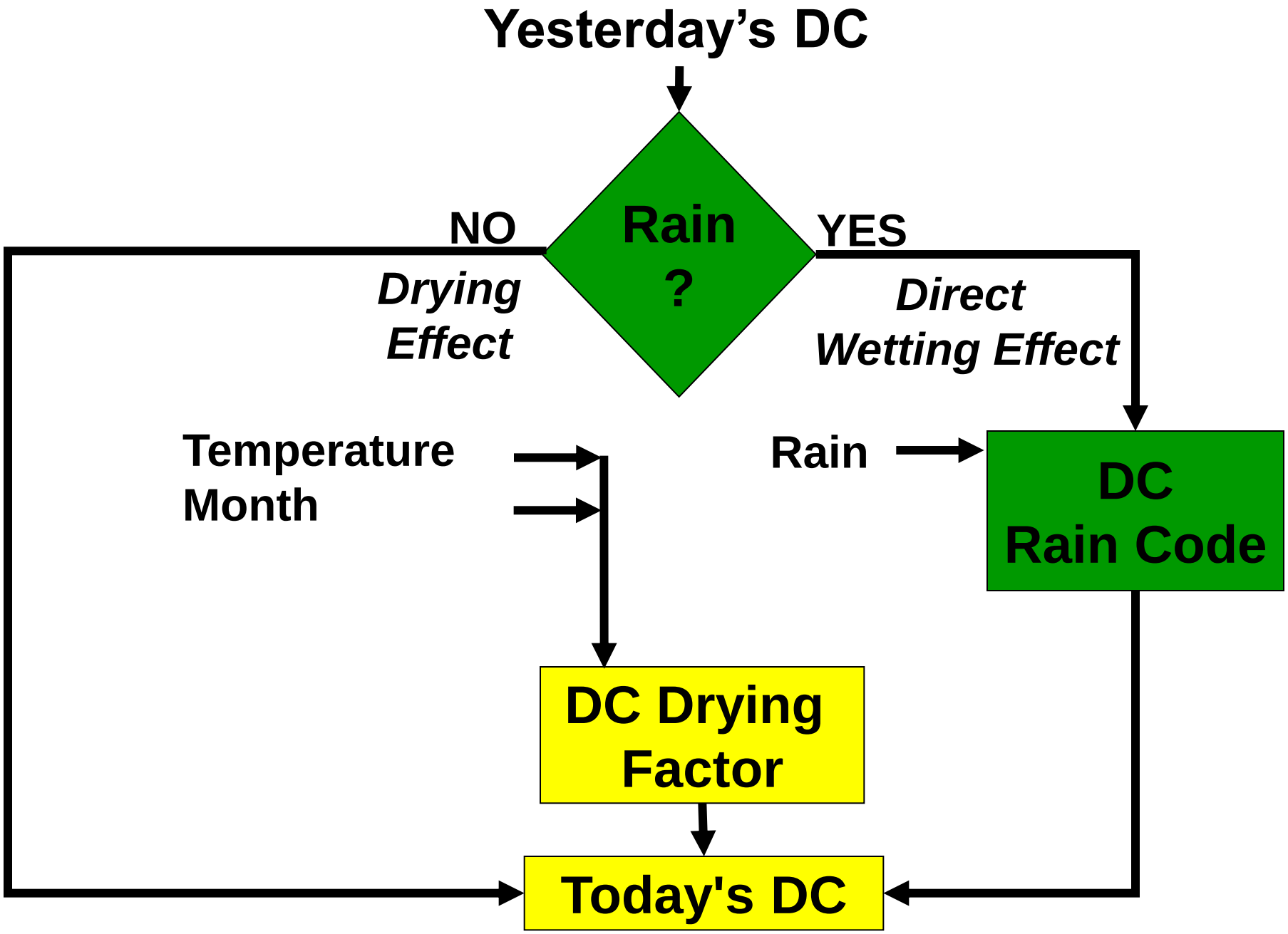
Seasonal Variation in DC Drying

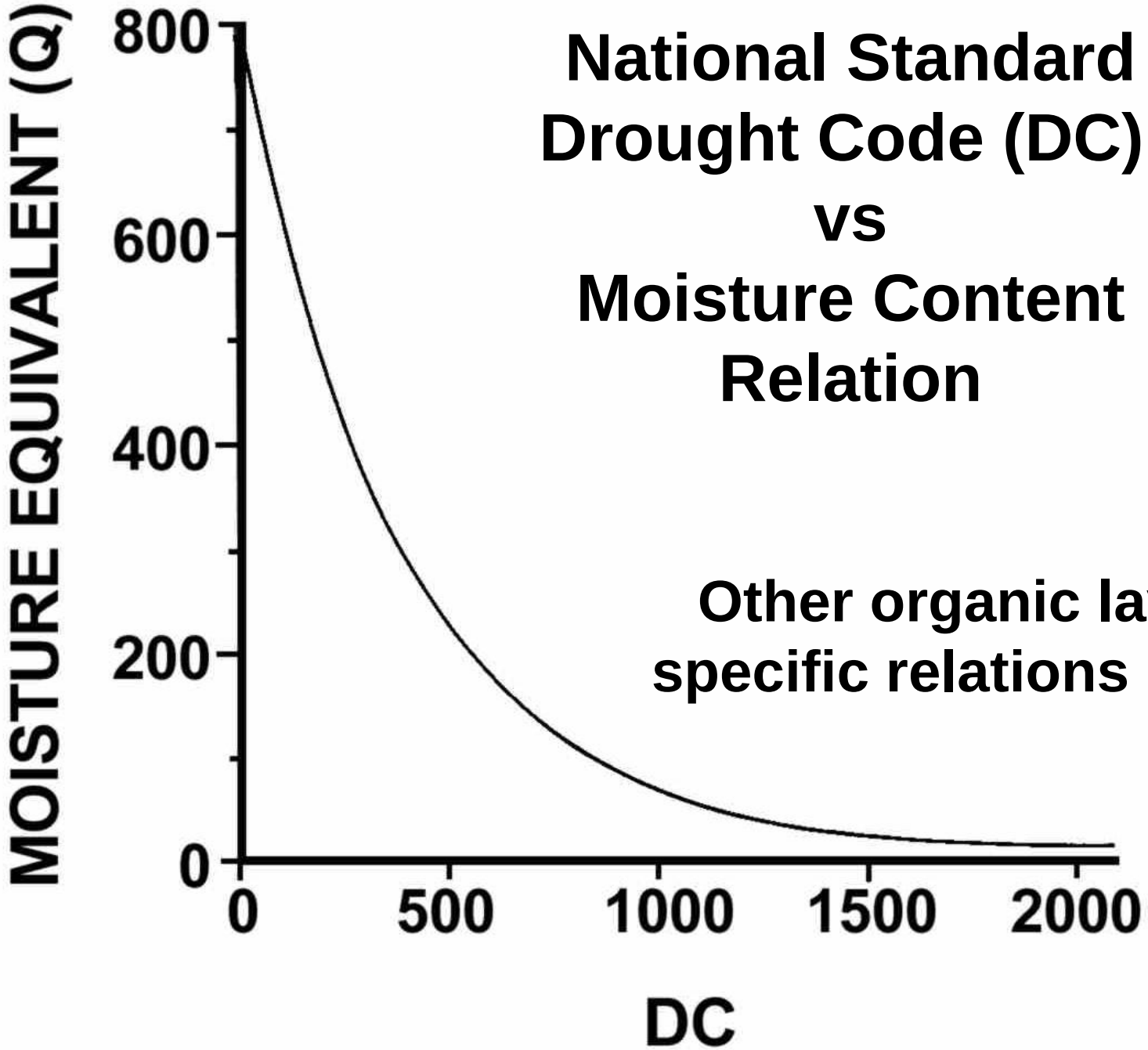
DROUGHT CODE — DC — TABLE 6

Temperature (°C)	Month											
	January	February	March	April	May	June	July	August	September	October	November	December
	Drying Factor											
20.5–22	4	4	4	5	6	7	8	7	6	5	4	4
22.5–24	4	4	4	5	7	8	8	7	6	5	4	4
24.5–26	4	4	4	5	7	8	8	8	6	5	4	4
26.5–28	5	5	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	5
28.5–30	5	5	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	5
30.5–32	5	5	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	5
32.5–34	6	6	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6	6
34.5–36	6	6	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6	6
36.5–38	6	6	6	8	9	10	10	10	8	7	6	6
≥38.5	7	7	7	8	9	10	11	10	9	8	7	7

The length of the day influences the duration of drying.

Calculation of the Drought Code (DC)





National Standard Drought Code (DC) vs Moisture Content Relation

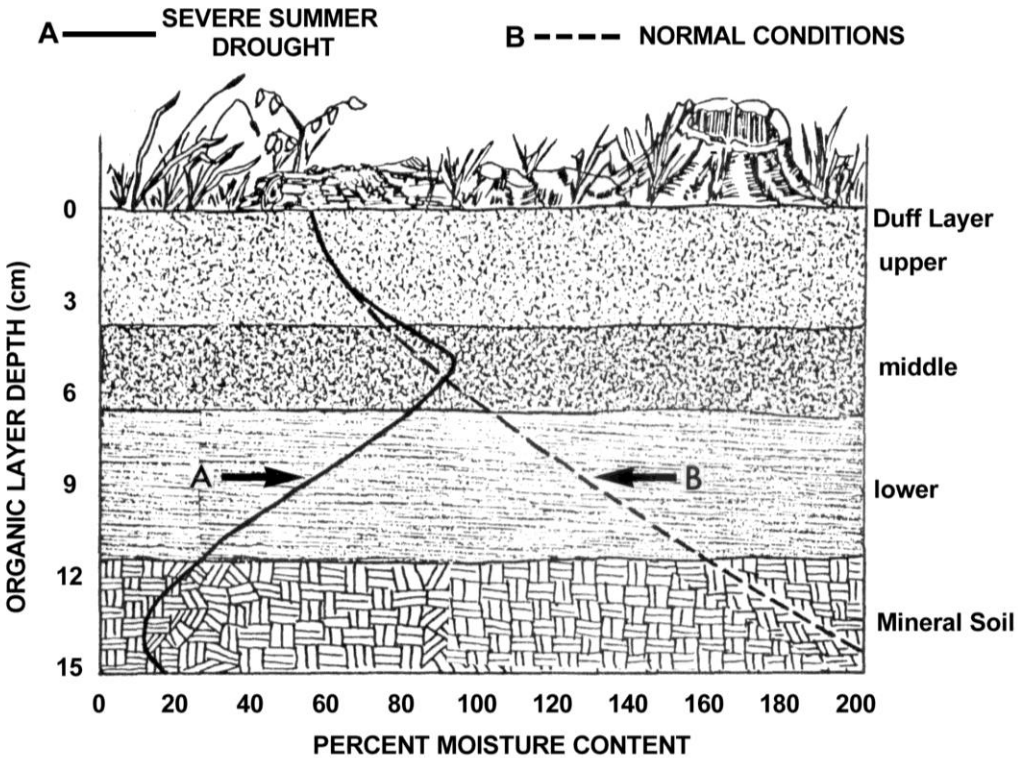
Other organic layer specific relations exist

Fall Drought Code	Overwinter precipitation (mm water equivalent) 0	20	40	60	80	100	120	140	160	180	200
	Spring Drought Code										
0	15										
20	20	15									
40	40	15									
60	60	21	15								
80	80	39	15								
100	100	57	18	15							
120	120	75	34	15							
140	140	93	50	15							
160	160	110	66	26	15						
180	180	128	82	41	15						
200	200	145	97	55	16	15					
220	220	163	113	68	28	15					
240	240	180	128	82	41	15					
260	260	197	143	95	53	15					
280	280	214	158	108	64	25	15				
300	300	231	173	121	76	35	15				
320	320	248	187	134	87	45	15				
340	340	265	201	147	98	55	17	15			
360	360	281	215	159	109	65	25	15			
380	380	297	229	171	120	75	34	15			
400	400	314	243	182	130	84	42	15			
420	420	330	256	194	140	93	50	15			
440	440	346	269	205	150	101	58	19	15		
460	460	361	282	216	159	110	66	26	15		
480	480	377	295	227	169	118	73	33	15		
500	500	392	307	237	178	126	80	39	15		
520	520	407	320	248	187	134	87	45	15		
540	540	422	332	258	195	141	94	51	15		
560	560	437	343	267	204	149	100	57	18	15	
580	580	452	355	277	212	156	106	63	23	15	
600	600	466	366	286	219	162	112	68	28	15	
620	620	480	377	295	227	169	118	73	33	15	
640	640	494	388	304	234	175	124	78	37	15	
660	660	508	398	312	242	181	129	83	42	15	
680	680	522	409	321	249	187	134	88	46	15	
700	700	535	419	329	255	193	139	92	50	15	
720	720	548	428	336	262	199	144	96	54	15	
740	740	561	438	344	268	204	149	101	57	18	15
760	760	574	447	351	274	209	153	104	61	22	15
780	780	586	456	358	280	214	158	108	64	25	15
800	800	599	465	365	285	219	162	112	68	28	15

Adjustments to the spring DC starting value for high season ending value and/or below normal over winter precipitation

Example:
Fall DC: 500
Overwinter Precip: 100 mm
Spring DC = 126

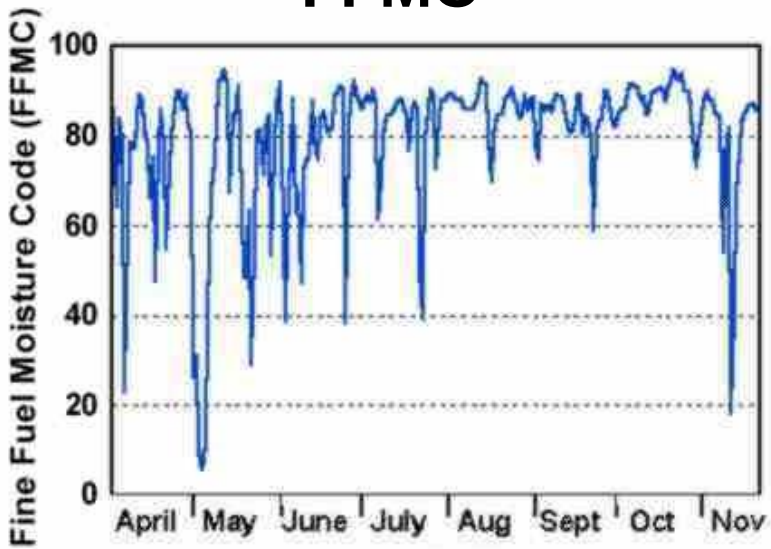
Drought Code (DC)
"rough rule of thumb"



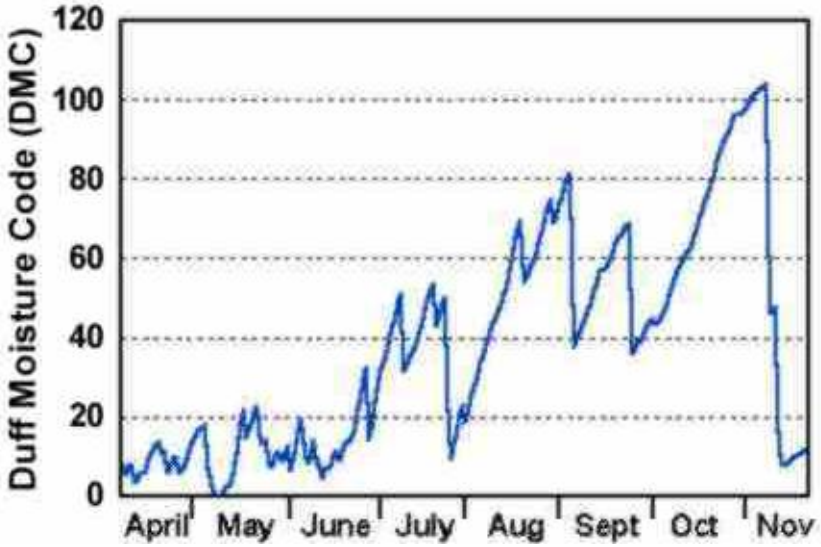
In many forest fuel complexes a DC of around 300 is generally considered a critical point or threshold for the onset of significant ground or sub-surface fire persistence or activity and in turn mop-up problems.

Daily variations in FWI System Fuel Moisture Codes

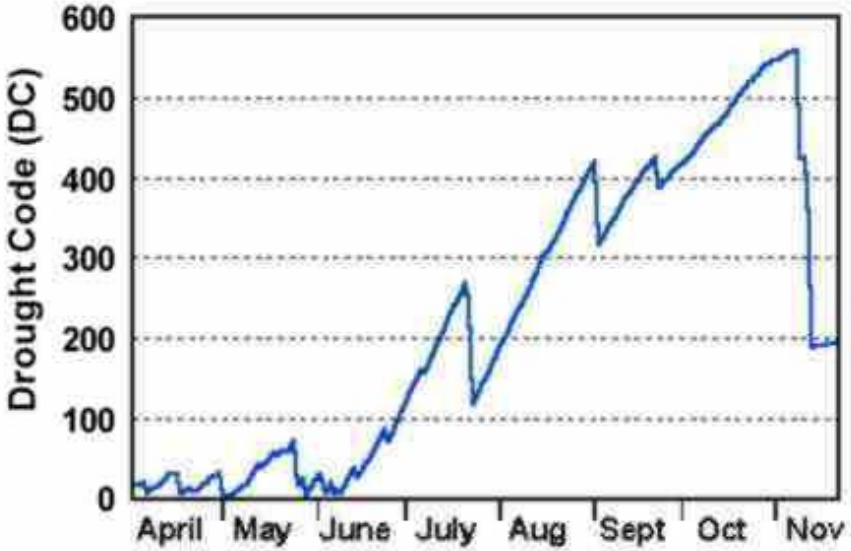
FFMC



DMC



DC



FWI System Fuel Moisture Codes

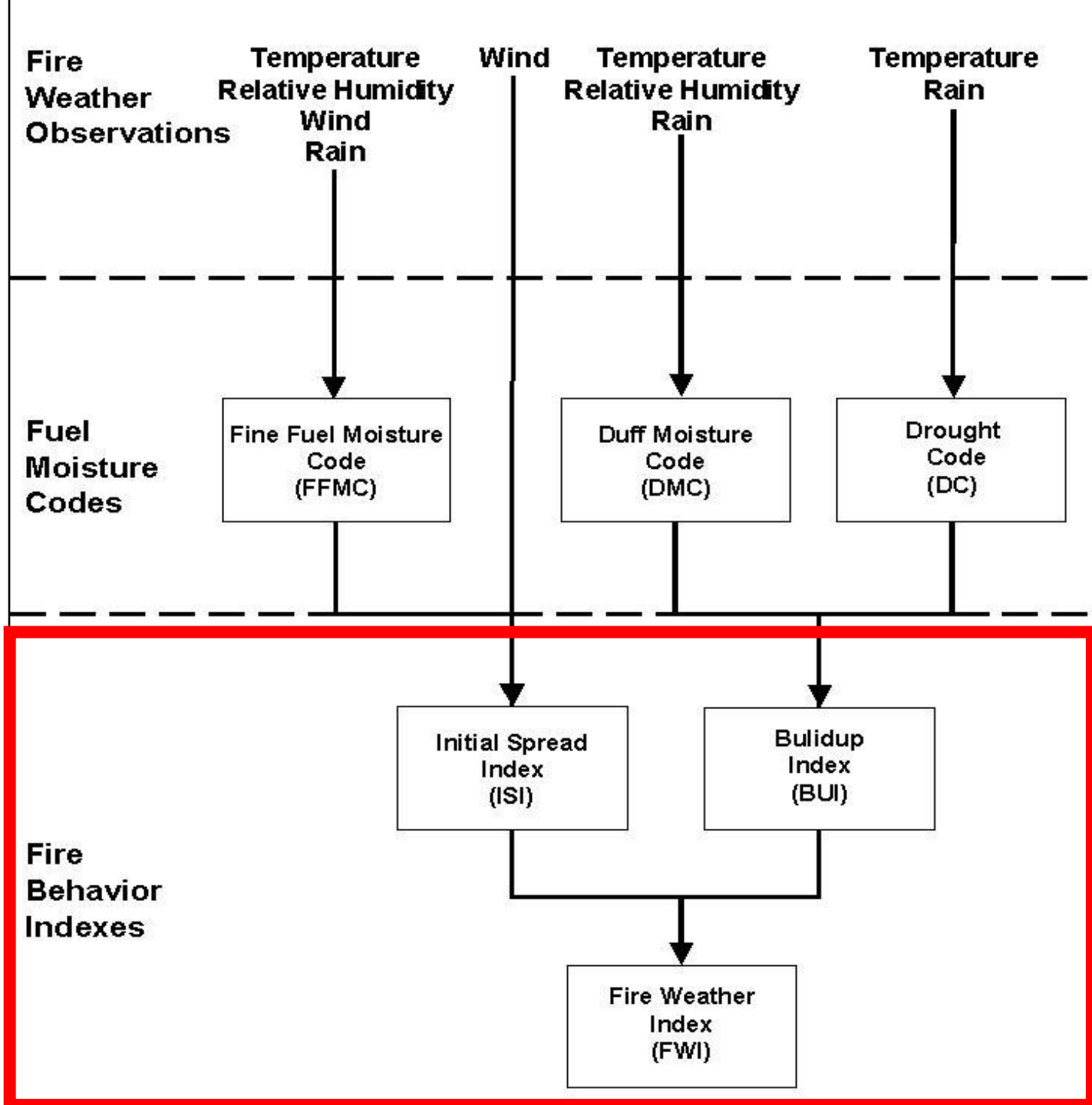
"Memories“:

FFMC - integrates weather effects of past several days

DMC - integrates weather effects over past couple of weeks

DC - integrates temperature and rainfall trend over period of months

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



Basic Features of a Forest Fire:

It spreads …

it consumes or "eats" fuel and …

it produces heat energy and light in …

… a visible flaming combustion reaction.

Byram's Fireline Intensity

$$I = H \times W \times R$$

I	H	W	R
Fire Intensity (Btu/sec-ft)	**Heat of Combustion** (8000 Btu/lb)	**Fuel Consumed** (lb/ft^2)	**Rate of Fire Spread** (ft/sec)

The FWI System's fire behavior indexes are patterned after Byram's fireline intensity concept

$$I = H \cdot w \cdot r$$

FWI constant BUI ISI

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

Values increase as fire weather severity worsens

Initial Spread Index (ISI)

A numerical rating of the expected rate of fire spread. It combines the effects of wind and FFMC on rate of spread without the influence of variable quantities of fuel.

<u>Inputs:</u> FFMC, Wind

<u>Scale:</u> 0 to "open ended"

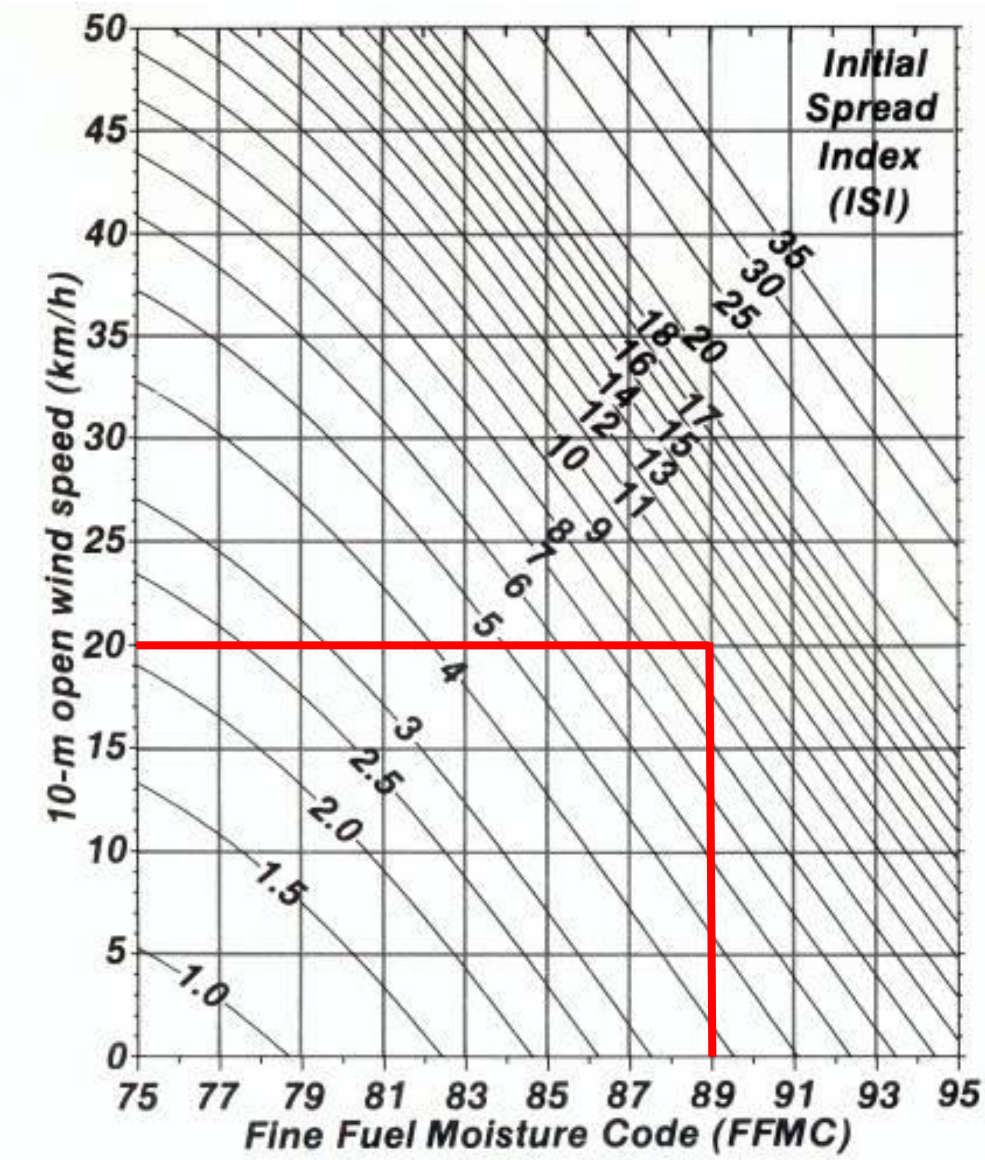
<u>Of note:</u> Lacks long-term effect of heavy fuel dryness. Best used as a correlator against actual head fire rate of spread in specific fuel types.

Initial Spread Index (ISI) "rough rule of thumb"

ISI values over 10 generally indicate a significant potential for spread in most forest fuel complexes.

For example:

ISI is a function of the FFMC and 10-m open wind. An FFMC of 89 and wind of 20 gives an ISI of 10.



Buildup Index (BUI)

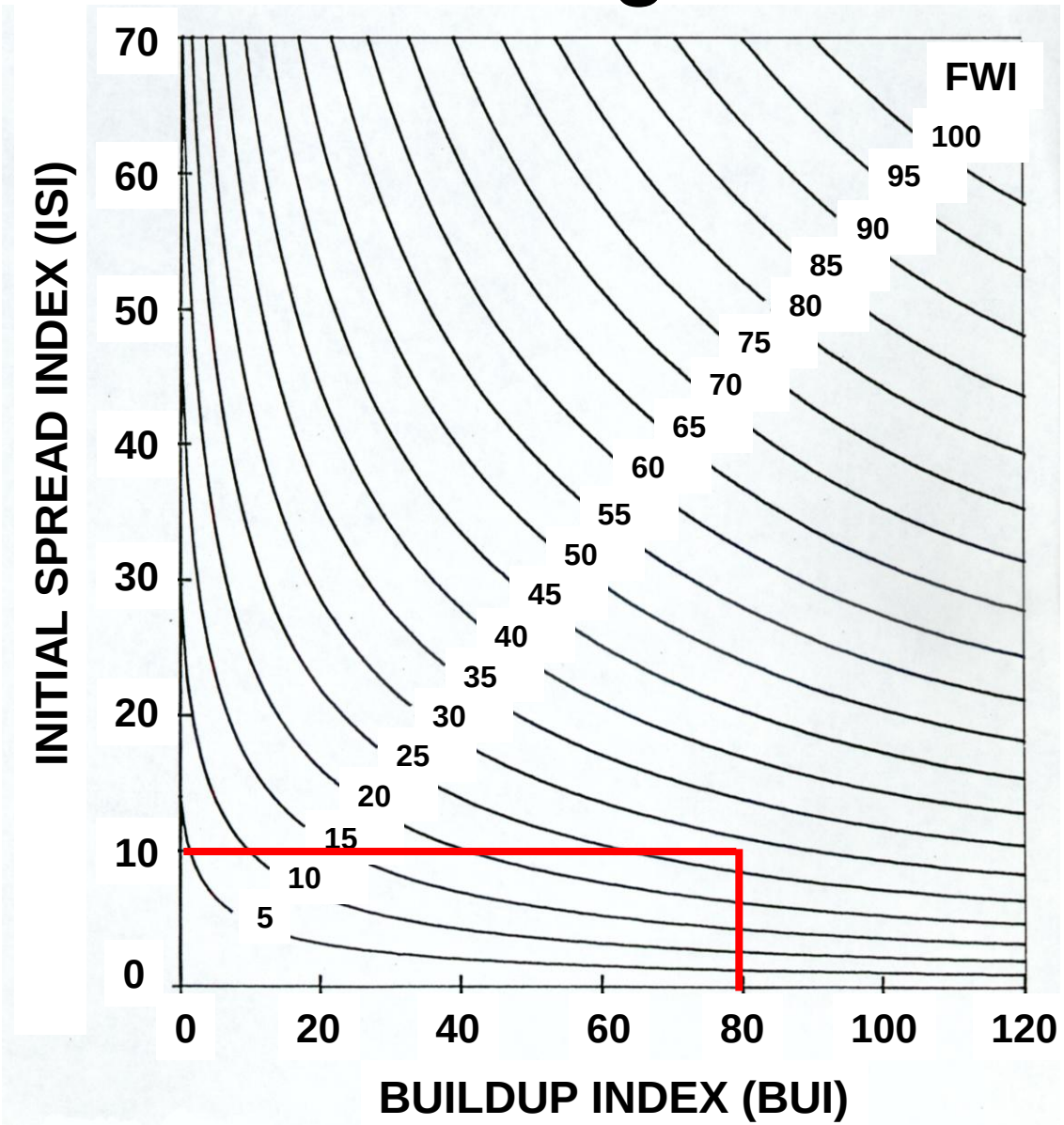
A numerical rating of the total amount of fuel available for combustion that combines DMC and DC.

<u>Inputs:</u> DMC, DC

<u>Scale:</u> 0 to "open ended"

<u>Of note:</u> Compound measure of duff and heavy fuel dryness. Integrates medium and long-term weather history. Good indicator of fire potential over wide areas. Best used as a correlator against actual fuel consumption in specific fuel types.

Buildup Index (BUI) "rough rule of thumb"



In most boreal forest fuel complexes, a BUI > 80 represents a very significant level because given a nominal ISI of 10 (and thus a FWI ~28), the onset of extreme fire behavior is in turn quite likely.

Fire Weather Index (FWI)

A numerical rating of fire intensity that combines ISI and BUI. It is suitable as a general index of fire danger throughout the forested areas of Canada.

<u>Inputs:</u> ISI, BUI

<u>Scale:</u> 0 to "open ended"

<u>Of note:</u> Complex series of effects blended into one number. Integrates effects of weather history and current weather on fire behavior potential. Good correlator against fire intensity in a number of fuel types.

Different ISI and BUI combinations can result in the same FWI value

For example:

BUI 200
ISI 5

BUI 24
ISI 18

FWI
24

Different DMC and DC combinations can also result in the same BUI

For example:

DMC 13
DC 329

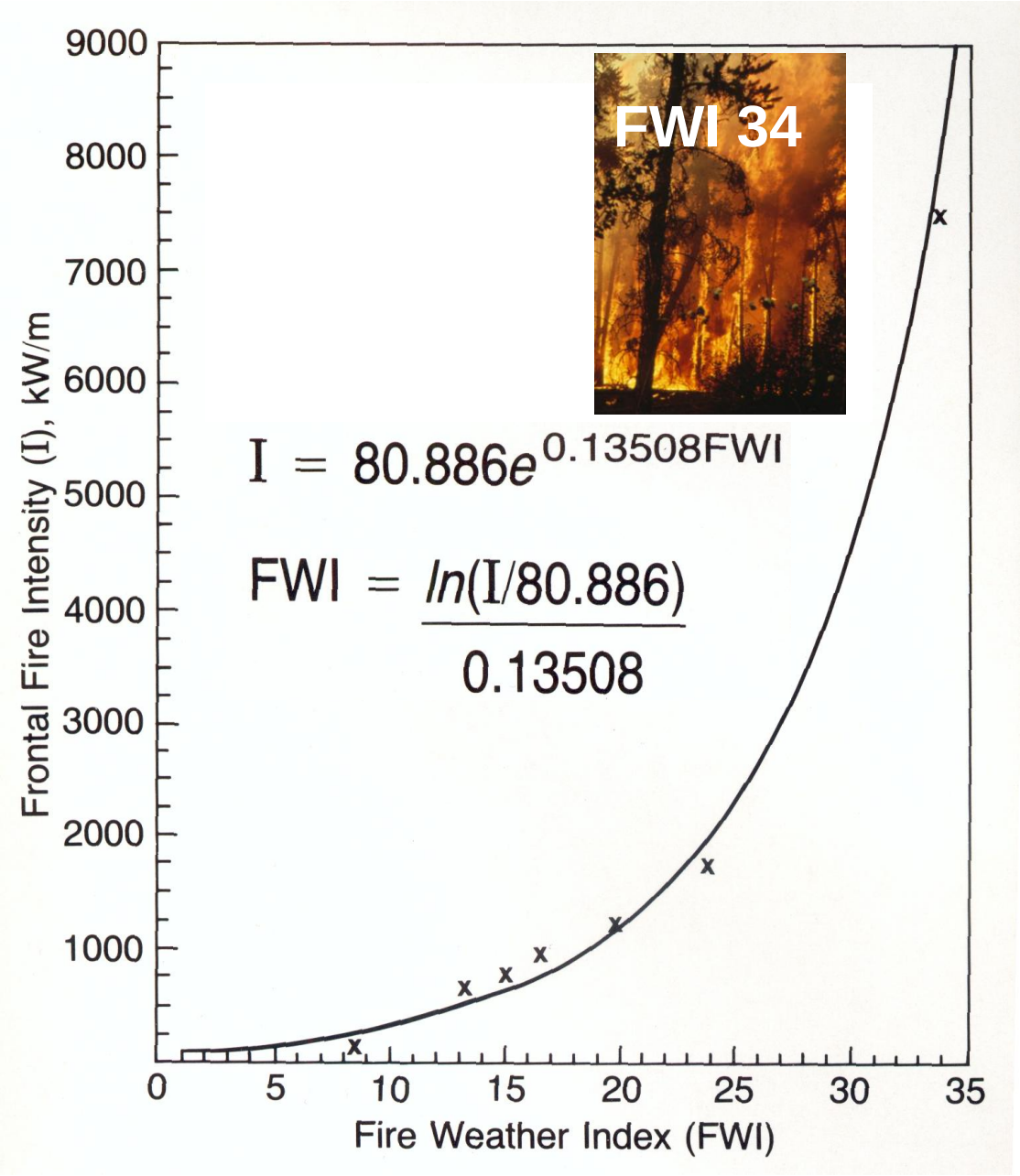
DMC 22
DC 60

BUI
24

In cases where a low BUI is involved, one needs to check for the possibility of a high DC.

Poster “Fire Behavior in Jack Pine Stands Related to the Canadian Forest Fire Weather Index (FWI) System

Fire intensity as a function of the FWI for the Darwin Lake Project experimental fires

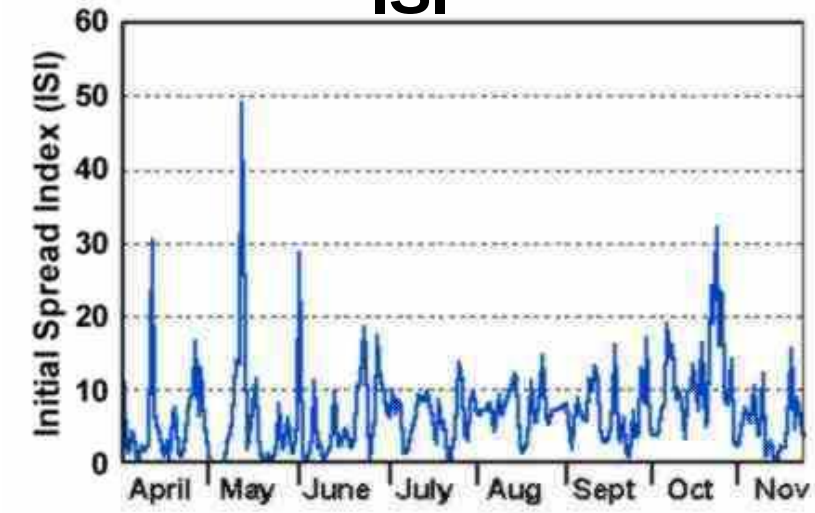


Fire Weather Index (FWI)
"rough rule of thumb"

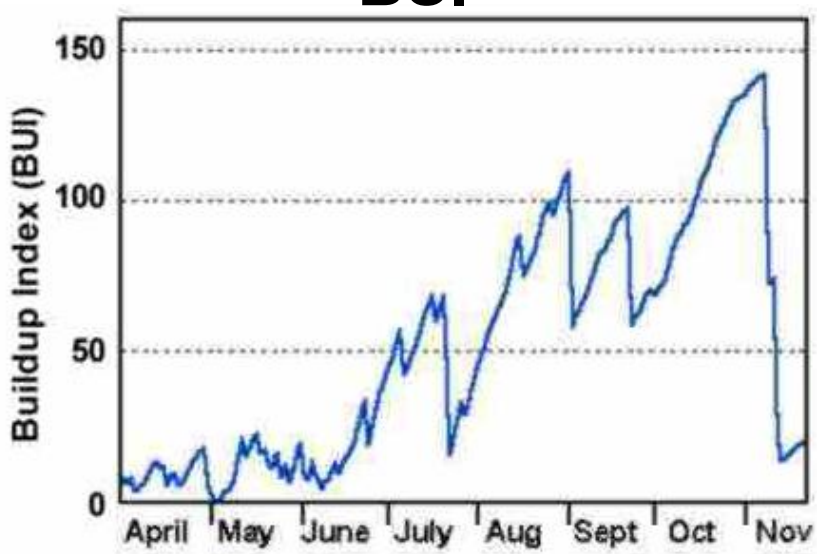
Most wildfire "disasters" in forested areas are associated with FWI values of greater than about 50

Daily variations in FWI System Fire Behavior Indexes

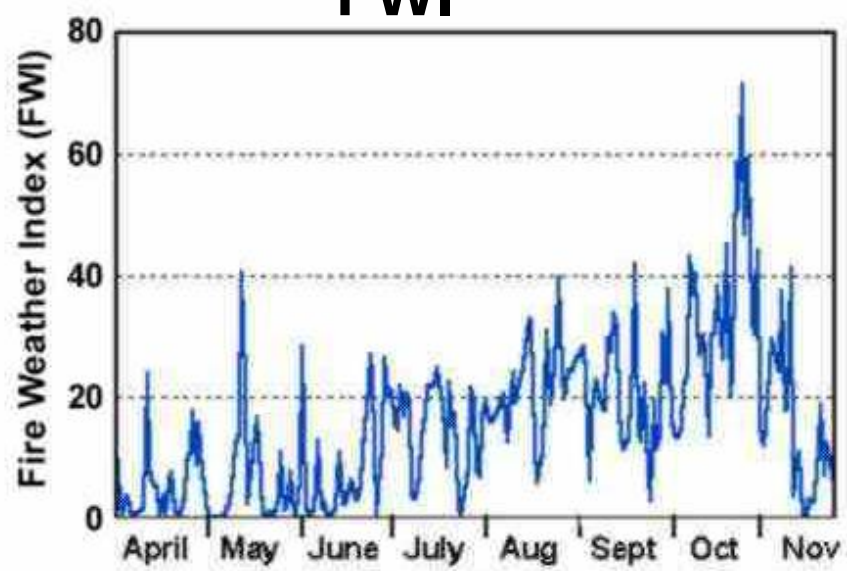
ISI



BUI

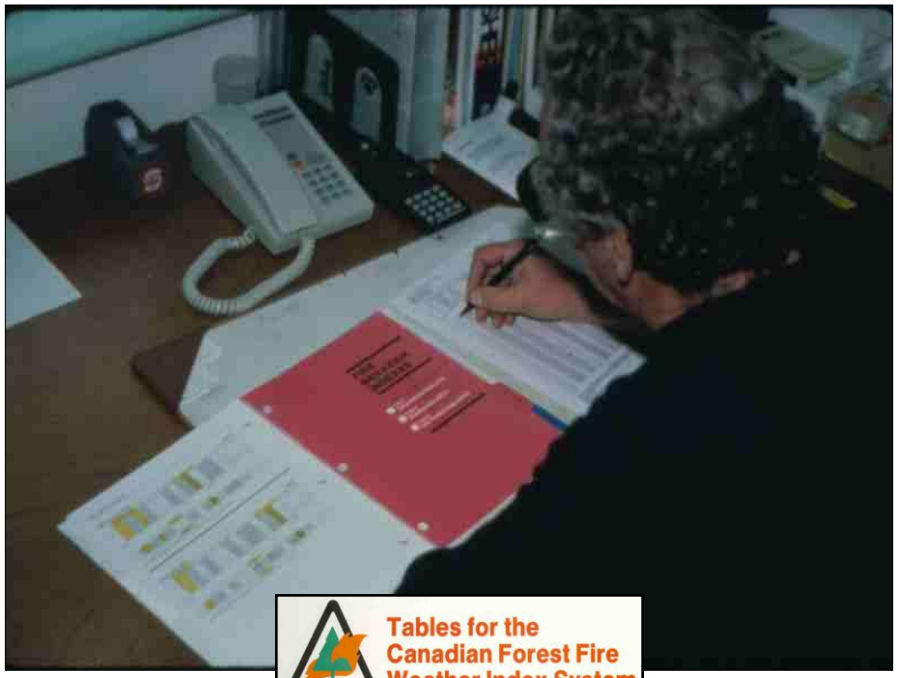


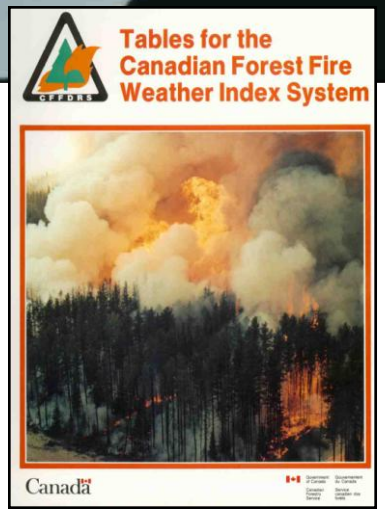
FWI



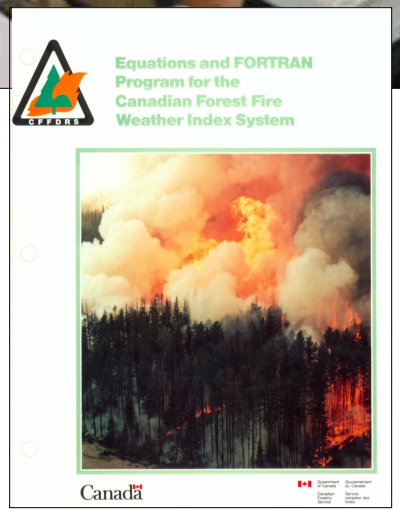
FWI System Calculations

Tables





Computer



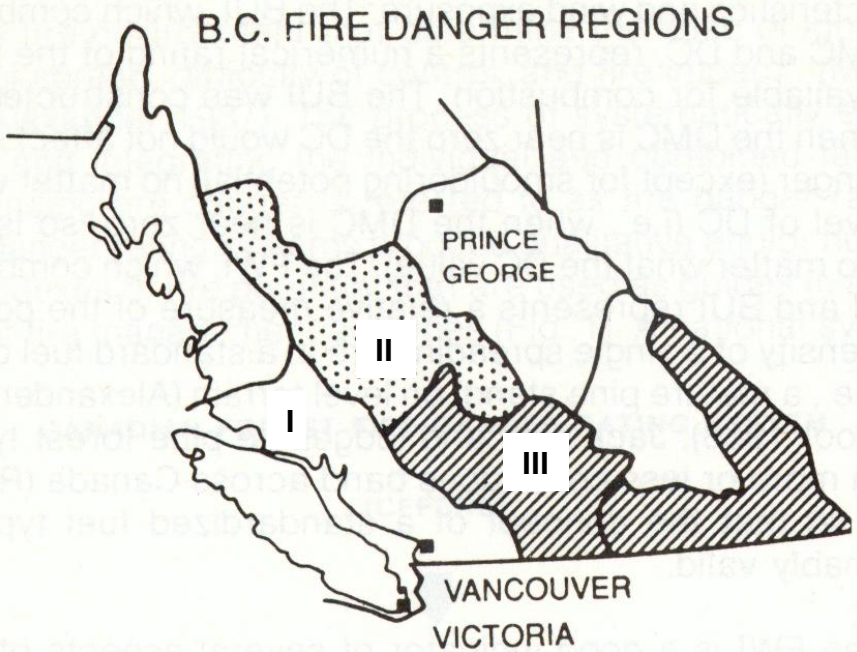
Informing the Public of Impending Fire Danger

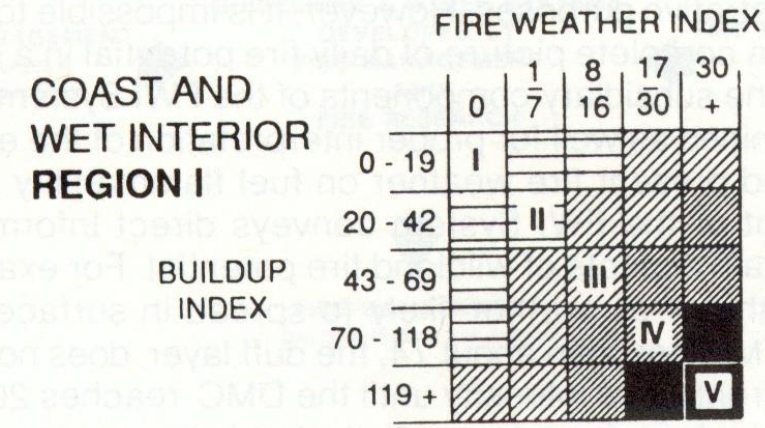
Yukon Territory

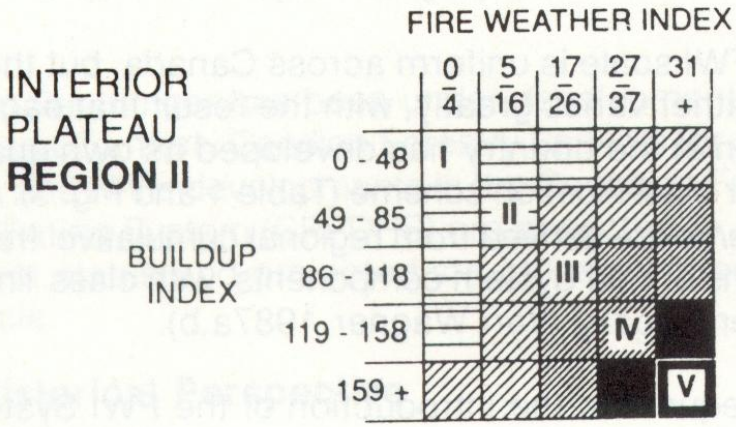
Fire Danger Classification Schemes Used in Canada (exclusive of British Columbia)

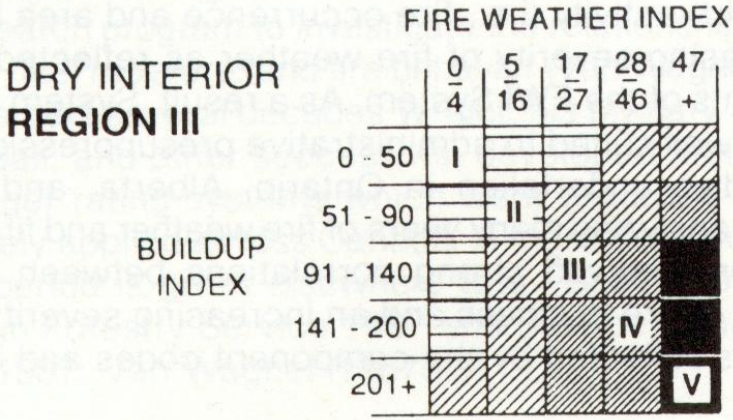
Province/ Territory	Fire Danger Class				
	Low	Moderate	High	Very High	Extreme
	---------- Fire Weather Index (FWI) ----------				
YT	0-13	14-23	24-28	-	29+
NT	0-4	5-12	13-18	19-24	25+
AB	0-4	5-10	11-18	19-29	30+
SK & MB	0-5	6-16	17-30	-	31+
ON	0-3	4-10	11-22	-	23+
QC	0-4	5-10	11-20	-	21+
NB & PE	0-1	2-8	9-15	16-21	22+
NS	0-1	2-8	9-21	-	22+
NF	0-3	4-7	8-14	15-20	21+

Fire Danger Classification Scheme Used in British Columbia

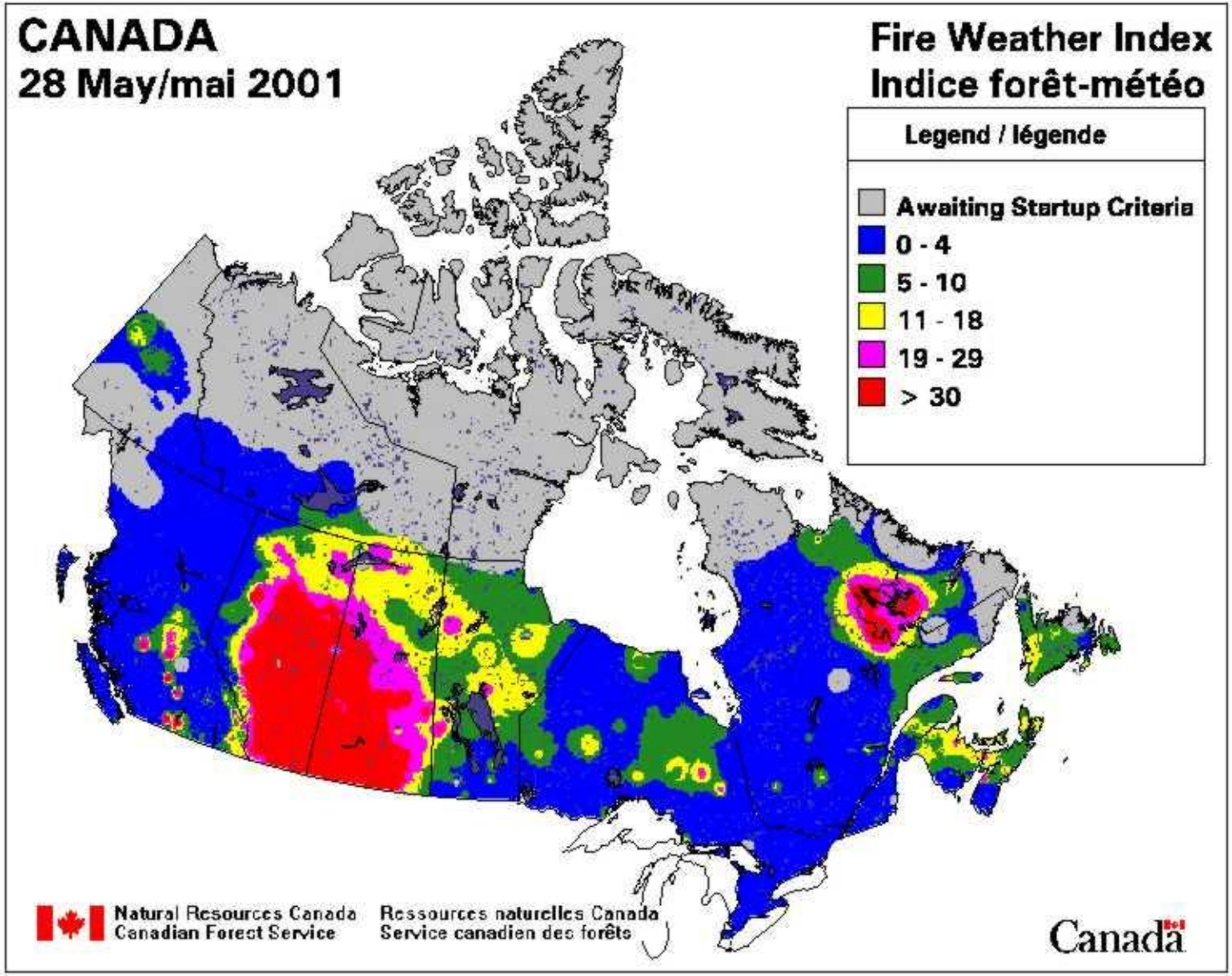








Canadian Wildland Fire Information System



http://fms.nofc.cfs.nrcan.gc.ca/cwfis/

"Operationalizing" of the FWI System components

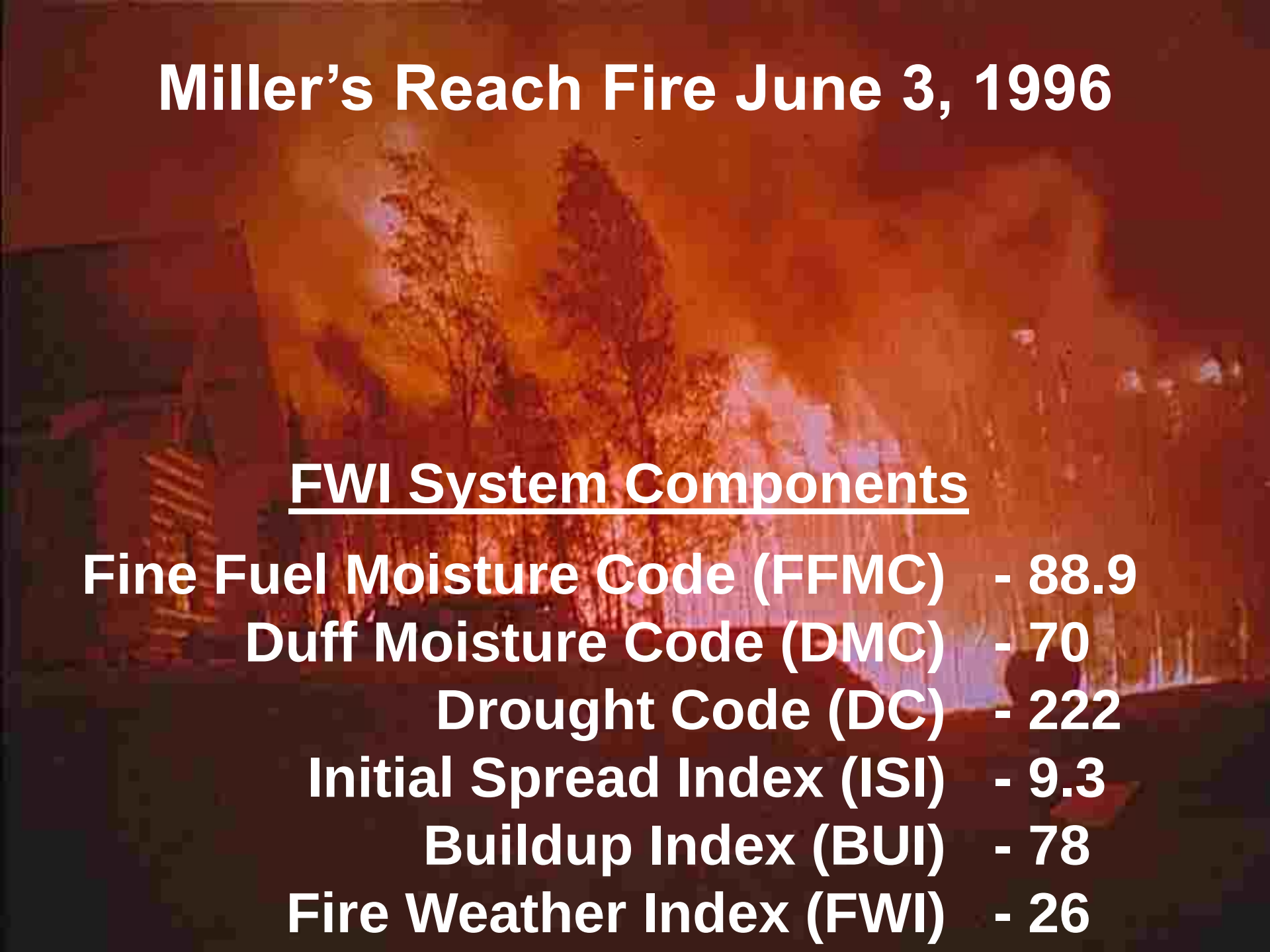
- Personal experience linking indices to wildfire & prescribed fire activity
- Examining historical summaries (i.e., fire danger climatology)
- Historical wildfire & prescribed fire case studies
- Comparison to statistical data from fire reports
- Recent wildfire case studies
- Experimental & operational burning trials

Miller's Reach Fire June 3, 1996

Standard Fire Weather Observations

Dry-bulb Temperature	- 62 °F
Relative Humidity	- 51%
20-ft Open Wind	- 10 mph
Days Since Rain	- 7

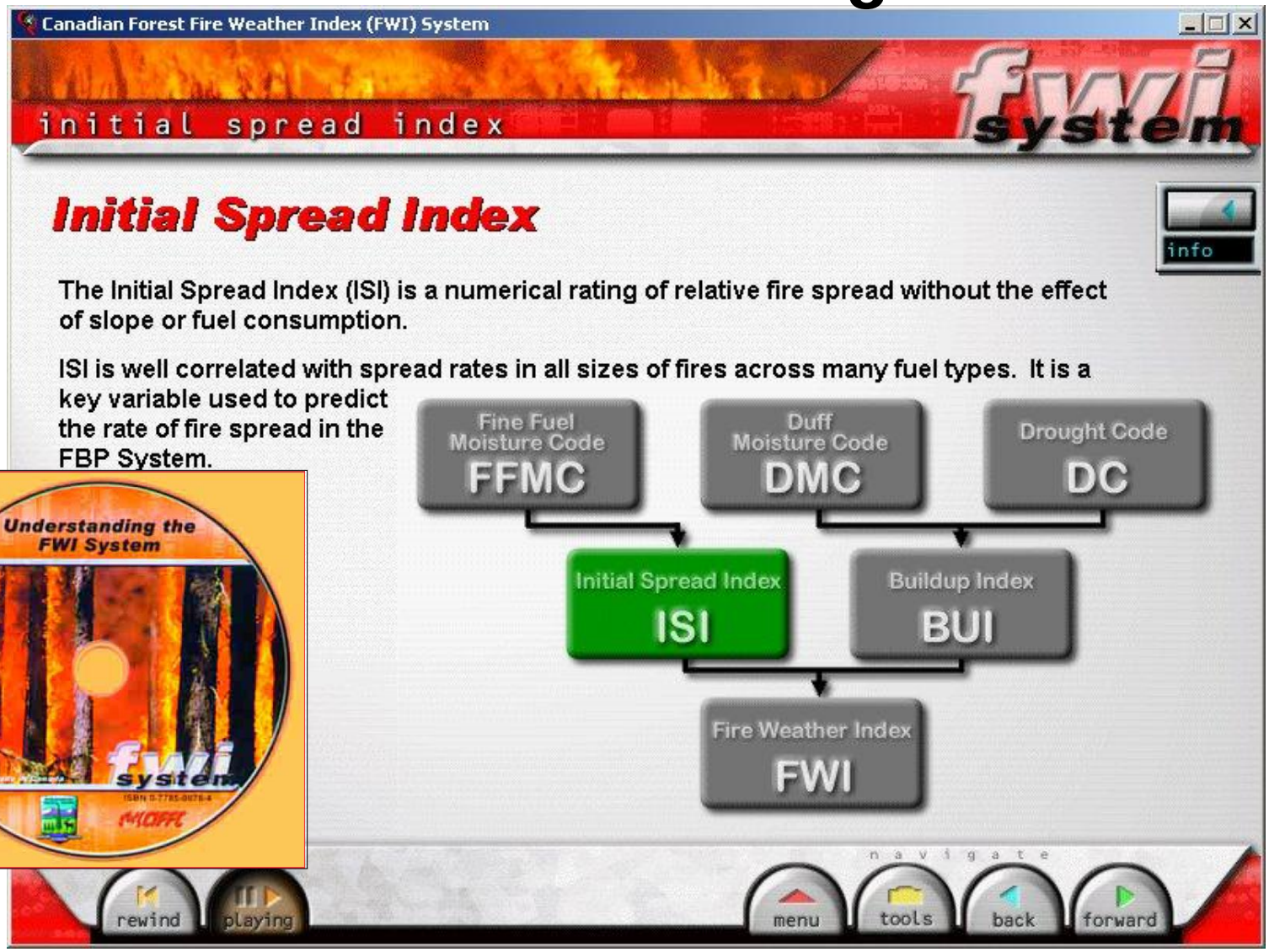
Miller's Reach Fire June 3, 1996

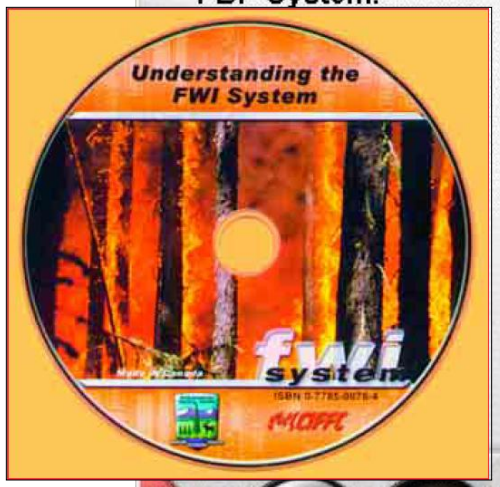


FWI System Components

Fine Fuel Moisture Code (FFMC)	- 88.9
Duff Moisture Code (DMC)	- 70
Drought Code (DC)	- 222
Initial Spread Index (ISI)	- 9.3
Buildup Index (BUI)	- 78
Fire Weather Index (FWI)	- 26

Understanding the FWI System
CD-ROM based training course





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Because the FWI System was developed to integrate the influence of weather on fire behavior in a stylized fuel complex, on level terrain, the same component value will obviously have different meanings among fuel types.

Fuel Type	Aspen Slash	Jack Pine Slash
ISI	18	18
Spread Rate	0.8 ft/min	11.5 ft/min
FWI	23	23
Fire Intensity	1859 Btu/sec-ft	19,635 Btu/sec-ft

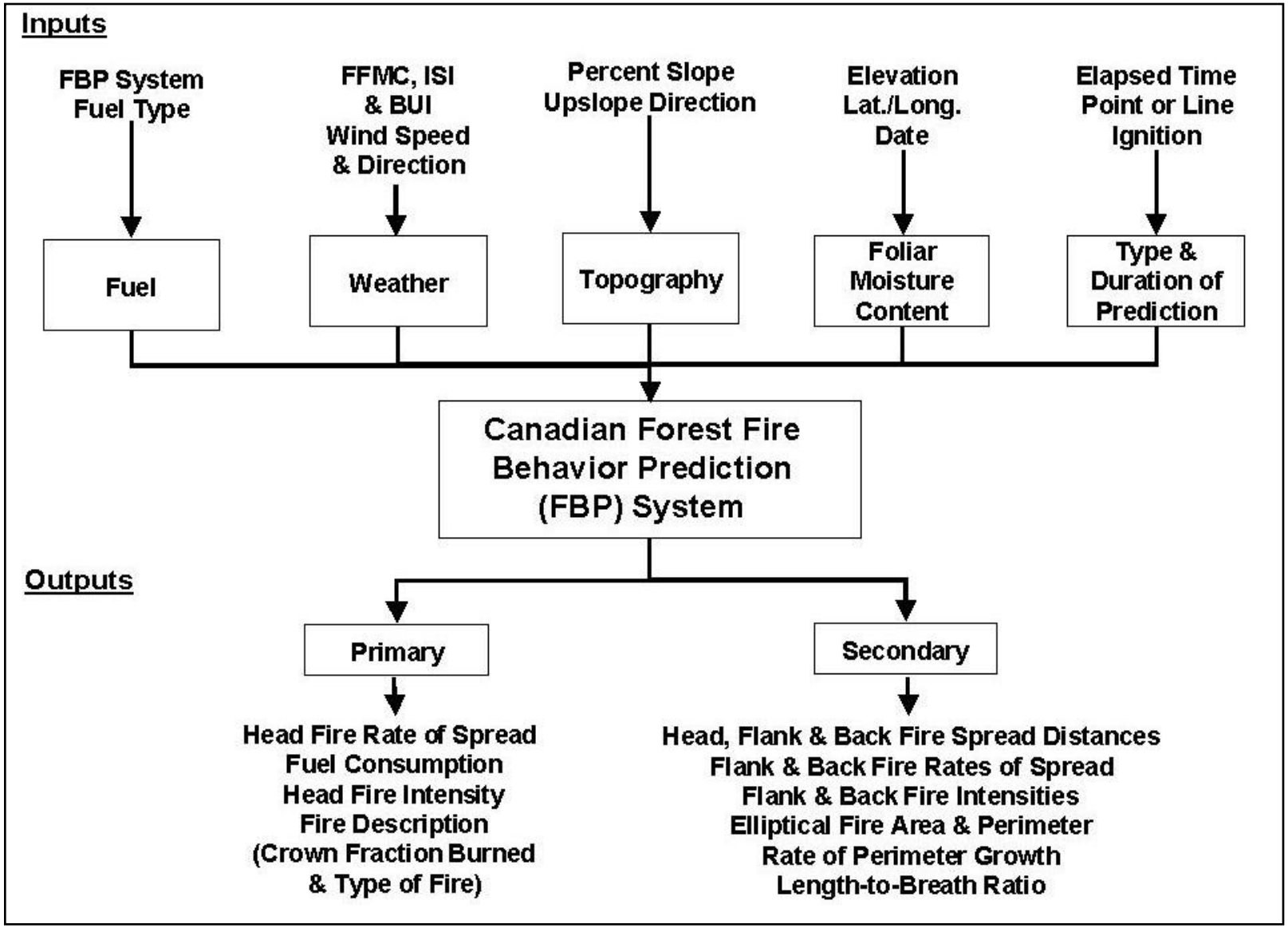
Adapted from: Alexander, M.E. 1982. Fire behavior in aspen slash fuels as related to the Canadian Fire Weather Index. Canadian Journal of Forest Research 12(4):1028-1029.

Canada like Australia has taken an empirical approach to developing fire behavior models

Fire Behavior Prediction Module or Subsystem

In contrast to the FWI System, the FBP System provides quantitative outputs of selected fire behavior characteristics for several major Canadian fuel types and topographic situations.

Structure of the Canadian Forest Fire Behavior Prediction (FBP) System



The fundamental mathematical relationships in the FBP System are based on three different fire behavior data sources

Experimental fire in red pine plantation, Petawawa, Ontario

Experimental fire in jack pine logging slash, NE Ontario

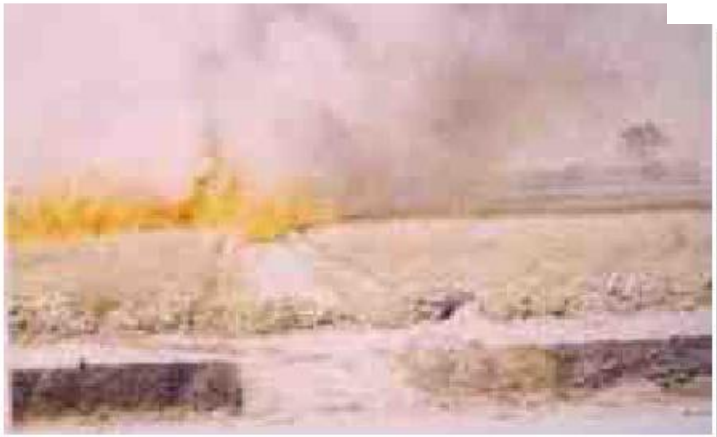
Line fire ignition in immature jack pine,
NE Ontario

Experimental fire in lodgepole pine,
central British Columbia

Experimental fire in spruce budworm-killed balsam fir fuel complex, NE Ontario

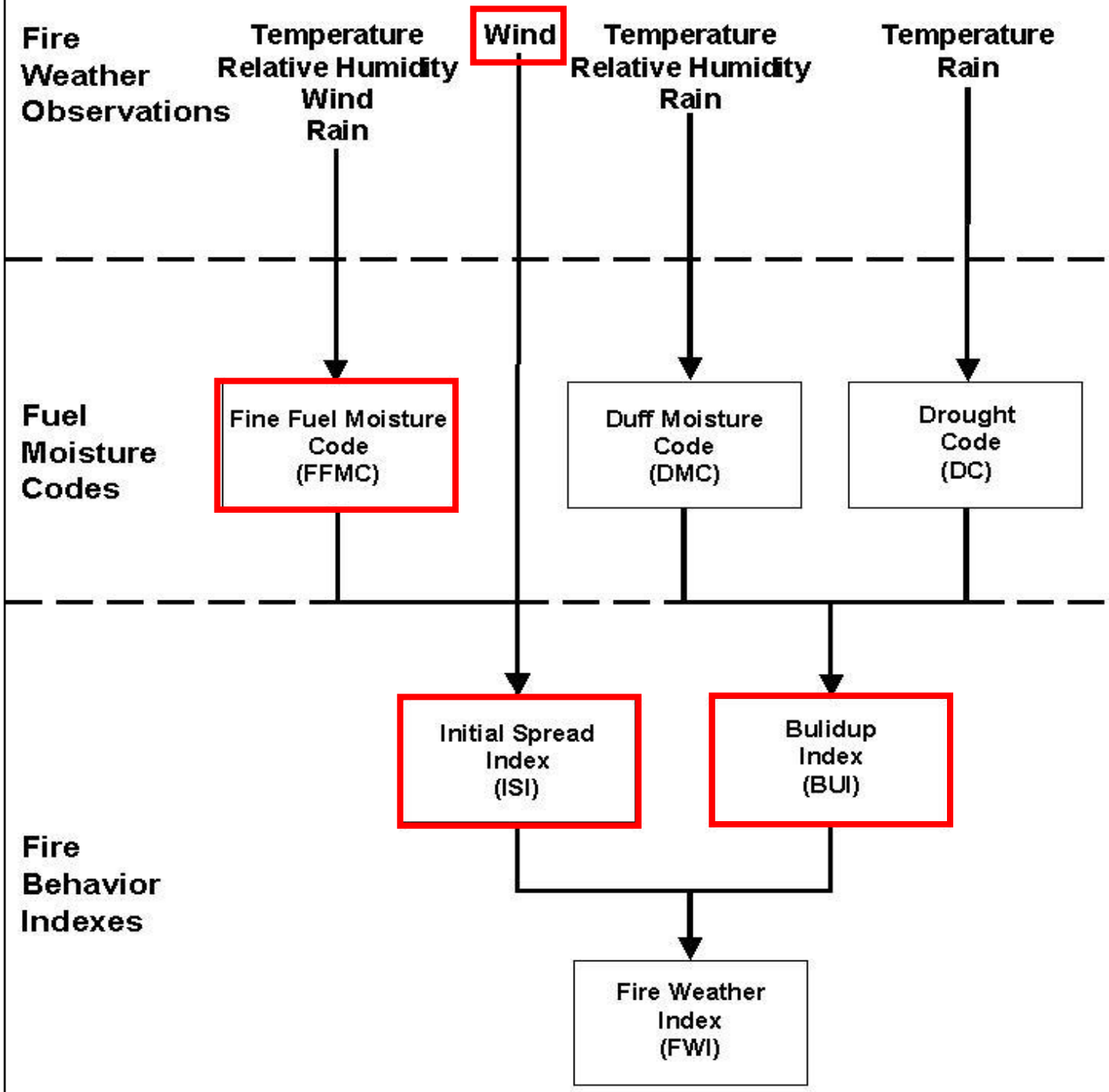
Experimental fire in black spruce-lichen woodland, Caribou Range, Northwest Territories

Experimental fires in matted and standing grass, Northern Territory, Australia

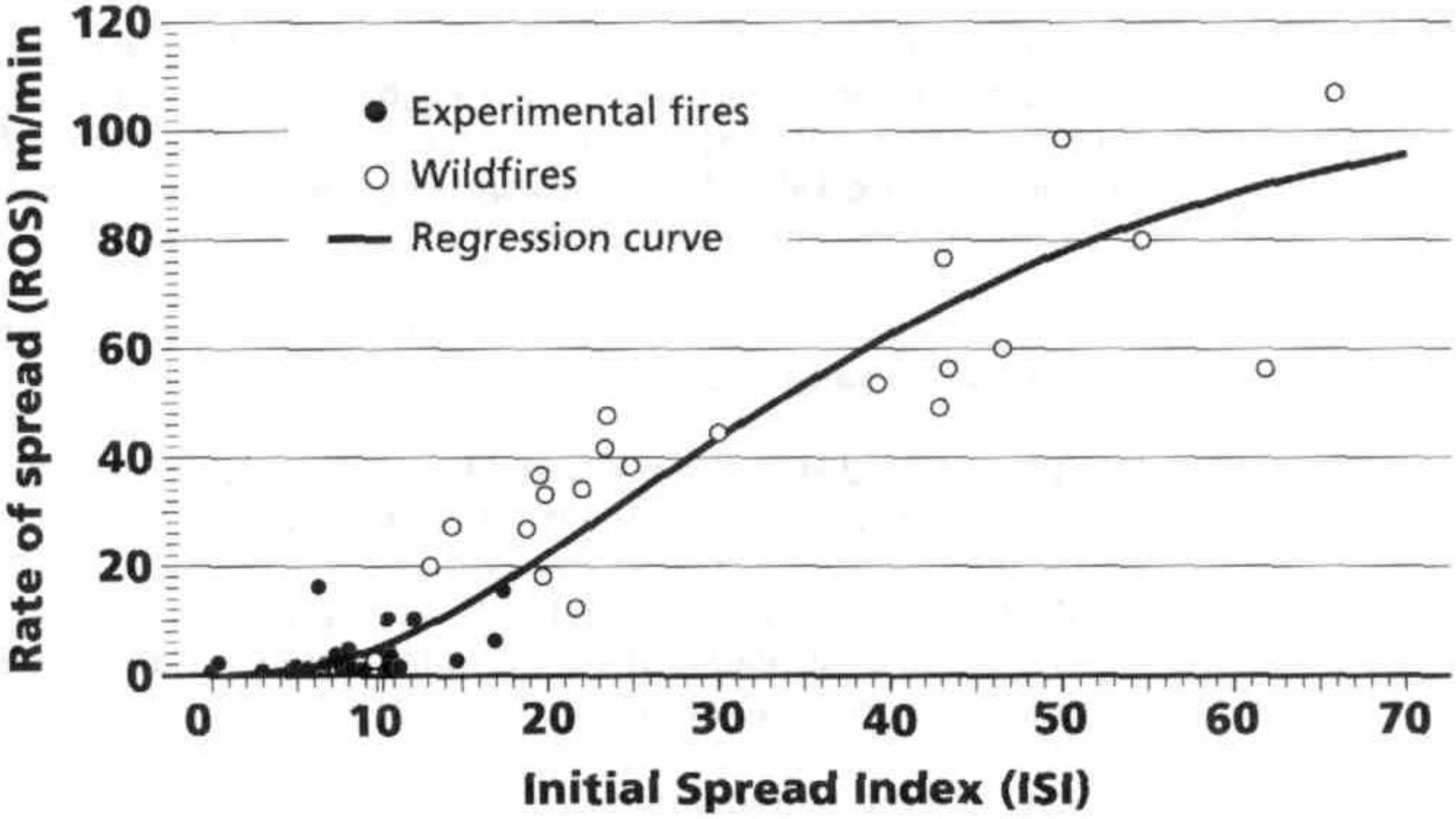


Experimental fire in jack pine/black spruce,
International Crown Fire Modelling Experiment,
Northwest Territories

Inputs and Outputs of the FWI System used in the FBP System



Basic rate of spread curve for FBP System Fuel Type C-3 (Mature Jack or Lodgepole Pine)



FBP System Fuel Types

General Category	Fuel Type	Input Modifier
Coniferous	C-1 Spruce-Lichen Woodland	-
	C-2 Boreal Spruce	-
	C-3 Mature Jack or Lodgepole Pine	-
	C-4 Immature Jack or Lodgepole Pine	-
	C-5 Red and White Pine	-
	C-6 Conifer Plantation	Live Crown Base Height
	C-7 Ponderosa Pine/Douglas-fir	-
Deciduous	D-1 Leafless Aspen	-
Mixedwood	M-1 Boreal Mixedwood-Leafless	% Softwood/Hardwood
	M-2 Boreal Mixedwood-Green	% Softwood/Hardwood
	M-3 Dead Balsam Fir/Mixedwood-Leafless	% Dead Fir
	M-4 Dead Balsam Fir/Mixedwood-Green	% Dead Fir
Slash	S-1 Jack or Lodgepole Pine Slash	-
	S-2 Spruce/Balsam Slash	-
	S-3 Coastal Cedar/Hemlock/Douglas-fir Slash	-
Open	O-1a Matted Grass	% Degree of Curing
	O-1b Standing Grass	% Degree of Curing

FBP System Fuel Type Characteristics

Fuel Type	Max. Surface Fuel Consumption (T/Ac)	Crown Base Height (ft)	Crown Fuel Load (T/Ac)
C-1 Spruce-Lichen Woodland	6.7	6.6	3.3
C-2 Boreal Spruce	22.3	9.8	3.6
C-3 Mature Jack or Lodgepole Pine	22.3	26.2	5.1
C-4 Immature Jack or Lodgepole Pine	22.3	13.1	5.4
C-5 Red and White Pine	22.3	59.0	5.4
C-6 Conifer Plantation	22.3	22.9	8.0
C-7 Ponderosa Pine/Douglas-fir	15.6	32.8	2.2
D-1 Leafless Aspen	6.7	-	-
M-1 Boreal Mixedwood-Leafless	22.3	19.6	3.6
M-2 Boreal Mixedwood-Green	22.3	19.6	3.6
M-3 Dead Balsam Fir/Mixedwood-Leafless	22.3	19.6	3.6
M-4 Dead Balsam Fir/Mixedwood-Green	22.3	19.6	3.6
S-1 Jack or Lodgepole Pine Slash	35.7	-	-
S-2 Spruce/Balsam Slash	71.4	-	-
S-3 Coastal Cedar/Hemlock/Douglas-fir Slash	142.7	-	-
O-1a Matted Grass	0.3	-	-
O-1b Standing Grass	0.3	-	-

Conifer Fuel Types

C-1

C-2

C-3

C-4

C-5

C-6

C-7

Conifer Fuel Types

C-1

C-2

C-3

C-4

C-5

C-6

C-7

Spruce-lichen Woodland

Forest floor: Continuous reindeer lichen
Ladder fuels: Tree crowns extend to the ground
Structure: Open black spruce with dense clumps

Conifer Fuel Types

C-1

C-2

C-3

C-4

C-5

C-6

C-7

Boreal Spruce

Forest floor: Continuous feathermoss
Ladder fuels: Tree crowns extend to the ground
Structure: Moderately stocked black spruce stands

Conifer Fuel Types

C-1

C-2

C-3

C-4

C-5

C-6

C-7

Mature Jack or Lodgepole Pine

Forest floor: Continuous feathermoss
Ladder fuels: Tree crowns separate from ground
Structure: Fully stocked stands

Conifer Fuel Types

C-1

C-2

C-3

C-4

C-5

C-6

C-7

Immature Jack or Lodgepole Pine

Forest floor: Continuous needle layer
Ladder fuels: Tree crowns extend to ground
Structure: Very dense stands

Conifer Fuel Types

C-1

C-2

C-3

C-4

C-5

C-6

C-7

Red and White Pine

Forest floor: Continuous needle layer
Ladder fuels: Tree crowns separate from ground
Structure: Moderately well stocked stands

Conifer Fuel Types

C-1

C-2

C-3

C-4

C-5

C-6

C-7

Red Pine Plantation

Forest floor: Continuous needle layer
Ladder fuels: Tree crowns separate from ground
Structure: Fully stocked stands

Conifer Fuel Types

C-1

C-2

C-3

C-4

C-5

C-6

C-7

Ponderosa Pine – Douglas Fir

Forest floor: Continuous needles and grass
Ladder fuels: Tree crowns separate from ground
Structure: open stands, uneven aged

Deciduous and Mixedwood Fuel Types

D-1

M-1

M-2

M-3

M-4

Deciduous and Mixedwood Fuel Types

D-1

M-1

M-2

M-3

M-4

Leafless Aspen

Forest floor: Continuous leaf layer
Ladder fuels: None
Structure: Moderate to well stocked stands

Deciduous and Mixedwood Fuel Types

D-1

M-1

M-2

M-3

M-4

Boreal Mixedwood - leafless

Forest floor: Continuous leaf layer and discontinuous feathermoss/needles layer

Ladder fuels: Crown fuels extend to ground, possible balsam understory

Structure: Moderate-well stocked stands

Deciduous and Mixedwood Fuel Types

D-1

M-1

M-2

M-3

M-4

Boreal Mixedwood – leafed out

Forest floor: Continuous leaf layer and discontinuous feathermoss/needles layer
Ladder fuels: Crown fuels extend to ground, possible balsam understory
Structure: Moderate-well stocked stands

Deciduous and Mixedwood Fuel Types

D-1

M-1

M-2

M-3

M-4

Dead Balsam Fir Mixedwood – leafless

Forest floor: Continuous leaf layer and discontinuous feathermoss/needles layer

Ladder fuels: Crown fuels extend to ground, possible dead balsam understory

Structure: Moderate-well stocked stands

Deciduous and Mixedwood Fuel Types

D-1

M-1

M-2

M-3

M-4

Dead Balsam Fir Mixedwood – leafed out

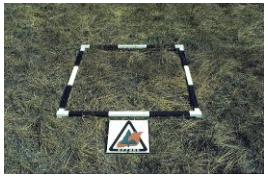
Forest floor: Continuous leaf layer and discontinuous feathermoss/needles layer

Ladder fuels: Crown fuels extend to ground, possible dead balsam understory

Structure: Moderate-well stocked stands

Open and Slash Fuel Types

O-1a



O-1b

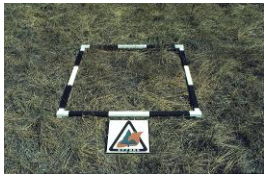
S-1

S-2

S-3

Open and Slash Fuel Types

O-1a



O-1b

S-1

S-2

S-3

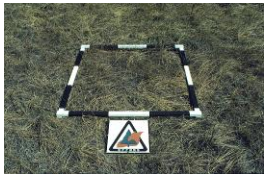
Grass – matted (spring)

Forest floor: Continuous grass layer, matted down by winter snows

Structure: Open with occasional thickets

Open and Slash Fuel Types

O-1a



O-1b

S-1

S-2

S-3

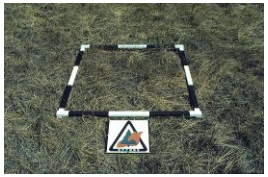
Grass - standing

Forest floor: Continuous grass layer, stranding grass from the summer is cured

Structure: Open with occasional thickets

Open and Slash Fuel Types

O-1a



O-1b

S-1

S-2

S-3

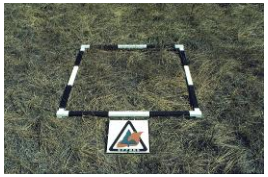
Slash : Jack or Lodgepole Pine

Forest floor: Discontinuous feathermoss and needle layer

Structure: Slash from clear-cut logging

Open and Slash Fuel Types

O-1a



O-1b

S-1

S-2

S-3

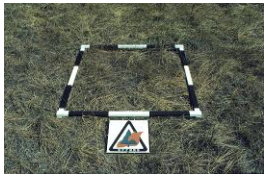
Slash: Spruce-Balsam

Forest floor: Discontinuous feathermoss and needle layer

Structure: Slash from clear-cut logging

Open and Slash Fuel Types

O-1a



O-1b

S-1

S-2

S-3

Slash : Coastal Cedar-Hemlock-Douglas Fir

Forest floor: Discontinuous feathermoss and needles layer

Structure: Slash from clear-cut logging

FBP System Fuel Type Poster

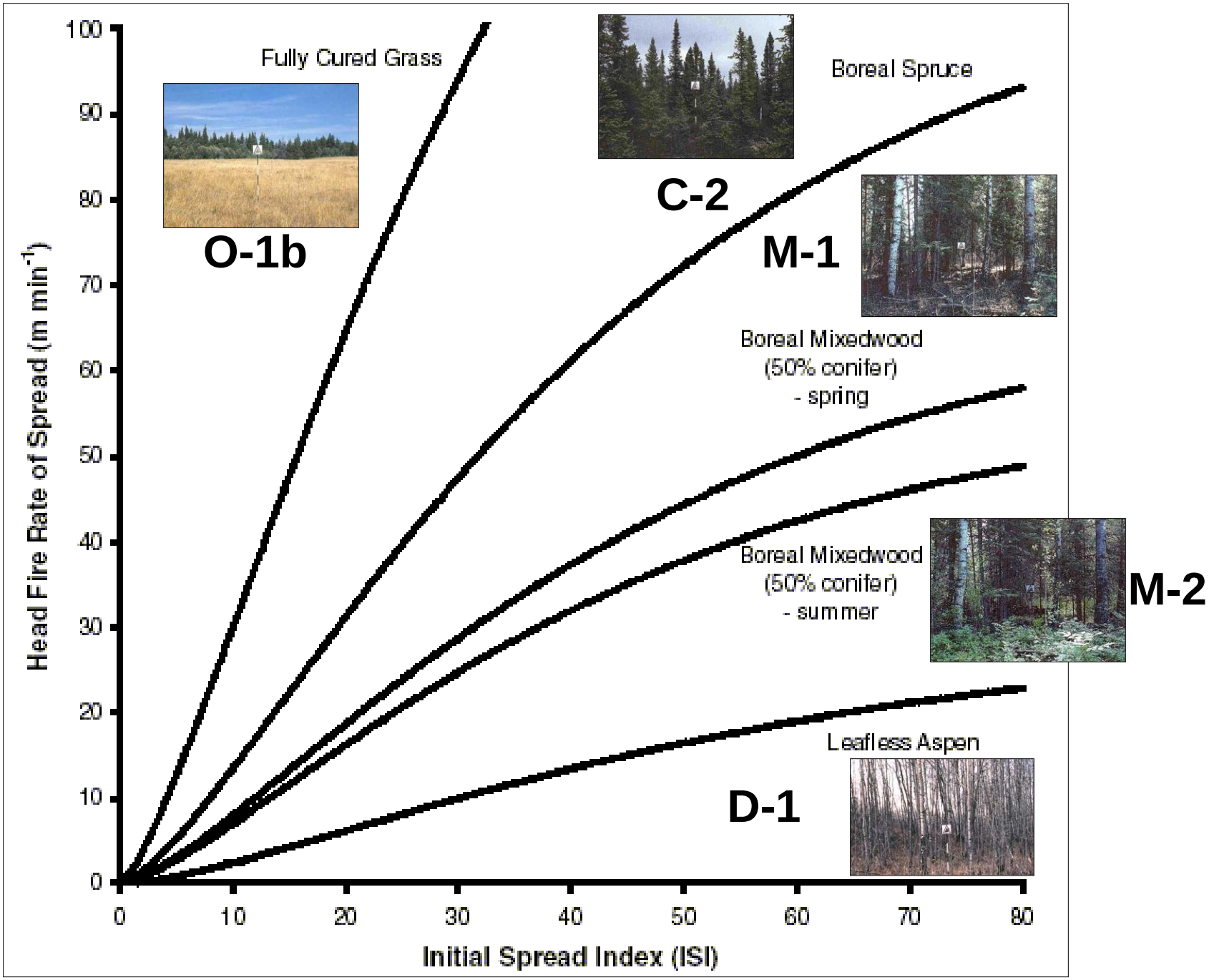
Example Fuel Type Description

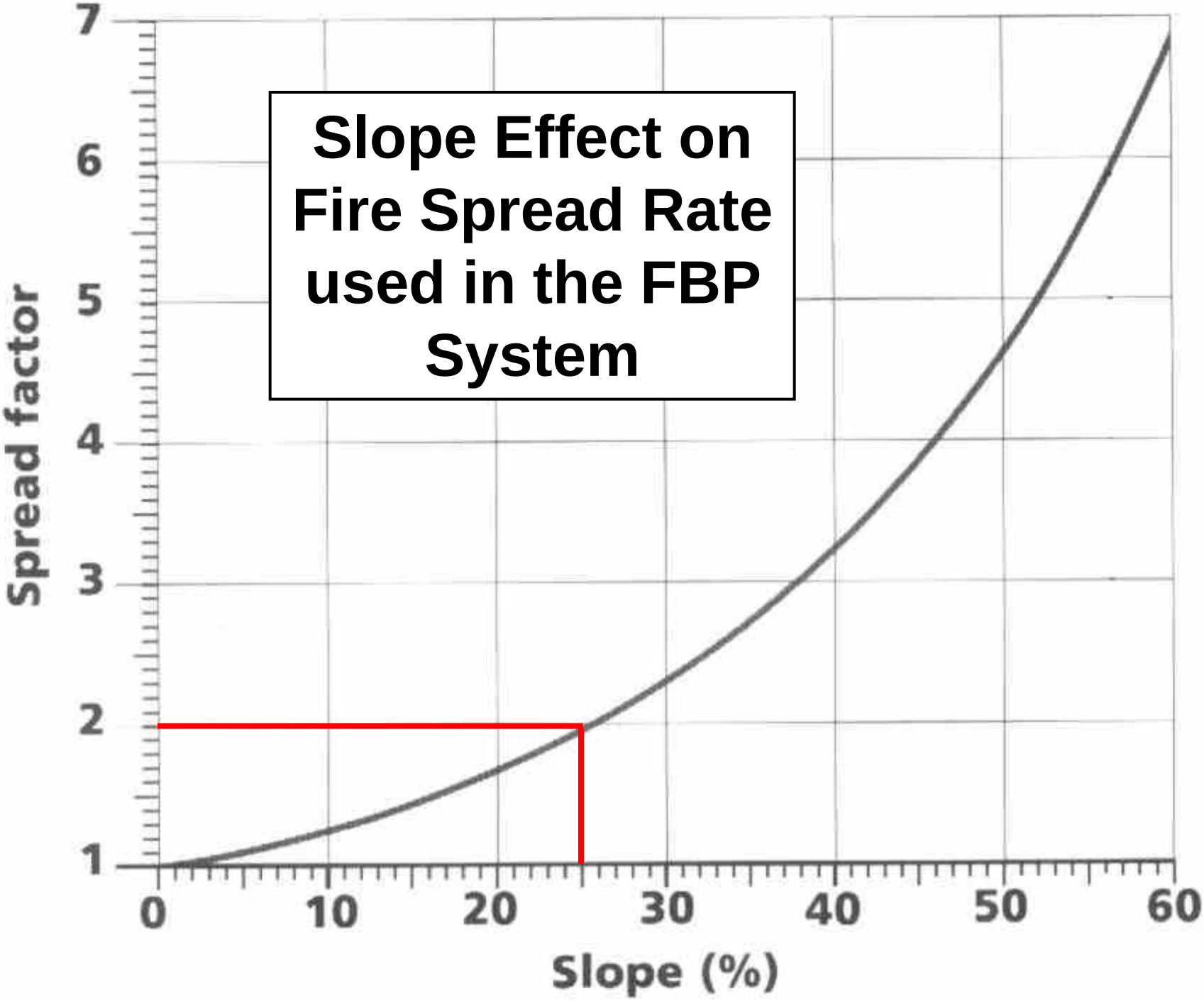
C-2 (Boreal Spruce)

This fuel type is characterized by pure, moderately well-stocked black spruce stands on lowland (excluding Sphagnum bogs) and upland sites. Tree crowns extend to or near the ground and dead branches are typically draped with bearded lichens (Usnea sp.). The flaky nature of the bark on the lower portion of stem boles is pronounced. Low to moderate volumes of down woody material are present. Labrador tea (Ledum Groenlandicum Oeder) is often the major shrub component. The forest floor is dominated by a carpet of feather mosses and/or ground-dwelling lichens (chiefly Clodonia). Sphagnum mosses may occasionally be present, but they are of little hindrance to surface fire spread. A compact organic layer commonly exceeds a depth of 23-30 cm (9 - 12 in.).

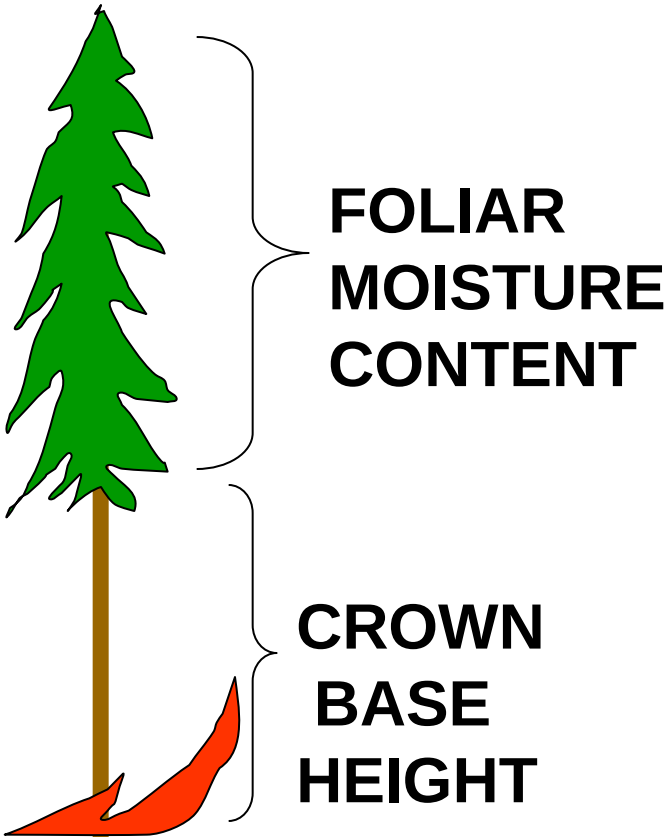
FBP System Sub-models

- Rate of Spread
  - Including a build-up effect, grass curing, etc.
- Surface fuel consumption
- Slope influence on rate of spread
  - Including wind/slope interaction
- Transition to crowning
- Foliar moisture content
- Crown fraction burned and total fuel consumed
- Head fire intensity
- Acceleration
- Elliptical growth
  - including flank and back spread rates, perimeter growth, area burned

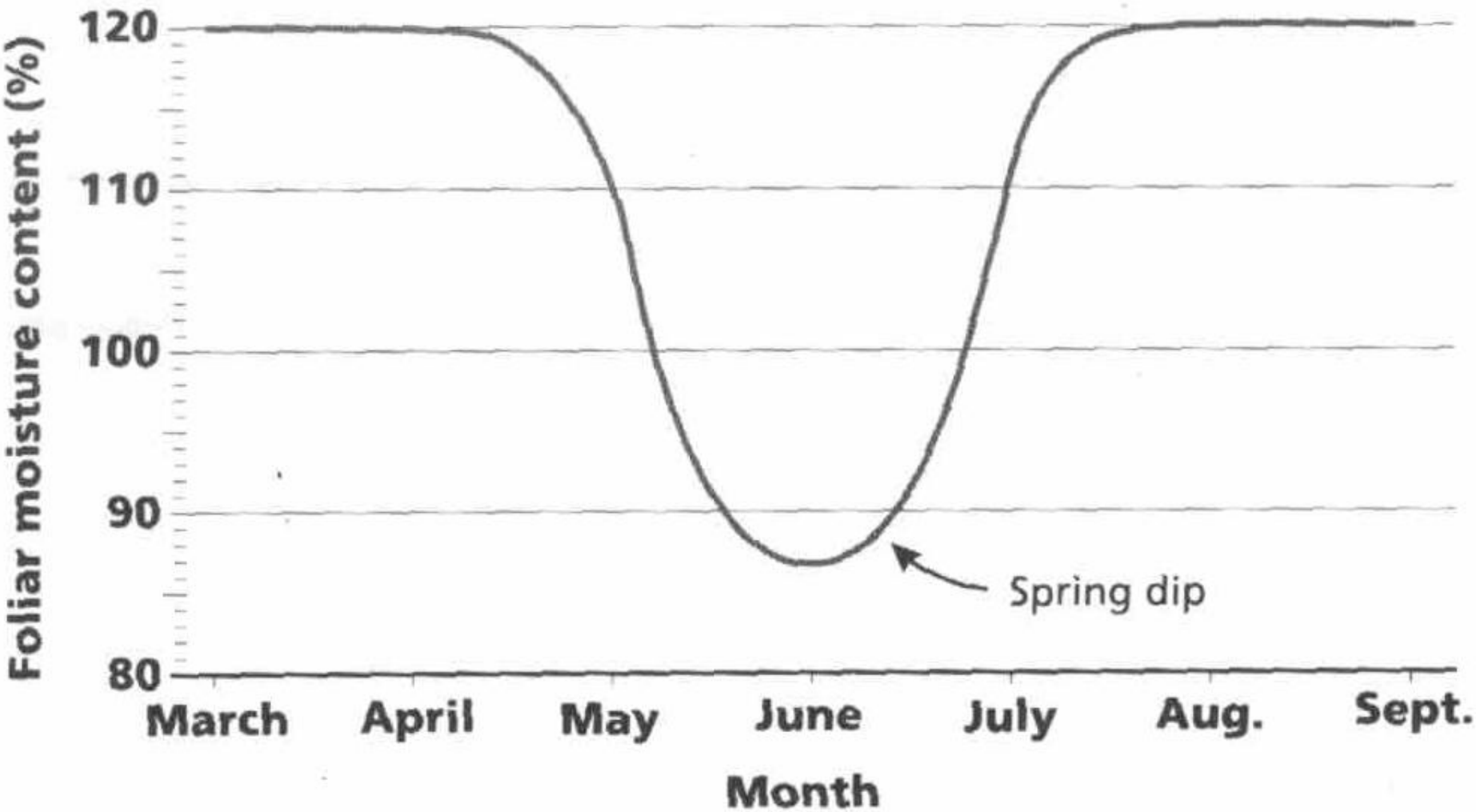

Fully Cured Grass
O-1b
Boreal Spruce
C-2
M-1
Boreal Mixedwood
(50% conifer)
- spring
Boreal Mixedwood
(50% conifer)
- summer
M-2
Leafless Aspen
D-1
Head Fire Rate of Spread (m min-1)
Initial Spread Index (ISI)
0
10
20
30
40
50
60
70
80
90
100


Slope Effect on Fire Spread Rate used in the FBP System
Spread factor
7
6
5
4
3
2
1
0
10
20
30
40
50
60
Slope (%)

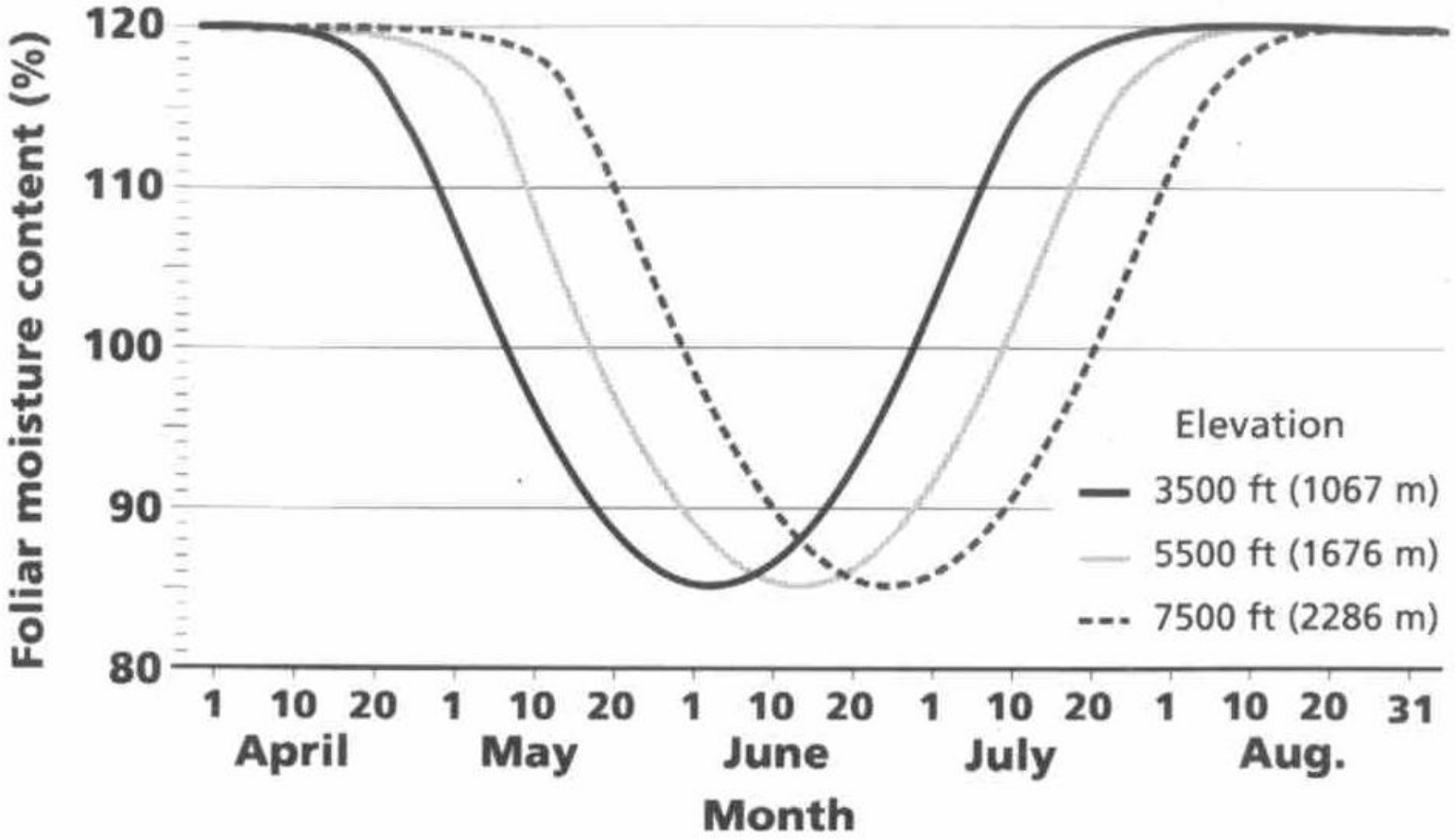
The onset of crowning occurs when the potential surface fire intensity attains or exceeds a certain critical value as determined by the foliar moisture content and the crown base height.



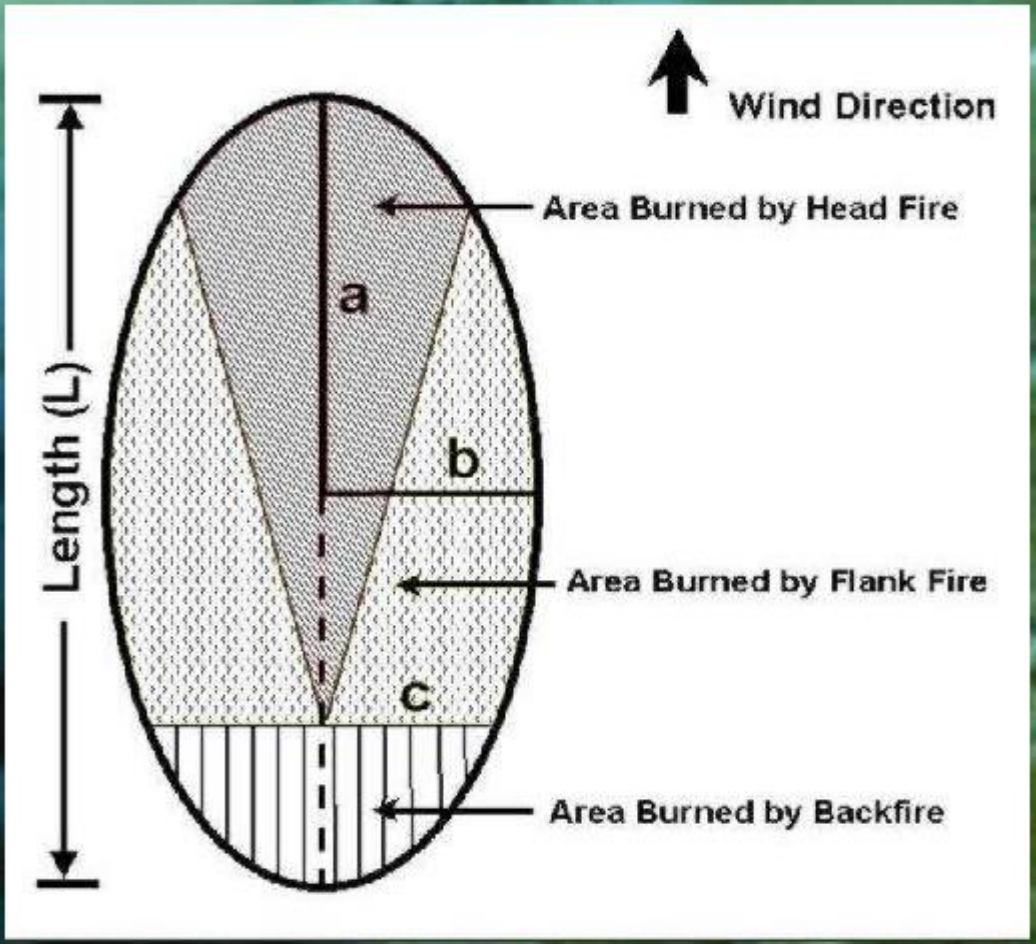
Conceptual example of the seasonal trend in the foliar moisture content of conifer foliage



An example of foliar moisture content calculated by the FBP System for west-central Alberta



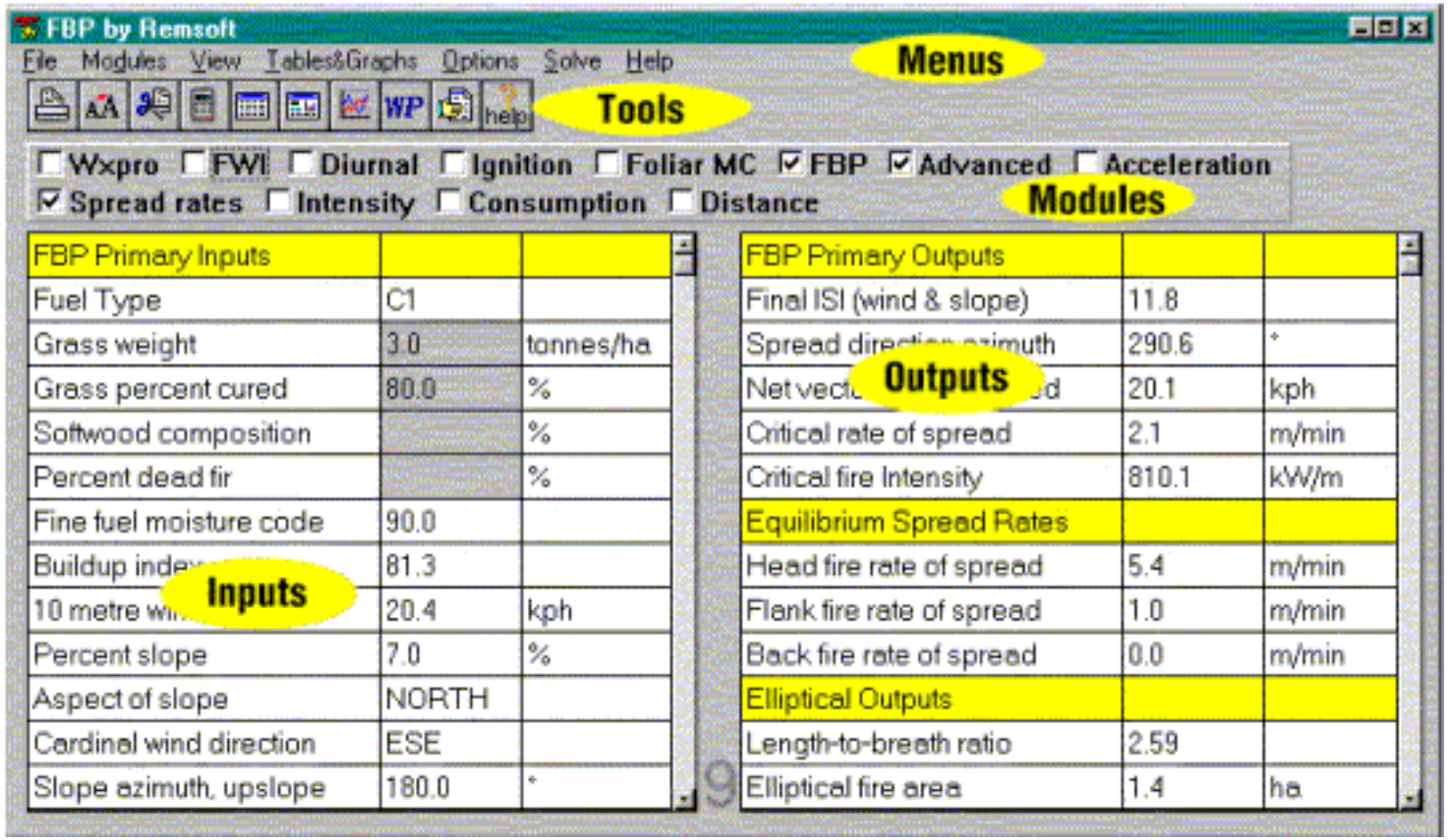
A Simple Elliptical Fire Growth Model is Employed in the FBP System



Commercial FBP System Software

Behave by Remsoft® http://www.remsoft.com/

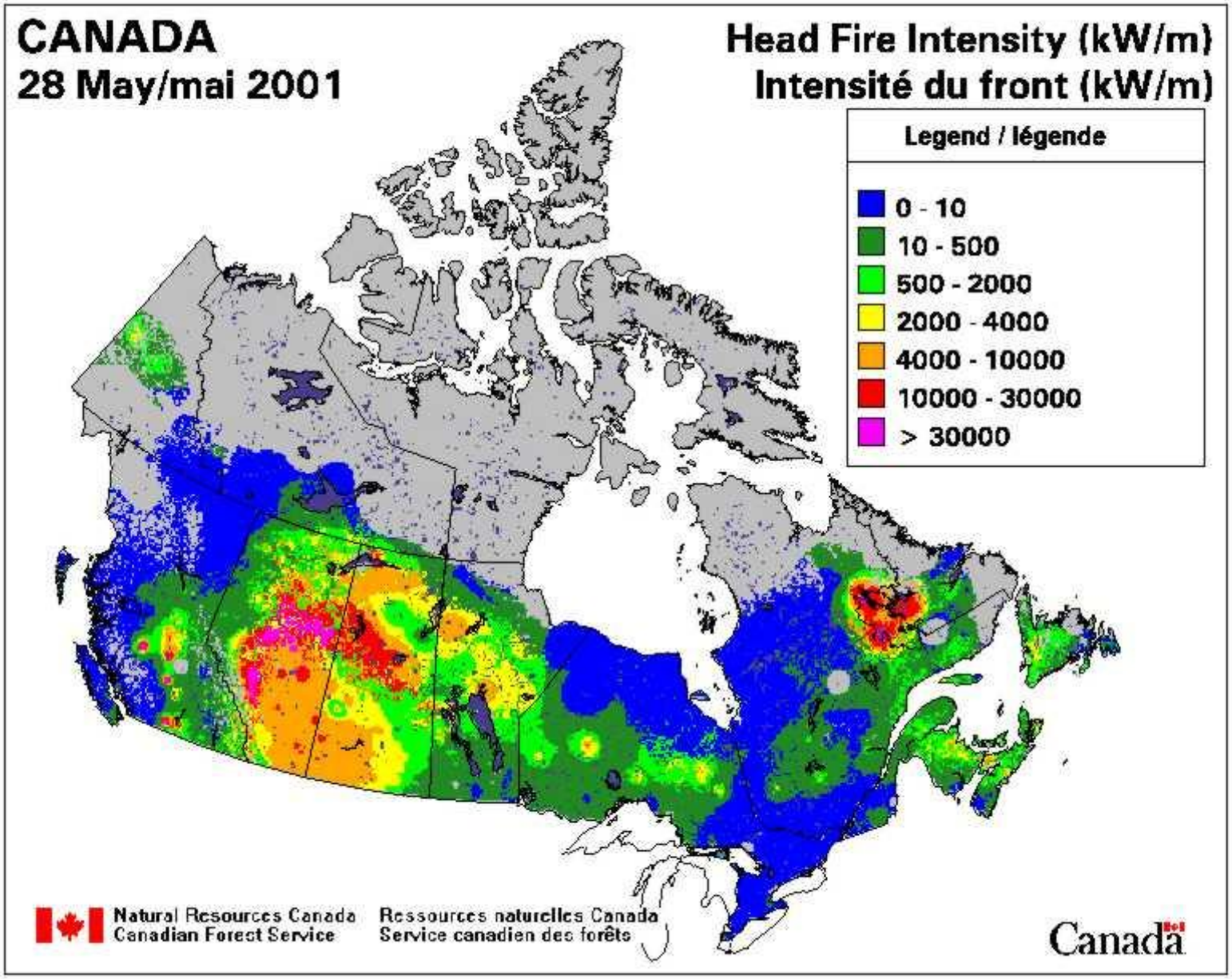
Remsoft®
Software for Sustainable Growth



FBP Primary Inputs		
Fuel Type	C1	
Grass weight	3.0	tonnes/ha
Grass percent cured	80.0	%
Softwood composition		%
Percent dead fir		%
Fine fuel moisture code	90.0	
Buildup inde	81.3	
10 metre wi	20.4	kph
Percent slope	7.0	%
Aspect of slope	NORTH	
Cardinal wind direction	ESE	
Slope azimuth, upslope	180.0	°

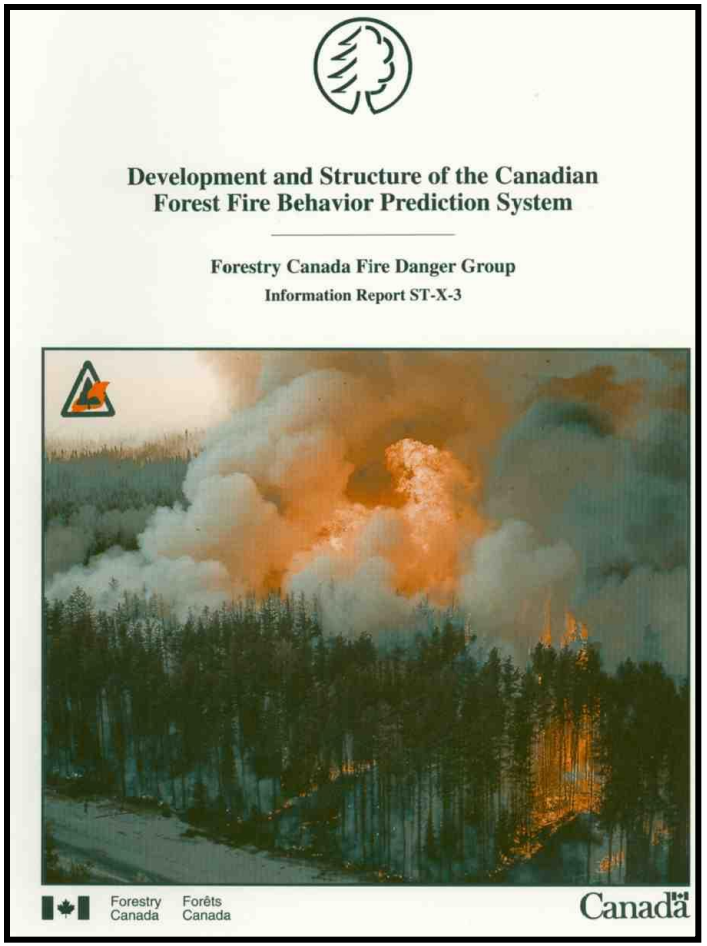
FBP Primary Outputs		
Final ISI (wind & slope)	11.8	
Spread direction azimuth	290.6	°
Net vect d	20.1	kph
Critical rate of spread	2.1	m/min
Critical fire Intensity	810.1	kW/m
Equilibrium Spread Rates		
Head fire rate of spread	5.4	m/min
Flank fire rate of spread	1.0	m/min
Back fire rate of spread	0.0	m/min
Elliptical Outputs		
Length-to-breath ratio	2.59	
Elliptical fire area	1.4	ha

Canadian Wildland Fire Information System

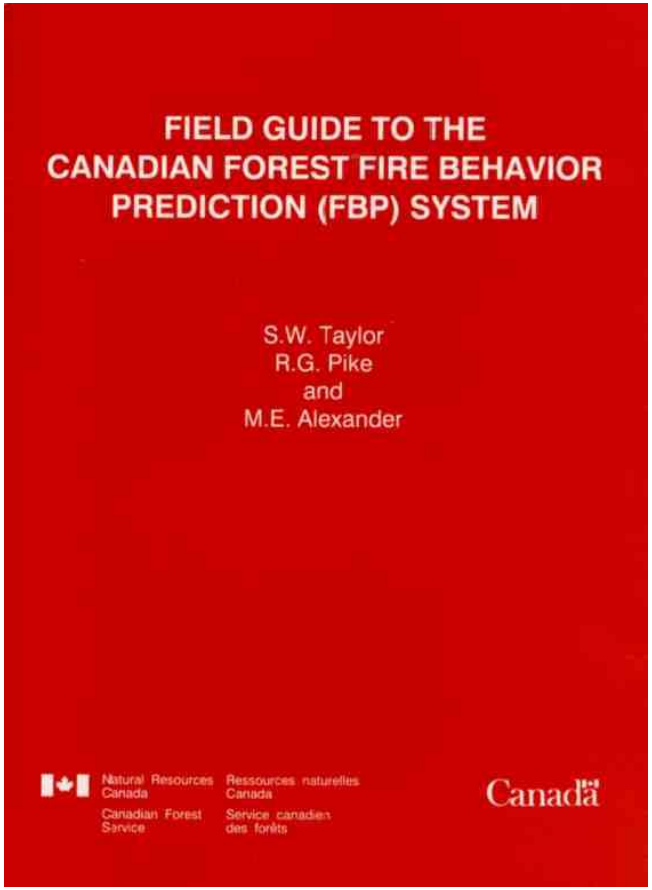


http://fms.nofc.cfs.nrcan.gc.ca/cwfis/

“Operational Use” of the FBP System



Technical & Scientific Documentation



Operational Field Manual (FBP System “Red Book”)

Flow chart of procedures used in the guide

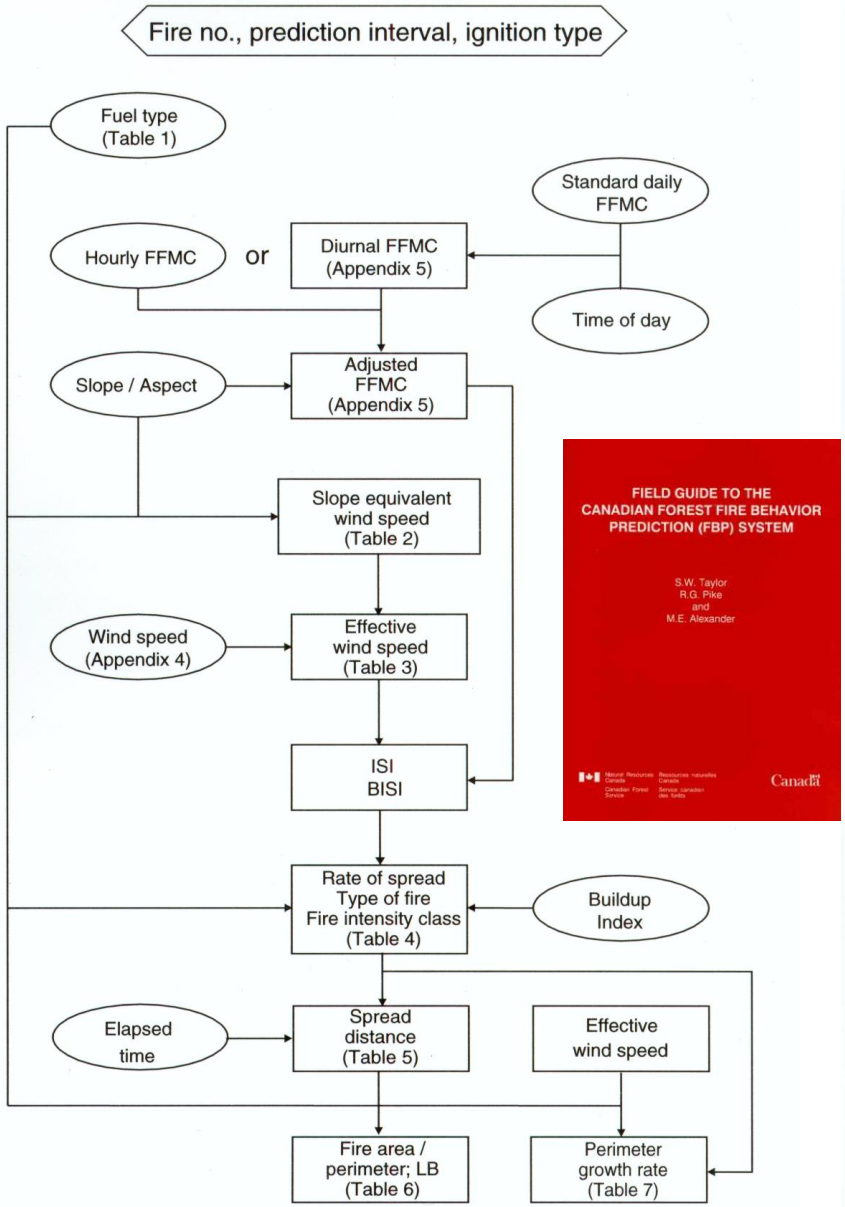


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Table 4.1
Equilibrium rate of spread (m/min) and fire intensity class

C-1 spruce–lichen woodland

Intensity class	
1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI 0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3
6	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.6
7	0.6	0.8	0.9	0.9	1	1	1	1
8	1	1	1	1	2	2	2	2
9	1	2*	2*	2*	2*	2*	2*	2*
10	2*	3*	3*	3*	3*	3*	3*	3*
11	3*	4*	4*	4*	4*	4*	5*	5*
12	4*	5*	5*	5*	6*	6*	6*	6*
13	5*	6*	7*	7*	7*	7*	7*	7*
14	6*	8*	8*	9*	9*	9*	9*	9*
15	7*	9*	10*	10*	11*	11*	11*	11*
16	8*	11*	12	12	13	13	13	13
17	9*	13	14	14	15	15	15	15
18	11*	15	16	16	17	17	17	18
19	12	17	18	19	19	20	20	20
20	14	19	20	21	21	22	22	22
21–25	18	25	27	28	29	29	30	30
26–30	26	35	38	39	40	41	42	42
31–35	33	45	48	50	51	52	53	54
36–40	39	53	56	59	60	62	63	63
41–45	44	59	63	66	68	69	70	71
46–50	50	64	68	71	73	75	76	77
51–55	51	68	72	75	78	79	81	81
56–60	52	71	75	78	81	83	84	85
61–65	54	73	77	81	83	85	86	87
66–70	55	75	79	83	85	87	88	89

Constants: foliar moisture content = 97%; CBH = 2 m; surface fuel consumption for FFMC 90. □ = average BUI. Type of fire: **surface**, **intermittent crown***, **continuous crown**. _ = CFB 50%.

Red Book “Quickie”: The Scenario

- a fire is reported 5 km from a community
- winds are currently and are also forecasted to blow directly towards the town at 15 km/h
- fire danger conditions: FFMC 92, BUI 90
- fuels and topography: area dominated by black spruce forests on level terrain

Question:
What would you tell the local community leaders?

Red Book "Quickie": The Schoolbook Solution

Computations:

- determine ISI value: 12
- determine Head Fire Intensity Class: 6 (> 10 000 kW/m)
- determine equilibrium head fire ROS: 17 m/min or ~ 1 km/h (m/min x 0.06 = km/h)
- determine time for fire to reach community (Distance/ROS): 5 km/1 km/h = 5 hours
- determine LB: 2.0
- determine fire breadth or maximum width (Distance/LB): 5 km/2.0 = 2.5 km

Table 4.2
Equilibrium rate of spread (m/min) and fire intensity class
C-2 boreal spruce

Intensity class
1 < 10 kW/m
2 10 – 500
3 500 – 2 000
4 2 000 – 4 000
5 4 000 – 10 000
6 > 10 000

ISI \ BUI	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0.1	0.3	0.4	0.5	0.5	0.6	0.6	0.6
2	0.3	0.9	1	1	1	2*	2*	2*
3	0.6	2	2	2*	3*	3*	3*	3*
4	0.9	3	3*	4*	4*	4*	4*	5*
5	1	3*	4*	5*	5*	6*	6*	6*
6	2	4*	5*	6*	7*	7*	8*	8*
7	2	5*	7*	8*	9*	9*	10*	10*
8	2	7*	8*	9*	10*	11	12	12
9	3	8*	9*	11*	12	13	14	14
10	3	9*	11*	12	14	15	16	16
11	4	10*	12	14	16	17	18	18
12	4	11*	14	16	17	19	20	20
13	4	12	15	17	19	21	22	22
14	5	13	16	19	21	23	24	25
15	5	15	18	21	23	25	26	27
16	6*	16	19	22	25	27	28	29
17	6*	17	21	24	27	29	30	31
18	6*	18	22	26	28	31	32	33
19	7*	19	23	27	30	33	34	35
20	7*	20	25	29	32	34	36	37
21–25	8*	24	29	34	37	40	42	43
26–30	10*	29	35	41	46	49	52	53
31–35	12*	34	41	48	53	57	60	62
36–40	14*	39	47	54	60	65	68	70
41–45	15	43	52	60	66	72	75	78
46–50	16	46	56	65	72	78	82	84
51–55	17	49	60	70	77	83	87	90
56–60	18	52	64	74	82	88	92	95
61–65	19	55	67	77	85	92	97	100
66–70	20	57	69	80	89	96	101	104

Constants: foliar moisture content = 97% ; crown base height = 3 m. □ = average BUI.
Type of fire: **surface**, **intermittent crown***, **continuous crown**. _ = CFB 50%.

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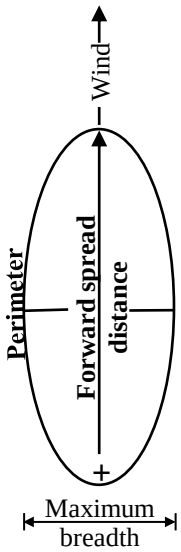
Implications:
Fire is uncontrollable and will reach the community in less than 5 hours on 2.5 km front

Alexander & Fogarty (1997)
Grassland Fire Behavior Pocket Card

A SIMPLE FIELD GUIDE FOR ESTIMATING THE BEHAVIOUR AND SUPPRESSION REQUIREMENTS OF FIRES DRIVEN BY WIND COMING FROM A CONSTANT DIRECTION, IN OPEN, FULLY CURED GRASSLANDS AT LOW FUEL MOISTURE.

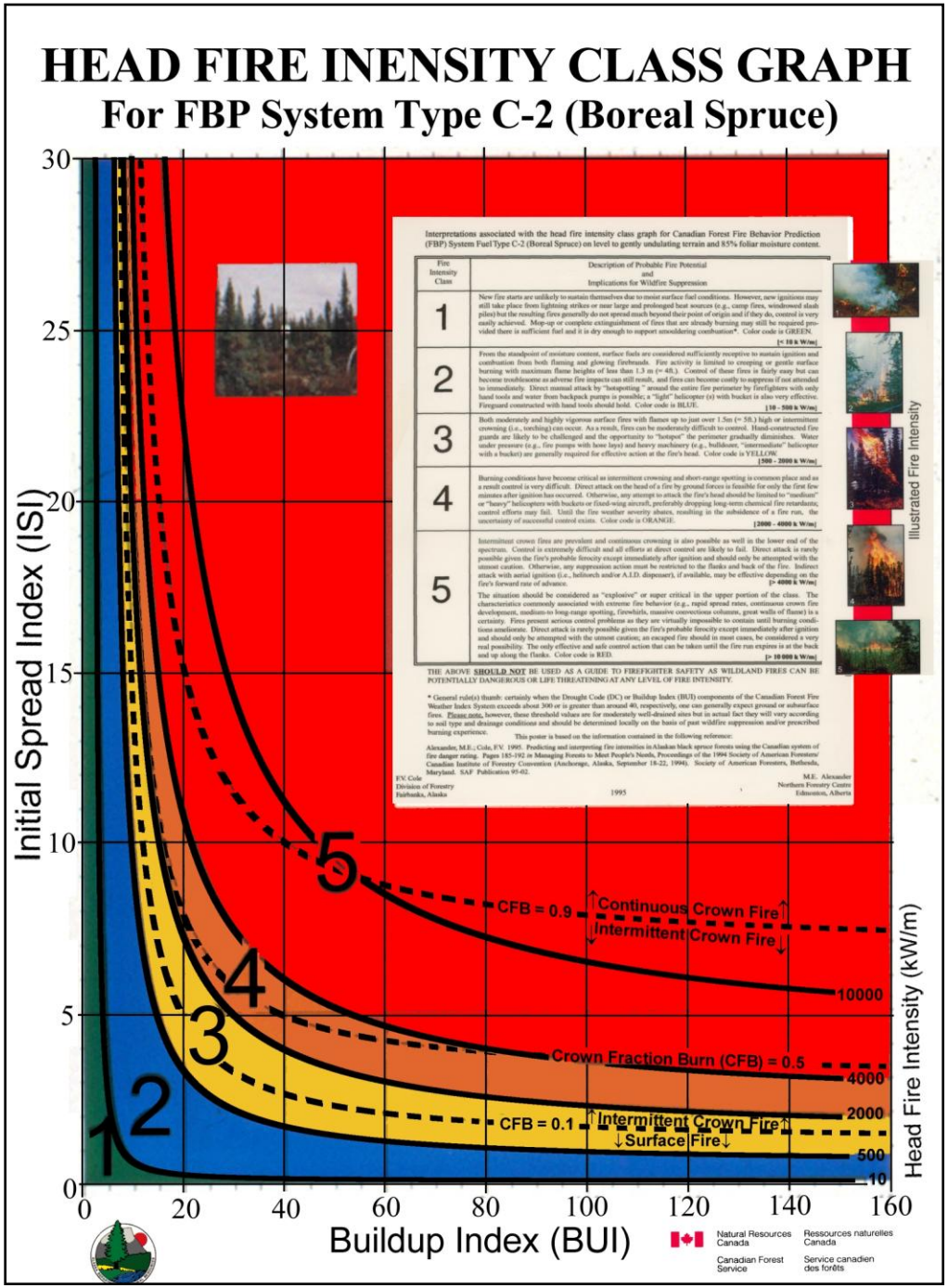
Caution: Flame heights at the fire's head will be greater than 2.5 metres. Under NO circumstances should direct attack be mounted on the head fire. Any containment action must begin from a secured anchor point and progress along the flanks toward the head as the fire edge or perimeter is "knocked down".

Beaufort Wind Force[a]	Forward spread distance/perimeter length/maximum breadth versus elapsed time since ignition ----------kilometres----------				Head fire intensity --kW/m--	Head fire flame length -metres-	Minimum firebreak width required to stop head fire[b] -------metres-------	
	0.5 hour	1 hour	1.5 hour	2 hour			Trees absent	Trees present
0-1	0.7/2.4/0.4	1.3/4.9/0.7	2.0/7.3/1.1	2.6/9.8/1.4	2300	2.7	5	12
2	1.0/2.7/0.4	2.0/5.5/0.7	2.9/8.2/1.1	3.9/10.9/1.5	3450	3.3	6	13
3	1.6/3.7/0.4	3.2/7.4/0.8	4.8/11.1/1.2	6.3/14.8/1.6	5550	4.1	7	15
4	2.7/5.7/0.6	5.3/11.5/1.1	8.0/17.2/1.7	10.7/22.9/2.2	9350	5.2	8	30+
5	4.4/9.1/0.8	8.7/18.2/1.5	13.1/27.3/2.3	17.5/36.4/3.1	15 300	6.5	10	30+
6	6.1/12.5/1.0	12.2/25.0/1.9	18.2/37.5/2.9	24.3/50.0/3.8	21 300	7.6	12	30+
7	7.2/14.8/1.0	14.5/29.5/2.0	21.7/44.3/3.1	28.9/59.1/4.1	25 300	8.2	13	30+
8 & higher	7.5/15.2/1.0	15.0/30.5/2.1	22.5/45.7/3.1	30.0/60.9/4.1	26 200+	8.4+	14+	30+



[a] See reverse side for details on the Beaufort Wind Scale.

[b] The "Trees absent" and "Trees present" classes refer to the absence or presence of trees/scrub within 20 meters of the windward side of the firebreak. The presence of trees or scrub has a significant influence on firebreak effectiveness because they supply woody material for firebrands which can spot across the break.



Cole & Alexander (1995) wall poster

Alexander & Cole (1995) technical paper presented at the SAF/CIF Joint National Convention, Anchorage, Alaska, Sept. 18-22, 1994

Table 4.3
Equilibrium rate of spread (m/min) and fire intensity class

C-3 mature jack or lodgepole pine

Intensity class	
1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI 0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0	0	0	0	0	0	0	0
2	0	< 0.1	0.1	0.1	0.1	0.1	0.1	0.1
3	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
4	0.1	0.3	0.4	0.4	0.5	0.5	0.5	0.5
5	0.3	0.6	0.7	0.8	0.9	0.9	1	1
6	0.4	1	1	1	1	2	2	2
7	0.7	2	2	2	2	2	2	2
8	1	2	2	3	3	3	3	3*
9	1	3	3	4	4	4	4*	5*
10	2	4	4	5	5	6*	6*	6*
11	2	5	5	6	7*	7*	7*	7*
12	2	6	7	7	8*	8*	8*	8*
13	3	7	8	9	10*	10*	11*	11*
14	3	8	9	10*	11*	12*	12*	13*
15	4	9	11	12*	13*	14*	14	15
16	4	10	12	14*	15*	16	16	17
17	5	12	14	16*	17	18	19	19
18	6	13	15	17*	19	20	21	21
19	6	15	17*	19	21	22	23	24
20	7	16	19*	21	23	25	26	26
21–25	9	21	24*	27	30	31	33	34
26–30	12	28*	33	38	41	43	45	46
31–35	16	36*	42	47	51	55	57	58
36–40	18	43	50	56	61	65	68	69
41–45	21	49	57	64	70	74	77	79
46–50	23	54	63	71	77	82	86	88
51–55	25	58	69	77	84	89	93	95
56–60	27	62	73	82	89	95	99	101
61–65	28	65	77	86	94	100	104	106
66–70	29	68	80	90	97	103	108	110

Constants: foliar moisture content = 97%; crown base height = 8 m. ☐ = average BUI.
Type of fire: **surface, intermittent crown*,** continuous crown. _ = CFB 50%.

Table 4.3
Equilibrium rate of spread (m/min) and fire intensity class

C-3 mature jack or lodgepole pine

Intensity class	
1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI 0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0	0	0	0	0	0	0	0
2	0	< 0.1	0.1	0.1	0.1	0.1	0.1	0.1
3	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
4	0.1	0.3	0.4	0.4	0.5	0.5	0.5	0.5
5	0.3	0.6	0.7	0.8	0.9	0.9	1	1
6	0.4	1	1	1	1	2	2	2
7	0.7	2	2	2	2	2	2	2
8	1	2	2	3	3	3	3	3*
9	1	3	3	4	4	4	4*	5*
10	2	4	4	5	5	6*	6*	6*
11	2	5	5	6	7*	7*	7*	7*
12	2	6	7	7	8*	8*	8*	8*
13	3	7	8	9	10*	10*	11*	11*
14	3	8	9	10*	11*	12*	12*	13*
15	4	9	11	12*	13*	14*	14	15
16	4	10	12	14*	15*	16	16	17
17	5	12	14	16*	17	18	19	19
18	6	13	15	17*	19	20	21	21
19	6	15	17*	19	21	22	23	24
20	7	16	19*	21	23	25	26	26
21–25	9	21	24*	27	30	31	33	34
26–30	12	28*	33	38	41	43	45	46
31–35	16	36*	42	47	51	55	57	58
36–40	18	43	50	56	61	65	68	69
41–45	21	49	57	64	70	74	77	79
46–50	23	54	63	71	77	82	86	88
51–55	25	58	69	77	84	89	93	95
56–60	27	62	73	82	89	95	99	101
61–65	28	65	77	86	94	100	104	106
66–70	29	68	80	90	97	103	108	110

Constants: foliar moisture content = 97%; crown base height = 8 m. ☐ = average BUI.
Type of fire: **surface, intermittent crown*,** continuous crown. _ = CFB 50%.

Application of CFFDRS to the WUI Fire Problem - An Example

Hay River, Northwest Territories

Black Spruce Forests

Fire Danger	HFI Class	Average Number of Days (basis: 1954 - 1996)					
		May	June	July	Aug.	Sep.	Season
Low	1-2	14	8	10	10	16	58
Moderate	3	9	9	9	11	8	46
High	4	4	4	5	4	2	19
Extreme	5-6	6	9	9	7	3	34

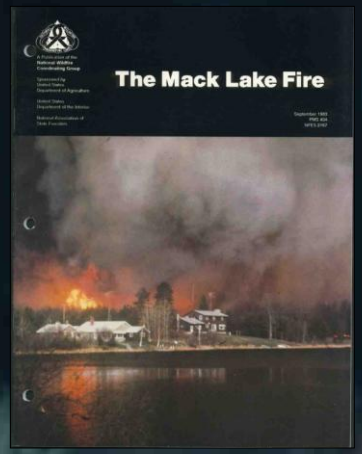
FBP System Fuel Types have been linked to Aerial Application of Foam Requirements

Recommended Foam Consistencies for Aerial Attack on Wildfires in Canadian Forest Fire Behavior Prediction (FBP) System Fuel Types

Ground Support (within 30 minutes)			No Ground Support		
TREE CANOPY:	FOREST FLOOR: Shallow	FOREST FLOOR: Deep	TREE CANOPY:	FOREST FLOOR: Shallow	FOREST FLOOR: Deep
Open	WET FBP System fuel types C-1, C-7, S-1, O-1)	DRIPPING FBP System fuel types C-2, S-2, S-3)	Open	DRIPPING FBP System fuel types C-1, C-7, S-1, O-1)	DRY FBP System fuel types C-2, S-2, S-3)
Closed	DRIPPING FBP System fuel types C-4, C-5, C-6, D-1)	WET *FOLLOWED BY* DRIPPING* FBP System fuel types C-3, M-1, M2 M-3, M-4)	Closed	WET *FOLLOWED BY* DRY-optional* FBP System fuel types C-4, C-5, C-6, D-1)	WET *FOLLOWED BY* DRY FBP System fuel types C-3, M-1, M2 M-3, M-4)

*i.e., two loads.

Mack Lake Fire, Michigan
May 5, 1980



Dry-bulb Temperature 80 °F
Relative Humidity 24%
33-ft Open Wind 20.5 mph
Days Since Rain 6

FFMC 94.6
DMC 35
DC 59
ISI 43.2
BUI 35
FWI 50

Mack Lake Fire, Michigan May 5, 1980

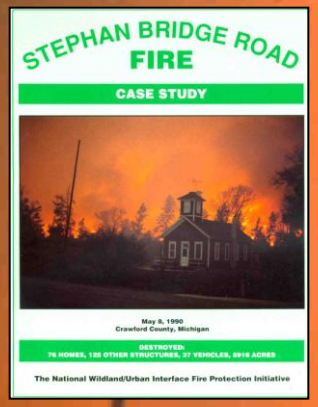
The following comparisons are based on the major run of the Mack Lake Fire that occurred between 1230 and 1600 hours EDT on May 5, 1980 using FBP System Fuel Type C-4, a 0% Slope and 100% Foliar Moisture Content:

Fire Behavior Characteristic	Predicted	Observed
Head Fire Rate of Spread (ft/min)	187	184
Head Fire Intensity (Btu/sec-ft)	9731	8890
Forward Spread Distance (mi)	7.1	7.5
Area Burnt (Acres)	6262	6778
Fire Perimeter (mi)	15.4	12.4

Predicted Type of Fire at the "Head" :

Continuous Crown Fire (100% Crown Fuel Involvement)

Stephan Bridge Road Fire
Michigan May 8, 1990



Dry-bulb Temperature 82 °F
Relative Humidity 26%
10-m Open Wind 17.4 mph
Days Since Rain 14

FFMC 93.6
DMC 68
DC 112
ISI 29.1
BUI 68
FWI 52

Stephan Bridge Road Fire Michigan May 8, 1990

The following comparisons are based on the major run of the Stephan Bridge Road Fire that occurred between 1540 and 1930 hours EDT on May 8, 1990 using FBP System Fuel Type C-4, a 0% Slope and 100% Foliar Moisture Content:

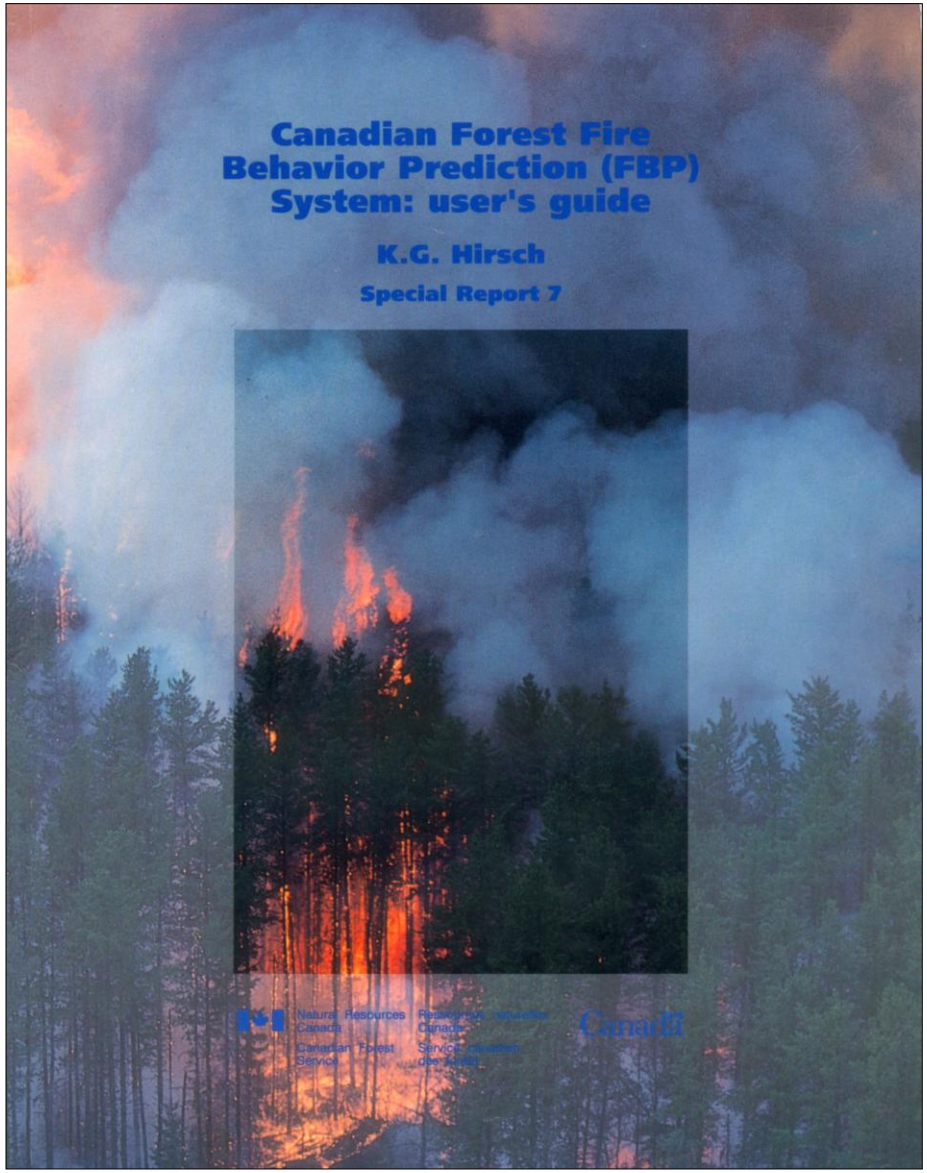
Fire Behavior Characteristic	Predicted	Observed
Head Fire Rate of Spread (ft./min)	174	184
Head Fire Intensity (Btu/sec-ft)	14,859	N/A
Forward Spread Distance (mi.)	7.2	8.0
Area Burnt (Acre)	7129	4490
Fire Perimeter (mi)	15.8	15.4

Predicted Type of Fire at the "Head" :

Continuous Crown Fire (100% Crown Fuel Involvement)

FBP System Training Materials

Workbook



CD-ROM

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When ordering quote:
ISBN 0-660-17600-9

http://www.ubcpress.ca

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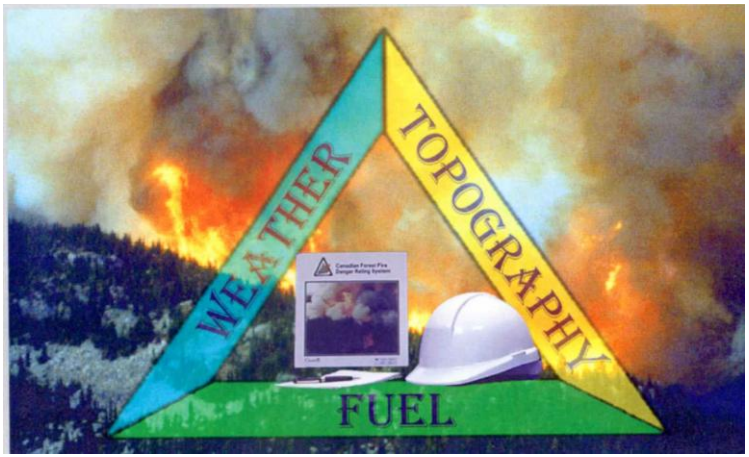
Advanced Wildland Fire Behavior Course

- Delivered regionally (West, East + French)

Wildland Fire Behavior Specialist Course

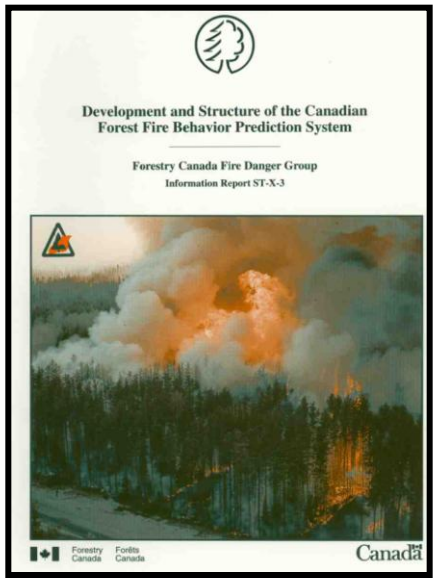
- Delivered Nationally

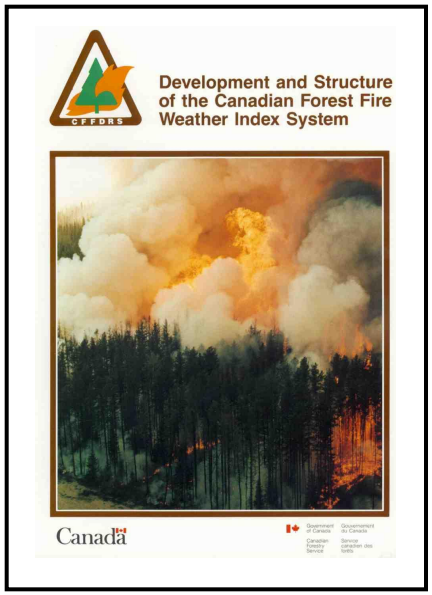


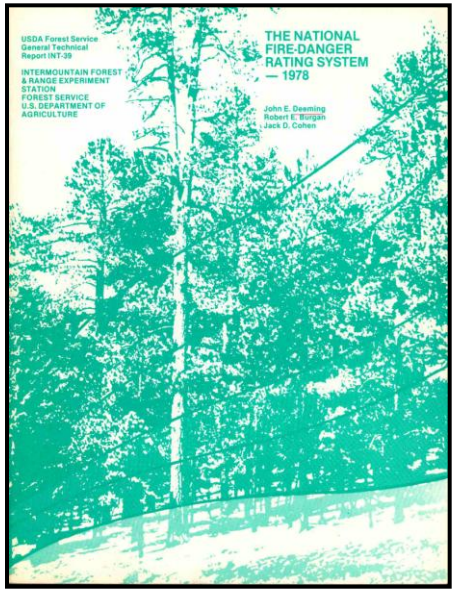
Course Dates & Locations Advertised on Canadian Interagency Forest Fire Centre web site:

www.ciffc.ca

Basic Similarities & Differences Between Canadian & U.S. Systems

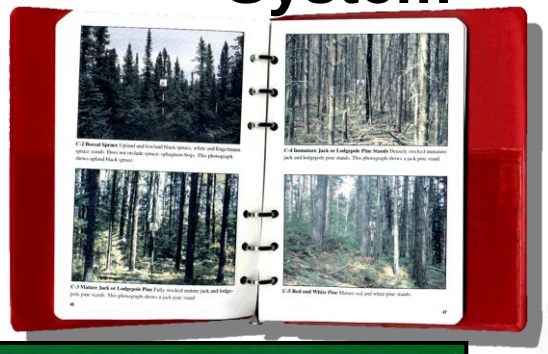


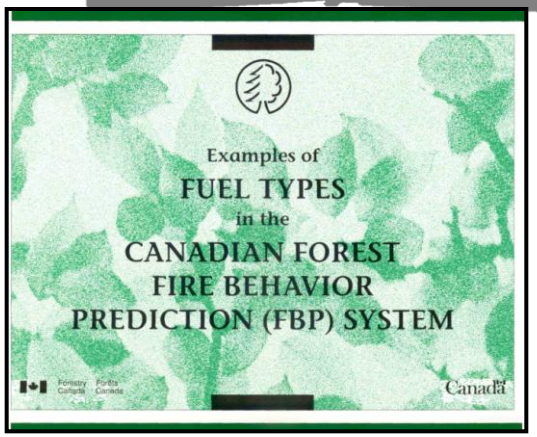


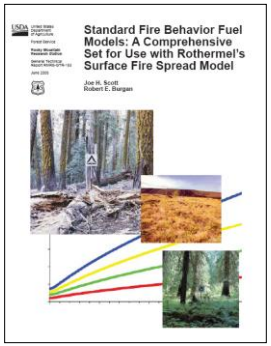


Fire Environment Inputs: Fuels

- Canadian
  - 1 Fuel Type in FWI System
  - 16 Fuel Types in FBP System
- U.S.
  - 13 Fire Behavior Fuel Models (1976)
  - 20 Fire Danger Fuel Models (1978)
  - Customized Fuel Models (1979)
  - 40 new Fire Behavior Fuel Models (2005)







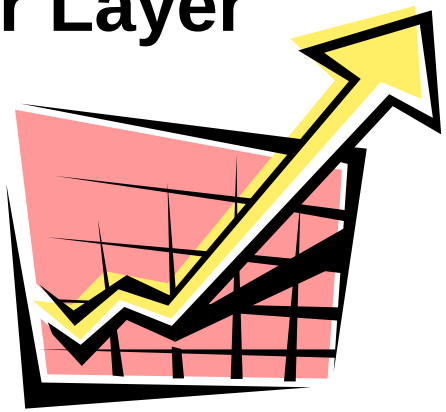
Fire Environment Inputs: Live Fuel Moisture

- **Canadian**
  - **Conifer Foliar MC Estimated From Calendar Date, Location (Lat./Long) and Elevation**

- **U.S.**
  - **Understory Live Moisture Content (Herbaceous & Woody) Estimates Based on Phenology Required for Certain Fuel Models.**

Fire Environment Inputs: Dead Fuel Moisture

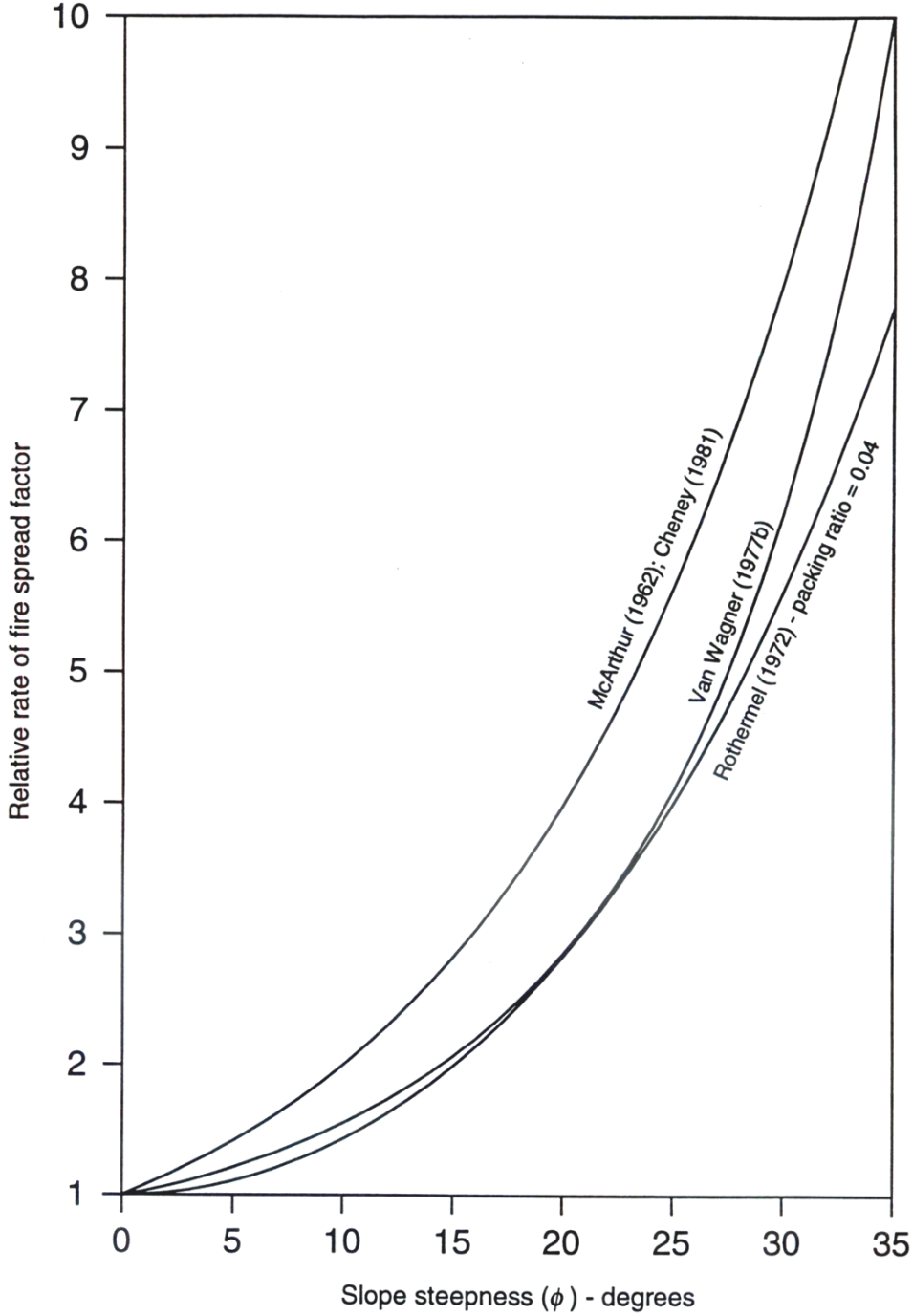
- Canadian
  - FWI System Fuel Moisture Codes Dependent on the Continuity of Daily Wx Readings
  - Emphasis on Forest Floor Layer



- U.S.
  - Dead Fuel Moisture Content (1-hr, 10-hr, 100-hr, 1000-hr TL's) Calculated From Current Wx Observations Plus Other Environmental Variables
  - Emphasis on Herbaceous & Woody Vegetation & Dead-Down Roundwood Fuels

Fire Environment Inputs: Topography

- **Canadian**
  - **Considers the Mechanical Effects of % Slope on Fire Behavior**
  - **Uses a Vectoring Approach For Cross-Slope Situations**
- **U.S.**
  - **Considers the Mechanical Effects of % Slope on Fire Behavior**
  - **Uses Basic Vectoring for Cross-Slope Situations**

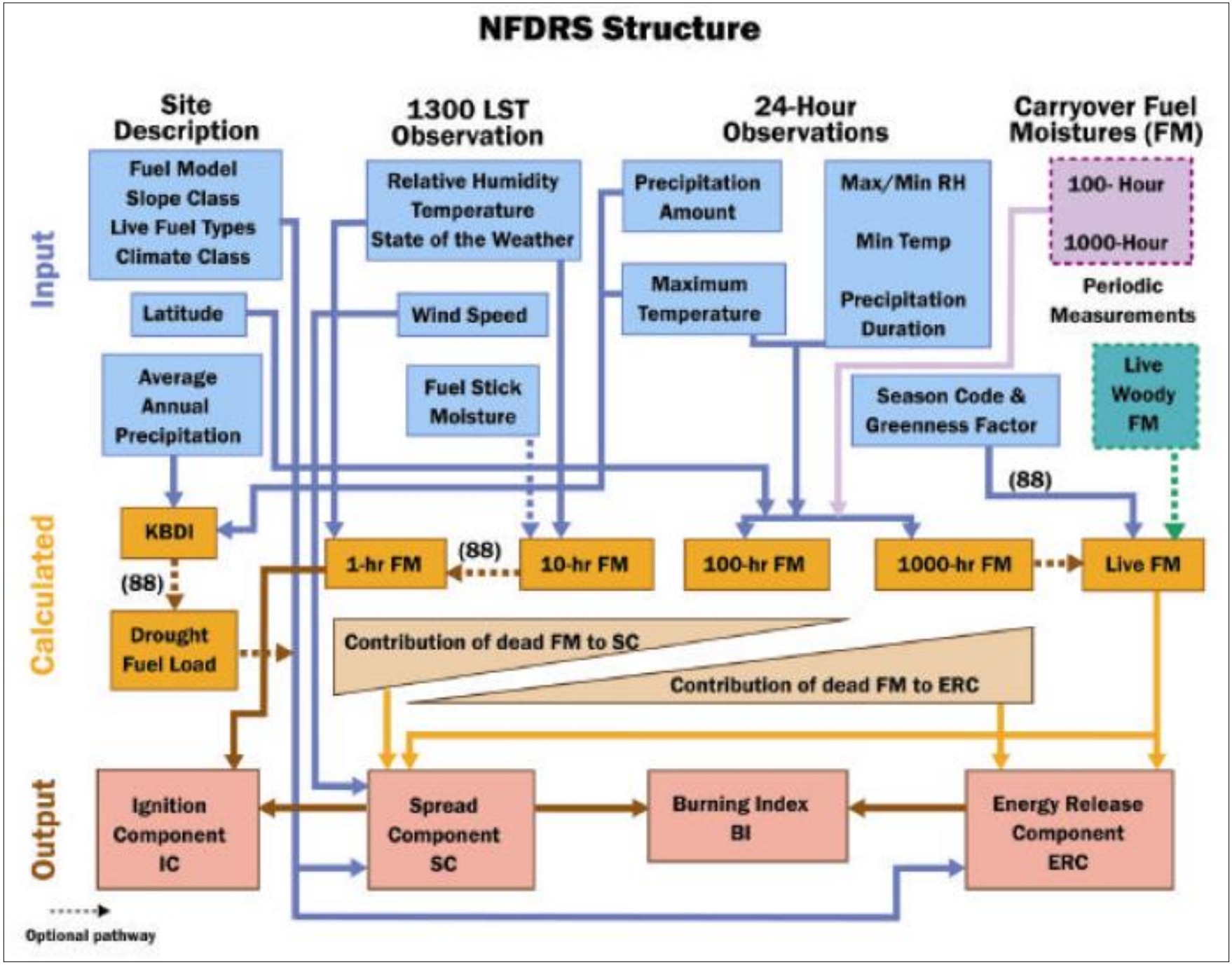


The effect of slope steepness on uphill rate of fire spread of free-burning wildland fires in the absence of wind according to Australian (McArthur 1962; Cheney 1981), Canadian (Van Wagner 1977b) and American (Rothermel 1972) authorities

Fire Environment Inputs: Weather

- **Canadian**
  - **Temp, RH, Rain**
  - **Open Wind Measured at 10-m Height**

- **U.S.**
  - **Temp, RH, Rain + additional parameters**
  - **Open Wind Measured at 20-ft (6.1-m) Height**
  - **Open Wind Adjusted for Vegetative Cover & Topographic Position to "Mid-flame" Wind Speed**

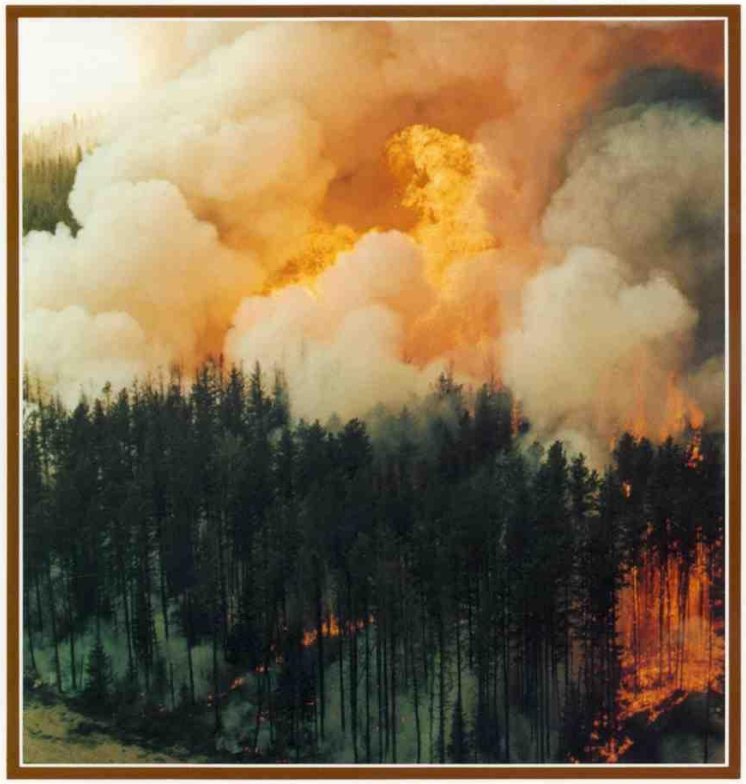

NFDRS Structure
Site Description
1300 LST Observation
24-Hour Observations
Carryover Fuel Moistures (FM)
Input
Fuel Model
Slope Class
Live Fuel Types
Climate Class
Relative Humidity
Temperature
State of the Weather
Precipitation Amount
Max/Min RH
Min Temp
Precipitation Duration
100- Hour
1000-Hour
Periodic Measurements
Latitude
Wind Speed
Maximum Temperature
Average Annual Precipitation
Fuel Stick Moisture
Season Code & Greenness Factor
Live Woody FM
(88)
Calculated
KBDI
(88)
1-hr FM
(88)
10-hr FM
100-hr FM
1000-hr FM
Live FM
Drought Fuel Load
Contribution of dead FM to SC
Contribution of dead FM to ERC
Output
Ignition Component IC
Spread Component SC
Burning Index BI
Energy Release Component ERC
Optional pathway

Fire Danger Index Equivalencies

Canadian		U.S.
FFMC	→	IC
DMC/BUI	→	ERC
DC	→	KBDI
ISI	→	SC
FWI	→	BI

CFFDRS

Development and Structure of the Canadian Forest Fire Weather Index System



Canada

Government of Canada / Gouvernement du Canada

Canadian Forestry Service / Service canadien des forêts

United States Department of Agriculture

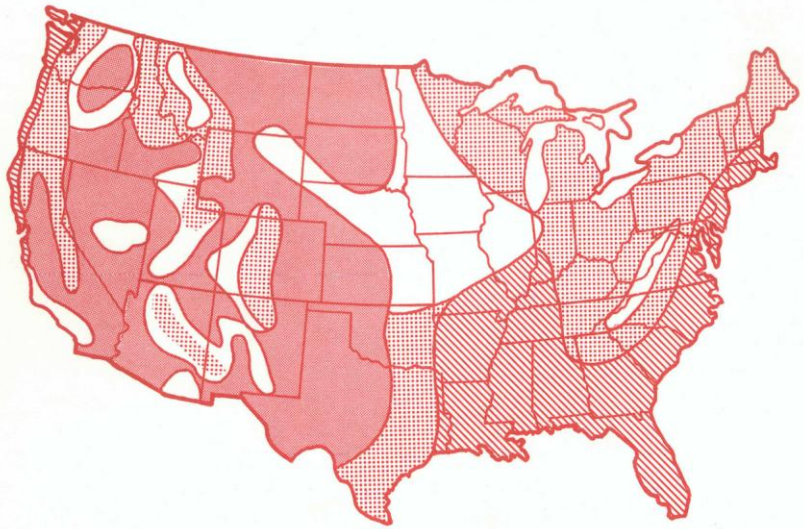
Forest Service

Intermountain Forest and Range Experiment Station Ogden, Utah 84401

General Technical Report INT-169

July 1983

The 1978 National Fire-Danger Rating System: Technical Documentation



forest management note

Note No. 43 Northern Forestry Centre Edmonton, Alberta

TWO *BASIC* PROGRAMS FOR FIRE DANGER AND FIRE BEHAVIOR COMPUTATIONS

Two computer programs pertaining to the Canadian Forest Fire Danger Rating System (CFFDRS) calculate Canadian Forest Fire Weather Index (FWI) System (Canadian Forestry Service 1984) component values and predict fire behavior using procedures from the Canadian Forest Fire Behavior Prediction (FBP) System (Lawson et al. 1985). The programs were written for a NEC PC-8201A[1] lap computer (Fig. 1) but can be adapted to any computer with approximately 24 KB of memory that supports some dialect of the BASIC computer language.

The first program, named LAPFWI (Lap computer Fire Weather Index), is a program to calculate component indexes of the FWI System (Van Wagner and Pickett 1985; Van Wagner 1987) and archive fire weather data. The FWI System consists of three fuel moisture codes, Fine Fuel Moisture Code (FFMC), Duff Moisture Code (DMC), and Drought Code (DC), and three fire behavior indexes, Initial Spread Index (ISI), Buildup Index (BUI), and Fire Weather Index (FWI). Calculation of the six components making up the FWI System is based on daily observations of dry-bulb temperature, relative humidity, 10-m open wind speed, and 24-hour accumulated rainfall recorded at 1200 h local standard time (LST) at a suitable weather station (Turner and Lawson 1978). Also computed by the program is the Daily Severity Rating System (DSR), a function of the FWI component as described by Van Wagner (1970, 1987) and the Cumulative Daily Severity Rating (CDSR) as described by Harvey et al. (1986). The program is based largely on a FORTRAN program written by Van Wagner and Pickett (1985), with some notable input-output exceptions. Fire weather data (measured, forecasted, or estimated) can either be processed from an archived data file or typed in directly. Output from LAPFWI can be displayed in two formats: screen display (from typed-in data only) or print form (if a printer is available).

The second program is LAPFBP (Lap computer Fire Behavior Prediction), which is designed to evaluate fire growth and crowning potential as outlined in the 1984 interim edition of the Canadian Forest Fire Behavior Prediction (FPB) System[2] (Lawson et al. 1985) with some minor additions. Currently, the primary output of the FBP System is head fire Rate Of Spread (ROS) based on fuel type (14 major Canadian fuel types currently recognized), weather (FFMC and 10-m open wind speed), and topographic slope and aspect. Crowning potential is determined, where applicable, on the basis of the calculated ISI or slope-adjusted ROS. Other outputs include some simple elliptical fire growth model information (Van Wagner 1969): length-to-breadth ratio; area; perimeter length; head, back, and flank fire spread distances; and fire mapping information. Additions to the program not outlined in the 1984 interim edition FBP System include the following:

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

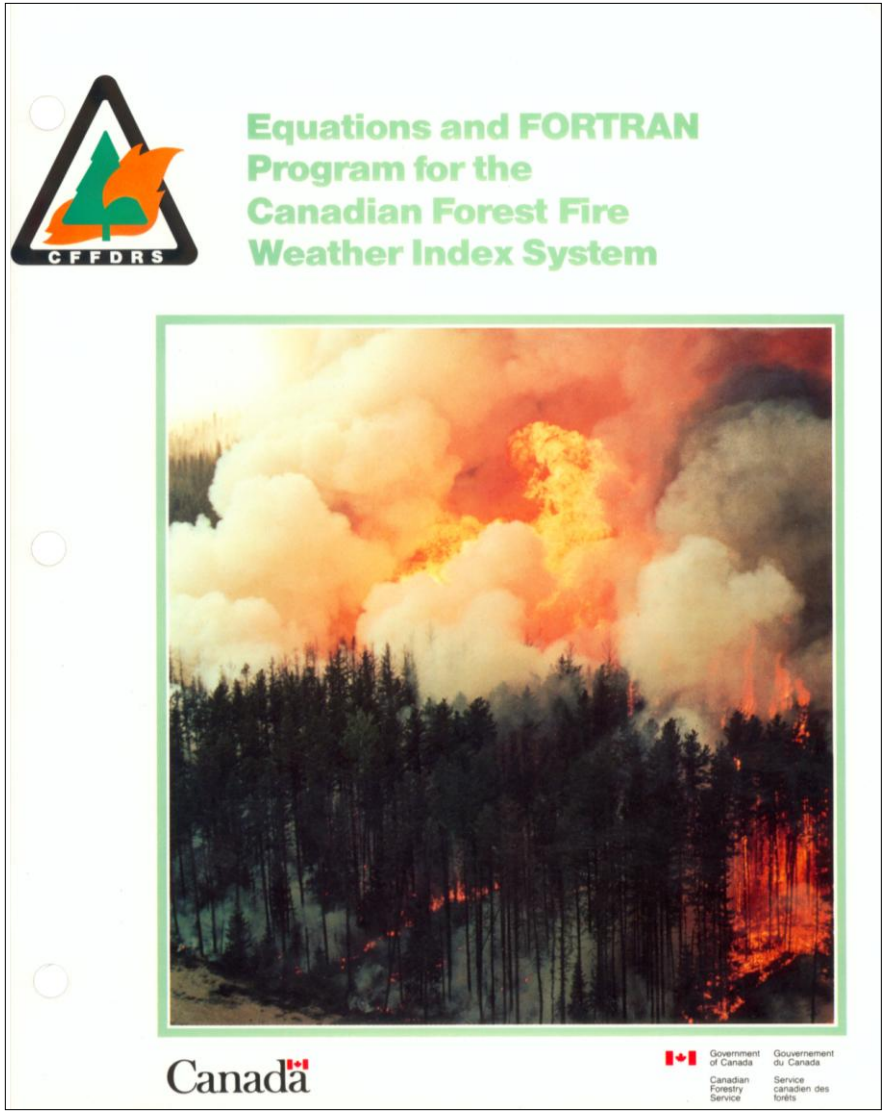
[2] Alexander, M.E.; Lawson, B.D.; Stocks, B.J.; Van Wagner, C.E. 1984. User guide to the Canadian Forest Fire Behavior Prediction System: rate of spread relationships. Interim edition. Environ. Can., Can. For. Serv., Fire Danger Group, Ottawa, Ontario.

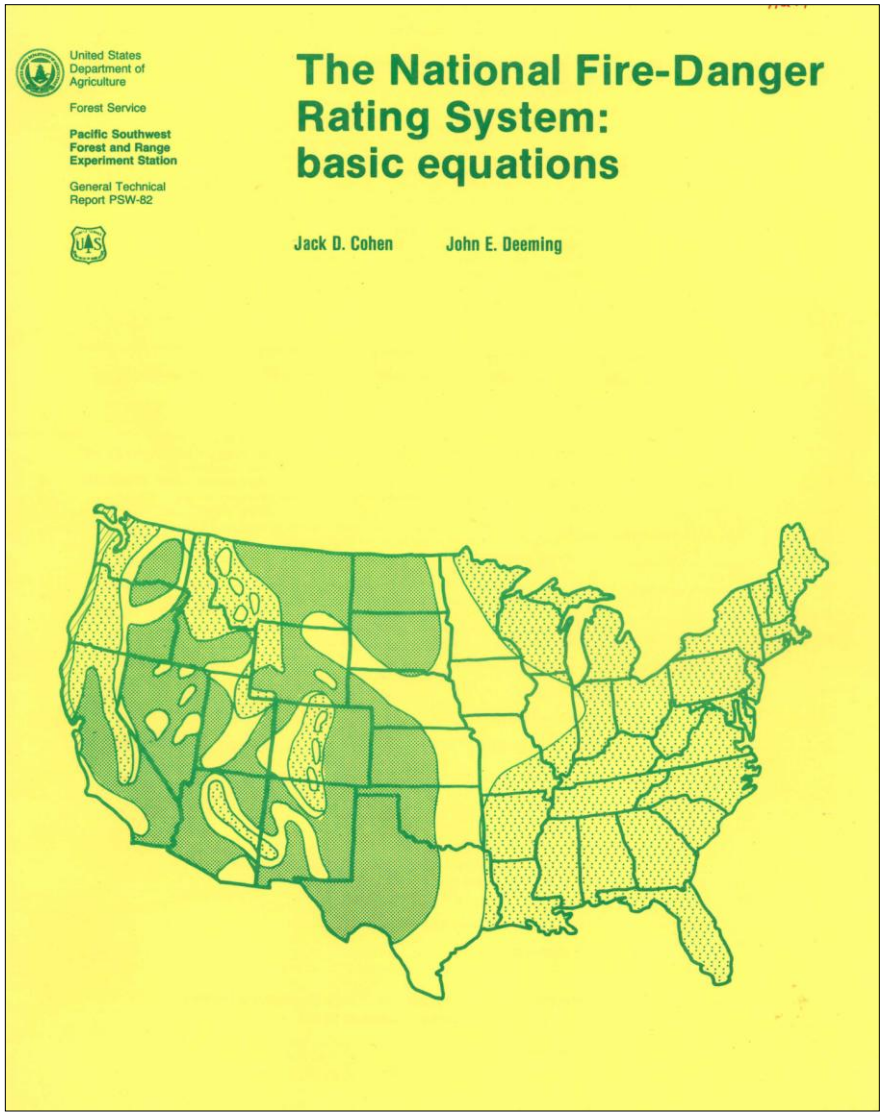
Government of Canada / Gouvernement du Canada
Canadian Forestry Service / Service canadien des forêts
Canada

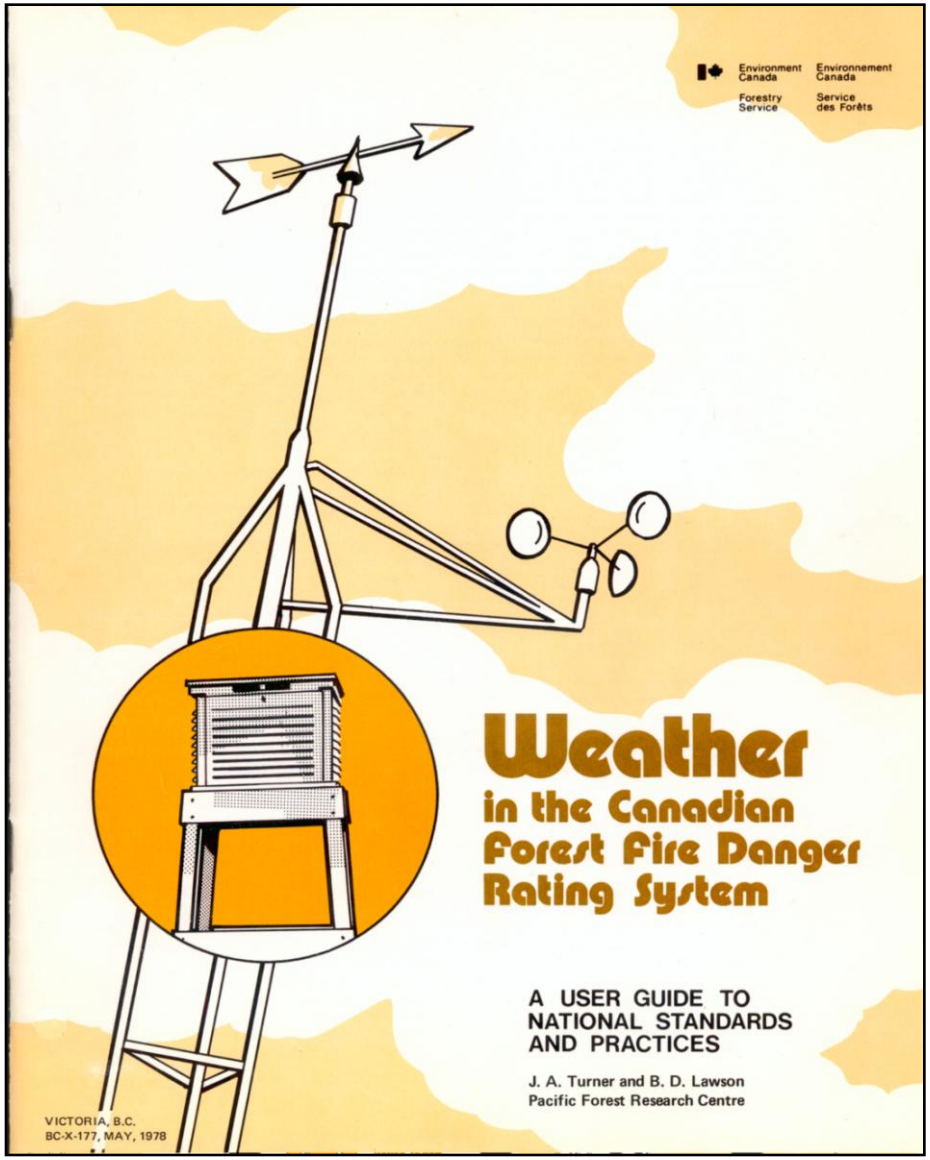
USDA United States Department of Agriculture
Forest Service
Intermountain Research Station
General Technical Report INT-GTR-366
December 1997

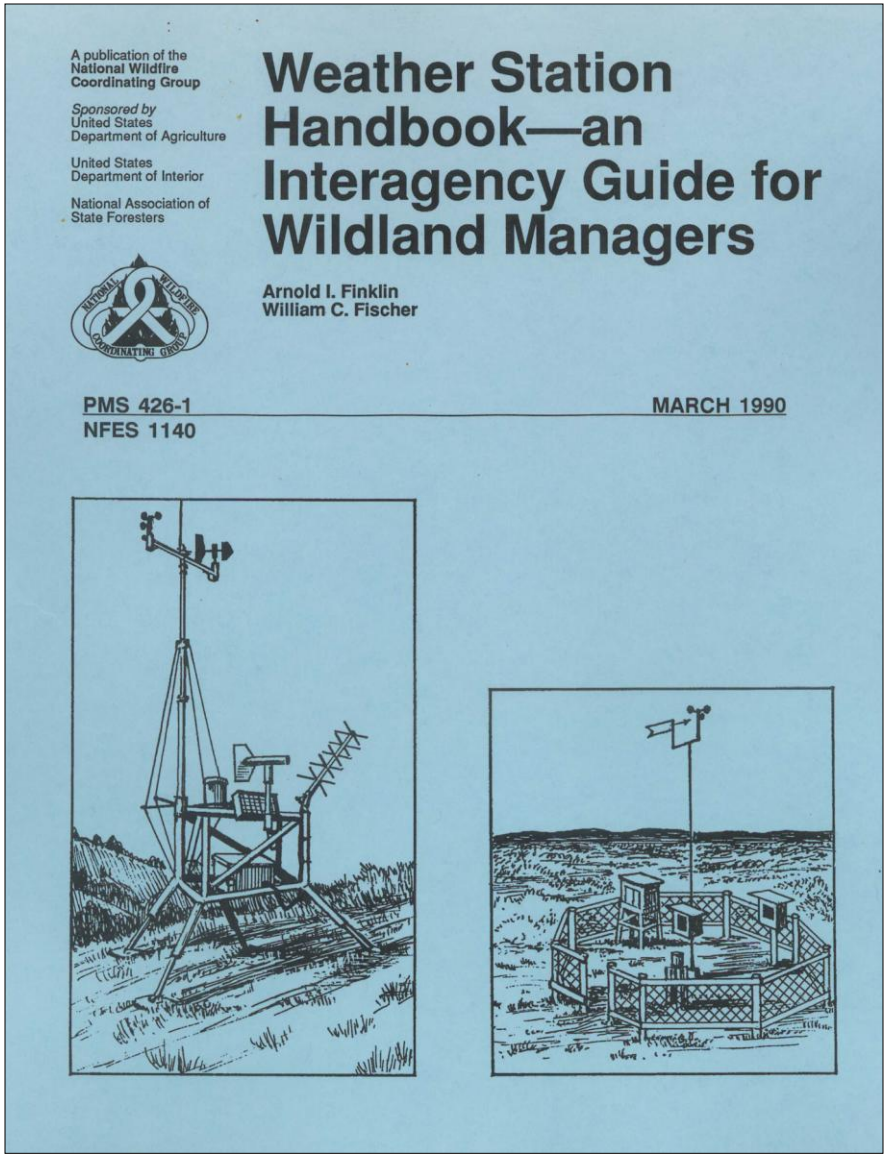
User's Guide to PCDANGER: National Fire Danger Rating System for Personal Computers

Larry S. Bradshaw
Erin M. Law


CFFDRS
Equations and FORTRAN Program for the Canadian Forest Fire Weather Index System
Canada
Government of Canada
Gouvernement du Canada
Canadian Forestry Service
Service canadien des forêts


United States Department of Agriculture
Forest Service
Pacific Southwest Forest and Range Experiment Station
General Technical Report PSW-82
The National Fire-Danger Rating System: basic equations
Jack D. Cohen
John E. Deeming


Environment Canada
Environnement Canada
Forestry Service
Service des Forêts
Weather
in the Canadian
Forest Fire Danger
Rating System
A USER GUIDE TO
NATIONAL STANDARDS
AND PRACTICES
J. A. Turner and B. D. Lawson
Pacific Forest Research Centre
VICTORIA, B.C.
BC-X-177, MAY, 1978


A publication of the
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United States
Department of Interior
National Association of
State Foresters
Weather Station
Handbook—an
Interagency Guide for
Wildland Managers
Arnold I. Finklin
William C. Fischer
PMS 426-1
NFES 1140
MARCH 1990

The Drought Code Component of the Canadian Forest Fire Behavior System

by J. A. Turner

Environment Canada / Environnement Canada

Forestry Service / Service des Forêts

U.S.D.A. Forest Service Research Paper SE-38

November 1968

Revised November 1988

A Drought Index for Forest Fire Control

U.S. Department of Agriculture–Forest Service

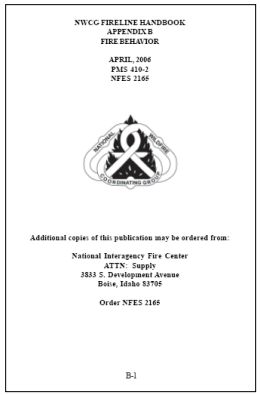
Southeastern Forest Experiment Station

Asheville, North Carolina

Fire Behavior Outputs

- **Canadian**
  - **Produces Estimates of ROS & Intensity**
  - **Predicts both Surface & Crown Fire Within a Given Fuel Type**
  - **Predicts Fuel Consumption**
  - **Allows for Acceleration From a Point Source Ignition**

- **U.S.**
  - **Produces Estimates of ROS & Intensity/Flame Length**
  - **Primary Prediction by Fuel Model is for Surface Fire**
  - **Crown Fire Prediction Handled Separately**
  - **No Direct Estimates of Fuel Consumption**
  - **No Allowance for Acceleration**


NWCG FIRELINE HANDBOOK
APPENDIX B
FIRE BEHAVIOR

APRIL, 2006
PMS 410-2
NFES 2165

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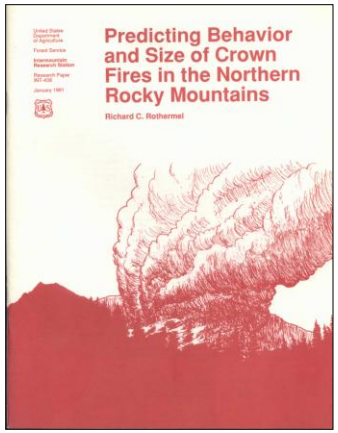
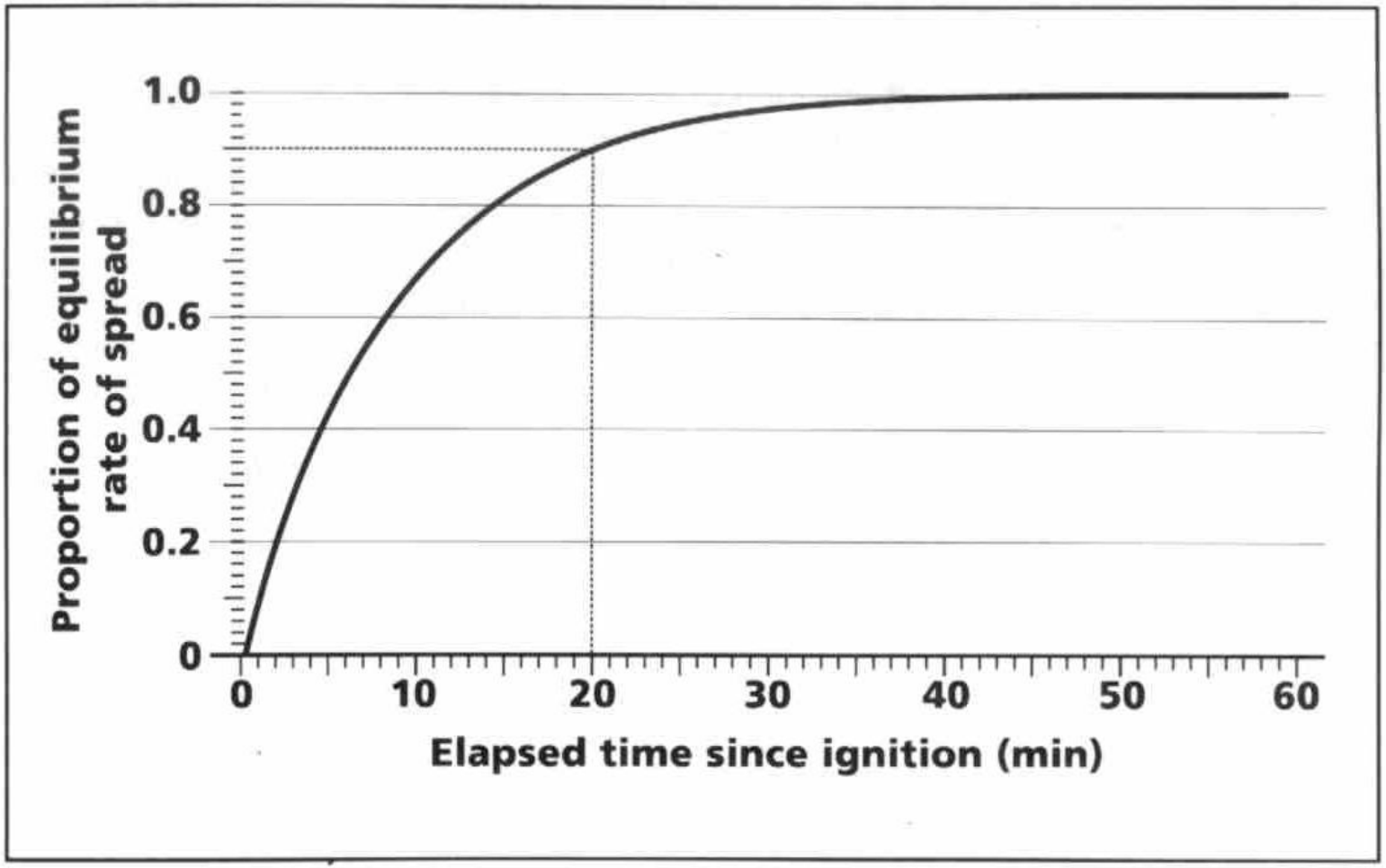
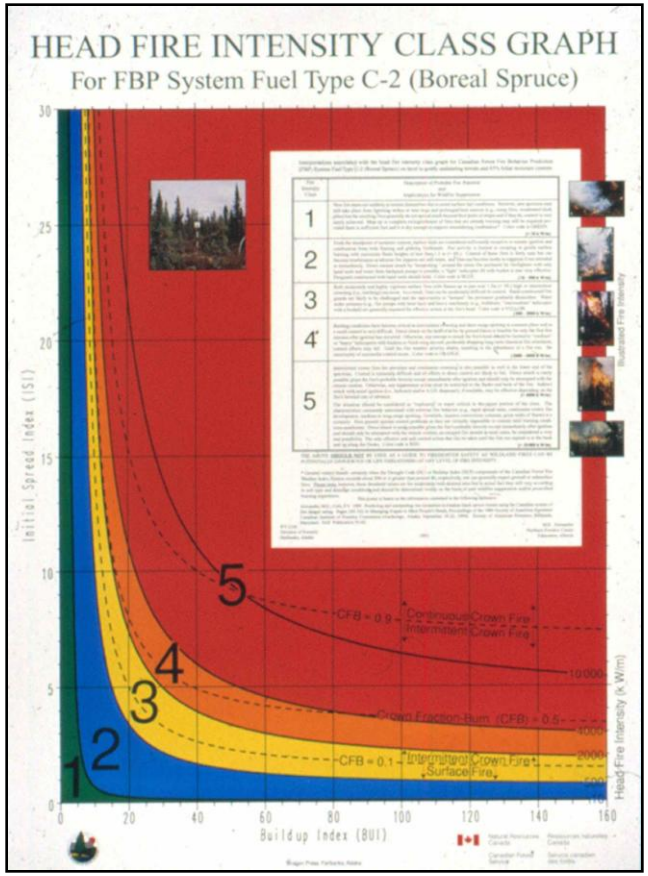
B-1

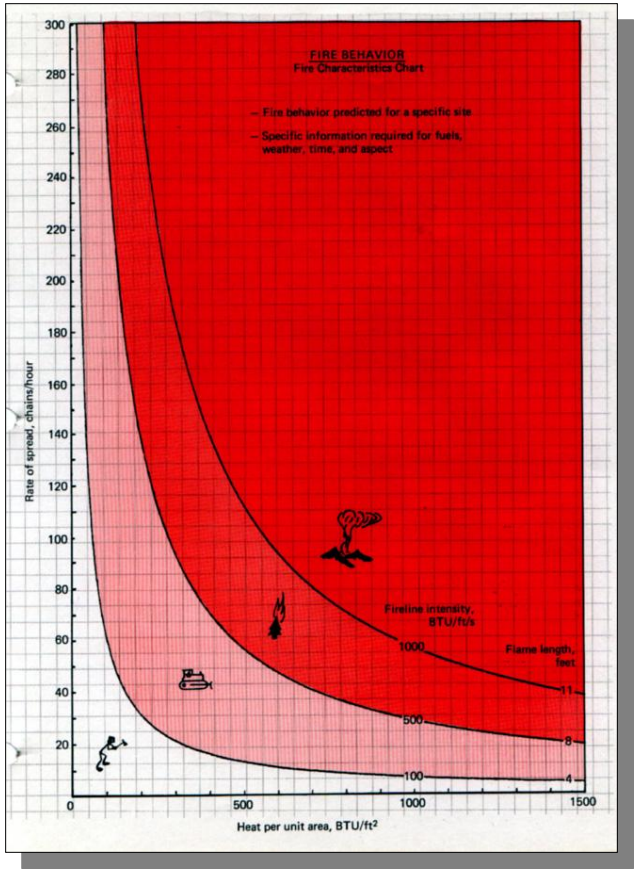


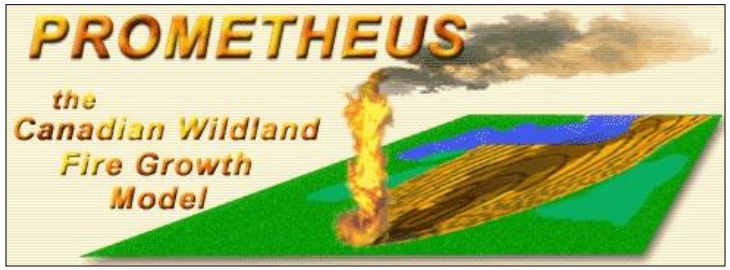
Acceleration curve for open canopy fuel types showing the proportion of equilibrium rate of spread as a function of elapsed time since ignition.

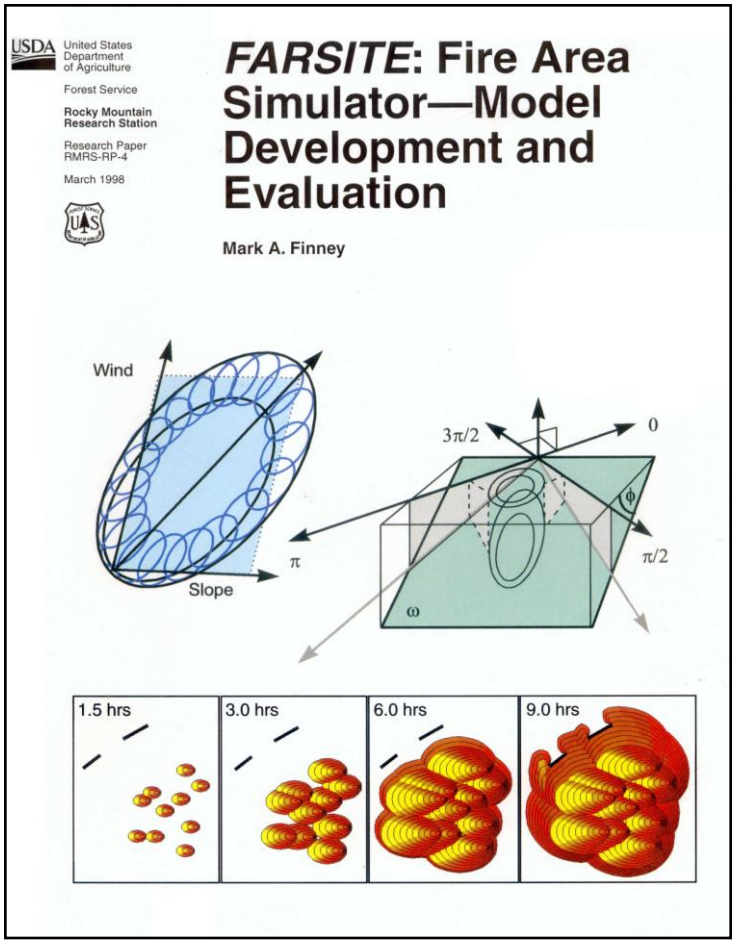


Fire Behavior Outputs:
Fire Intensity Class Graphs vs.Hauling Charts

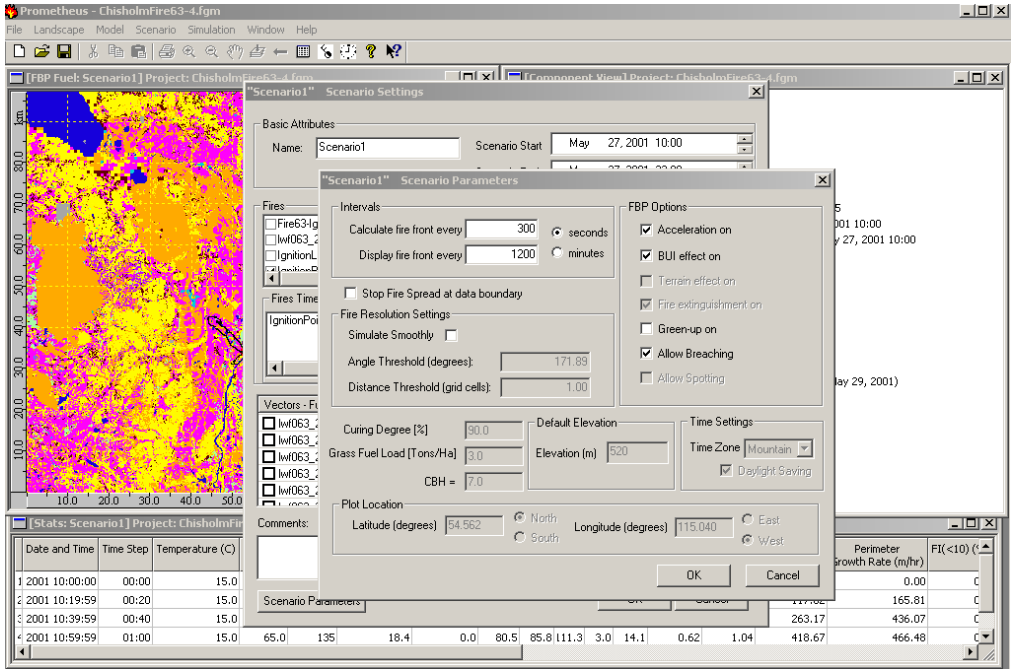








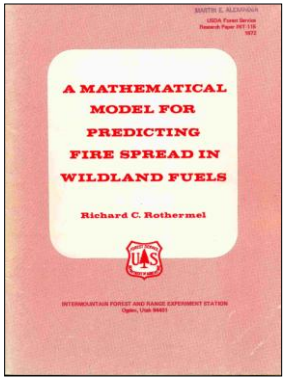
http://www.firegrowthmodel.com/



Technical Basis

- **Canadian**
  - **"Seamless" System Largely derived from empirical data coupled with simple logic**

- **U.S.**
  - **Systems based on laboratory fires and physical theory**



In his comparison of the 1972 National Fire Danger Rating System and the Canadian FWI System, Van Wagner (1975) concluded that:

The American system is probably at its best in the open, grassy forests or brush types with little or no duff layer common in many parts of the United States, but not well represented in Canada. The Canadian system, on the other hand, is at its best in forests with fairly complete canopy and a substantial layer of litter and duff but no marked seasonal variation in herbaceous vegetation.

The Rosie Creek Fire

By

Glenn P. Juday*

Introduction

The winter of 1982-83 was mild in interior Alaska. Aside from an early, heavy snowfall in October and November which insulated the ground against deep freezing, it was a dry winter as well. The weather station at the Fairbanks International Airport recorded below-normal snowfall from December through March. Breakup came early; the Tanana River at Nenana lost its ice cover on April 29. The average temperature for the month of April 1983 was 7.2°F above normal. By the end of May, the combination of early snowmelt, very low spring precipitation, warm weather, and drying winds produced a high fire danger.

Many people near Fairbanks were looking ahead to a busy construction season or to establishing or expanding cultivated areas. They took advantage of the warm, dry early spring to clear land. Most obtained open-burning permits from the state Division of Forestry (DOF) to burn the slash and clearing debris. Most followed common sense and stopped burning when warm temperatures and high winds caused extreme fire danger after May 28. But on Sunday, May 29, a man set fire to his land-clearing debris on the Tanana River lowlands near the mouth of the Rosie Creek. Carried by a powerful east wind, the fire escaped and began to race across the highly flammable black spruce-covered permafrost flats, headed west. Above the flats to the north, on the deep wind-deposited silt soils of the south-facing ridges, grew some of the largest and most productive white spruce forests in northern Alaska. The demand for forest products in interior Alaska had made these stands among the most important for forest management in this region of the state. Even more alarming, if the fire shifted to the east, its path would cross a rural residential area that had expanded greatly in population in the last few years.

What follows here is a reconstruction of the events of the Rosie Creek Fire, taken from the fire narrative (Alaska Department of Natural Resources, Division of Forestry, 1983a, b) and fire night reports. The chronology of this fire provides a good opportunity to see how a modern, wildland-fire-control organization works.

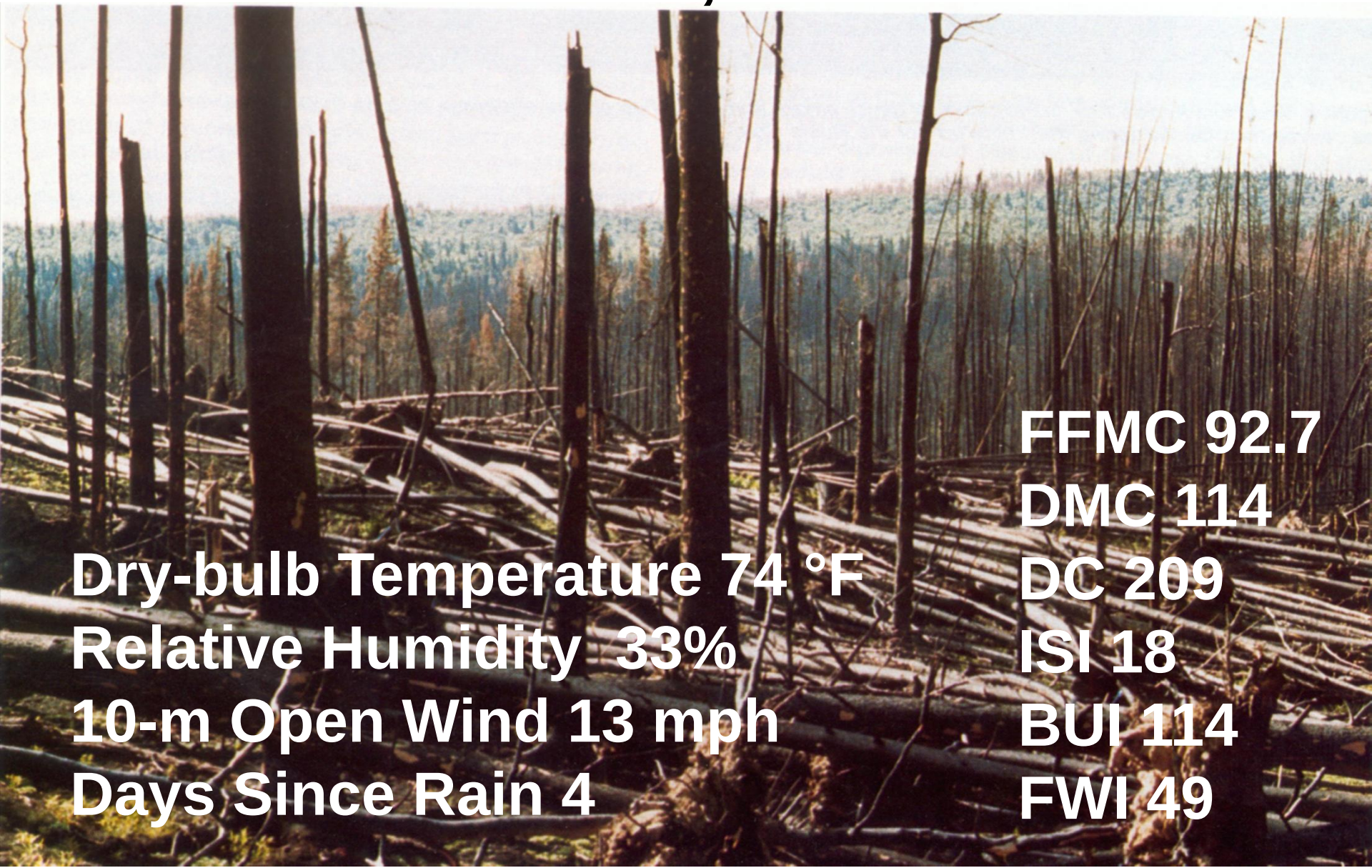
*Visiting Associate Professor and Coordinator, Rosie Creek Fire Research Project, Agricultural and Forestry Experiment Station, Fairbanks.

"Fire Behavior Prediction Olympics":

Canada vs. USA

Comparison of BEHAVE System (i.e., Norum 1982) versus Canadian FBP System based on the 1983 Rosie Creek Fire near Fairbanks, AK

Rosie Creek Fire near Fairbanks, Alaska
June 2, 1983



FBP System Red Book

Given ISI 18 and BUI 114

- **Head Fire Intensity Class 6**
- **Equilibrium head fire ROS: 31 m/min or 102 ft/min**
- **Continuous Crown Fire**

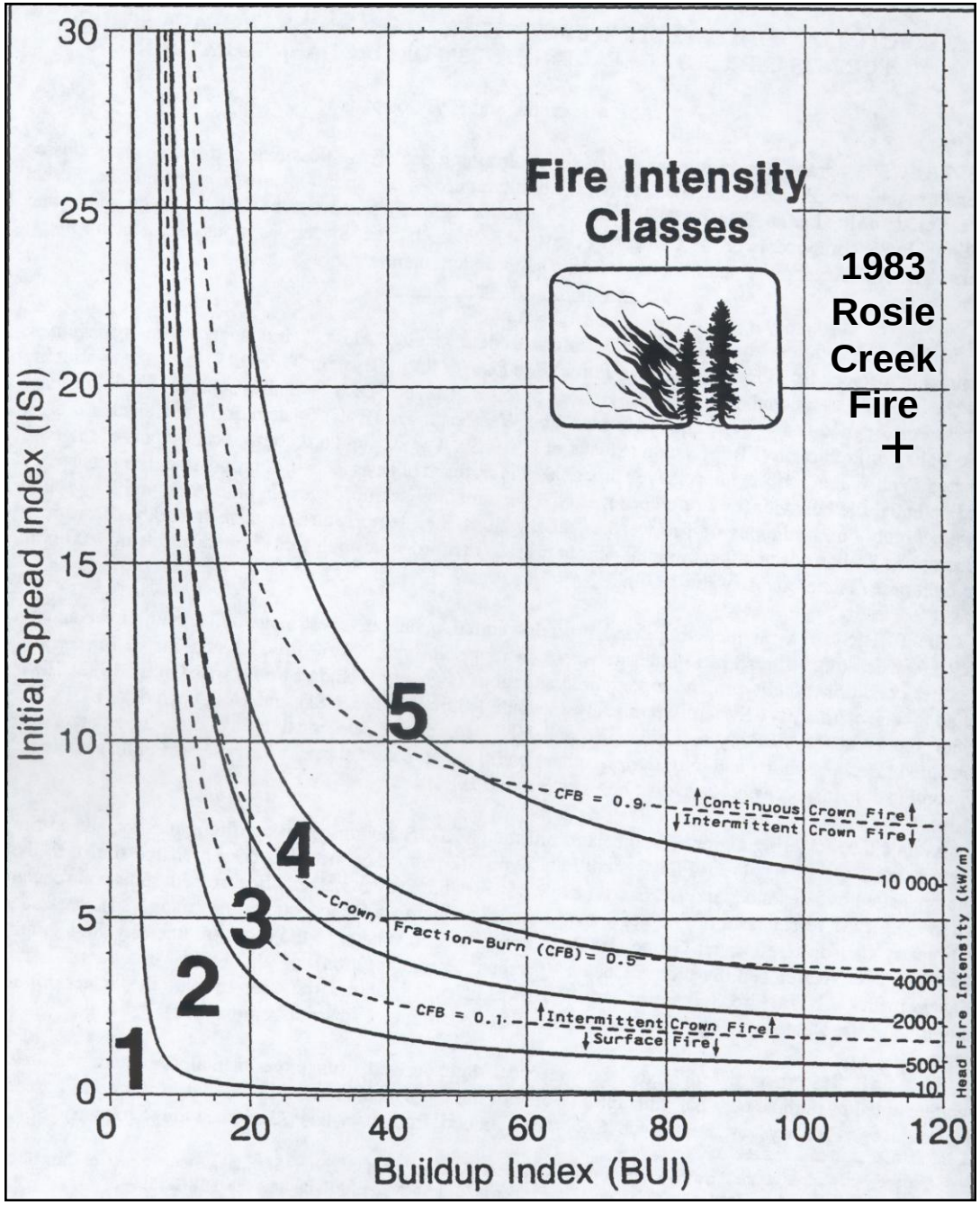
Table 4.2
Equilibrium rate of spread (m/min) and fire intensity class
C-2 boreal spruce

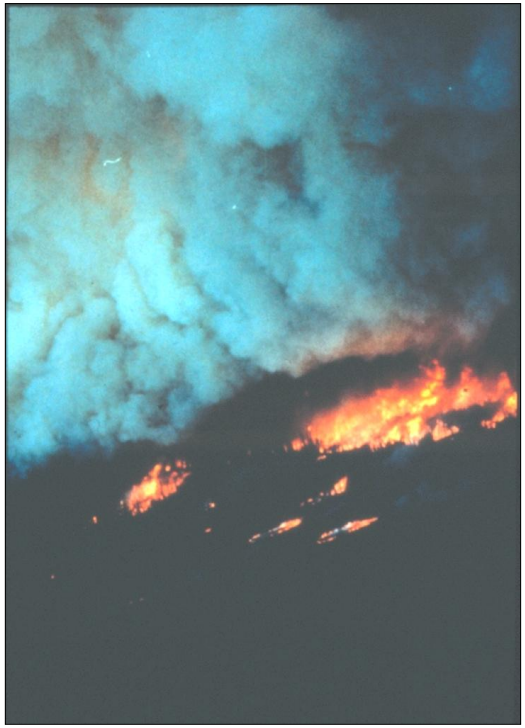
Intensity class
1 < 10 kW/m
2 10 – 500
3 500 – 2 000
4 2 000 – 4 000
5 4 000 – 10 000
6 > 10 000

ISI \ BUI	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0.1	0.3	0.4	0.5	(2) 0.5	0.6	0.6	0.6
2	0.3	0.9	1	1	(3) 1	2*	2*	2*
3	0.6	2	2	2*	3*	3*	3*	3*
4	0.9	3	3*	4*	(4) 4*	4*	4*	5*
5	1	3*	4*	5*	5*	6*	6*	6*
6	2	4*	5*	6*	(5) 7*	7*	8*	8*
7	2	5*	7*	8*	9*	9*	10*	10*
8	2	7*	8*	9*	10*	11	12	12
9	3	8*	9*	11*	12	13	14	14
10	3	9*	11*	12	14	15	16	16
11	4	10*	12	14	16	17	18	18
12	4	11*	14	16	17	19	20	20
13	4	12	15	17	19	21	22	22
14	5	13	16	19	21	23	24	25
15	5	15	18	21	(6) 23	25	26	27
16	6*	16	19	22	25	27	28	29
17	6*	17	21	24	27	29	30	31
18	6*	18	22	26	28	31	32	33
19	7*	19	23	27	30	33	34	35
20	7*	20	25	29	32	34	36	37
21–25	8*	24	29	34	37	40	42	43
26–30	10*	29	35	41	46	49	52	53
31–35	12*	34	41	48	53	57	60	62
36–40	14*	39	47	54	60	65	68	70
41–45	15	43	52	60	66	72	75	78
46–50	16	46	56	65	72	78	82	84
51–55	17	49	60	70	77	83	87	90
56–60	18	52	64	74	82	88	92	95
61–65	19	55	67	77	85	92	97	100
66–70	20	57	69	80	89	96	101	104

Constants: foliar moisture content = 97% ; crown base height = 3 m. □ = average BUI.
Type of fire: **surface, intermittent crown*, continuous crown**. _ = CFB 50%.

10





Rosie Creek Fire near Fairbanks, Alaska June 2, 1983

Description of Probable Fire Potential and Implications for Wildfire Suppression at Head Fire Intensity Class 5*

The situation should be considered as "explosive" or super critical in the upper portion of the class. The characteristics commonly associated with extreme fire behavior (e.g., rapid spread rates, continuous crown fire development, medium- to long-range spotting, firewhirls, massive convection columns, great walls of flame) is a certainty. Fires present serious control problems as they are virtually impossible to contain until burning conditions ameliorate. Direct attack is rarely possible given the fire's probable ferocity except immediately after ignition and should only be attempted with the utmost caution; an escaped fire should in most cases, be considered a very real possibility. The only effective and safe control action that can be taken until the fire run expires is at the back and up along the flanks.

***from Alexander and Cole (1995)**

United States
Department of
Agriculture

Forest Service

Pacific Northwest
Forest and Range
Experiment Station

Research Note
PNW-401
October 1982

Predicting Wildfire Behavior in Black Spruce Forests in Alaska

Rodney A. Norum

Abstract

The current fire behavior system, when properly adjusted, accurately predicts forward rate of spread and flame length of wildfires in black spruce (*Picea mariana* (Mill.) B.S.P.) forests in Alaska. After fire behavior was observed and quantified, adjustment factors were calculated and assigned to the selected fuel models to correct the outputs to more nearly coincide with observed values. Spotting distance models predict maximum spotting distances if some corrections and assumptions are made. Field-tested procedures are described.

Keywords: Fire behavior (forest), Alaska, black spruce, *Picea mariana*.

Dependable predictions of fire behavior are essential for making tactical plans for suppressing wildfire. Fires in Alaska's black spruce (*Picea mariana* (Mill.) B.S.P.) forests pose some unique problems in prediction.

In recent years, the current fire behavior system—Rothermel (1972) fire spread model—has gained acceptance as an accurate means of predicting fire behavior. Although the field-usable (Albini 1976) version of the model, in the form of nomographs, provides flexibility, some situations are not adequately described by the 13 stylized fuel models. In such cases, adjustment and adaptation of the model are necessary before fire behavior can be accurately forecast. The typical black spruce/feathermoss (*Picea mariana/Hylocomium splendens-Pleurozium schreberi*) forests of Alaska present such a problem.

The first documented attempt to use the Albini nomographs to predict wildfire behavior was made in 1977, when I was fire behavior officer for a fire in an area of black spruce near the village of Hughes in interior Alaska. The fire burned for several days, traversing slopes that ranged in steepness from flat to 32 percent under a variety of weather conditions. The fire burned as a surface fire, presenting an ideal opportunity for measuring rates of spread and flame lengths under varied conditions of slope and fuel moisture content. In addition, the availability of an accurate experimental prototype model of a microwave fuel moisture meter (McLeod 1976) made it possible to measure the moisture content of fuels collected near the fire. Temperature, relative humidity, and the velocity and direction of the wind were measured hourly and when fuel samples were collected. Everything necessary to document fuel conditions and fire behavior was available for comparison with values calculated by the Albini nomographs.

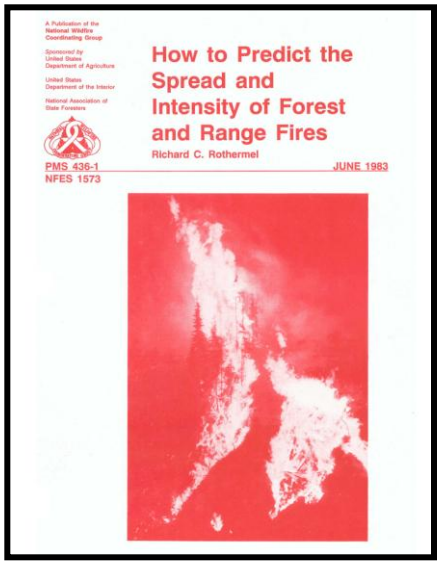
RODNEY A. NORUM is a research forester, Pacific Northwest Forest and Range Experiment Station, Institute of Northern Forestry, 308 Tanana Drive, Fairbanks, Alaska 99701.

Rod Norum found that Fire Behavior Fuel Model 9 Rate of Spread X 1.2 worked best for predicting head fire spread rates in Alaskan black spruce.

For flame lengths and in turn fire intensities he recommended using Fire Behavior Fuel Model 5.

1983 Rosie Creek Fire, Fairbanks, AK
BEHAVE Predictions

Estimating 1-hr Time Lag (TL) Fuel Moisture Content as per Rothermel (1983)



Temperature: 74 ºF
Relative Humidity: 33%

Reference Fuel Moisture: 5%
Adjust for shading, time of year (i.e., month), time of day, slope steepness, aspect and elevation: 3%

Dead Fuel Moisture Content: 5% + 3% = <u>8%</u>

Assumptions (as per Rothermel 1983):
10-hr TL = 8% + 1% = <u>9%</u> **100-hr TL = 8% + 2% = <u>10%</u>**

Assume <u>100%</u> for Live Moisture Content as per Rothermel (1983, Table II-2, p. 13)

1983 Rosie Creek Fire, Fairbanks, Alaska
BEHAVE Predictions

Estimating the Mid-flame Wind Speed

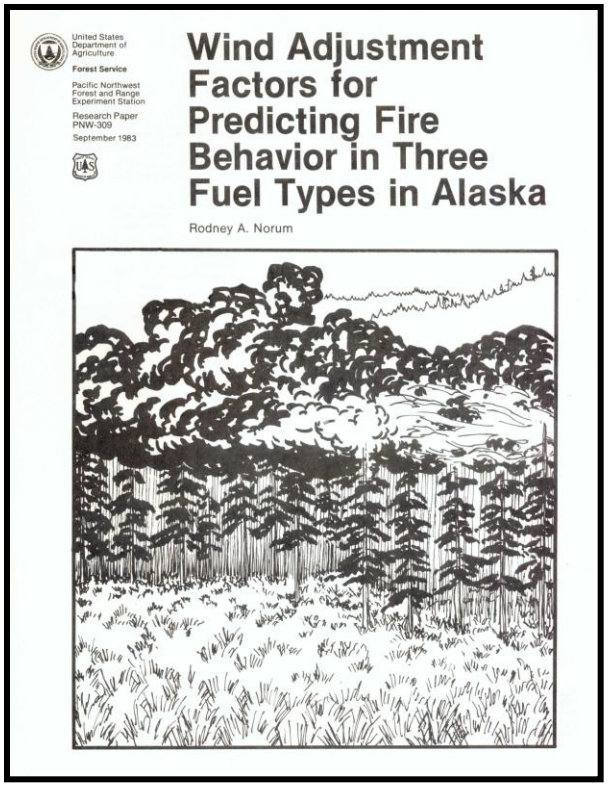
20-ft Open Wind Speed: 13 mph

Rod Norum has suggested a Wind Reduction Factor of 0.2 for Alaskan black spruce.

Dick Rothermel has suggested a Wind Reduction Factor of 0.4 for Fire Behavior Fuel Model 5

Mid-flame Wind Speed = 13 x 0.2 = <u>2.6</u> mph for Fire Behavior Fuel Model 9

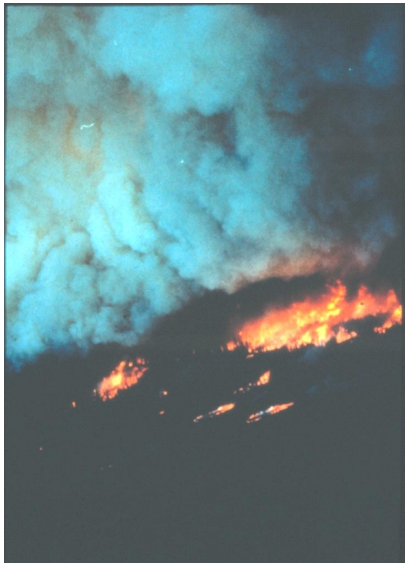
Mid-flame Wind Speed = 13 x 0.4 = <u>5.2</u> mph for Fire Behavior Fuel Model 5


United States Department of Agriculture
Forest Service
Pacific Northwest Forest and Range Experiment Station
Research Paper PNW-309
September 1983

Wind Adjustment Factors for Predicting Fire Behavior in Three Fuel Types in Alaska

Rodney A. Norum

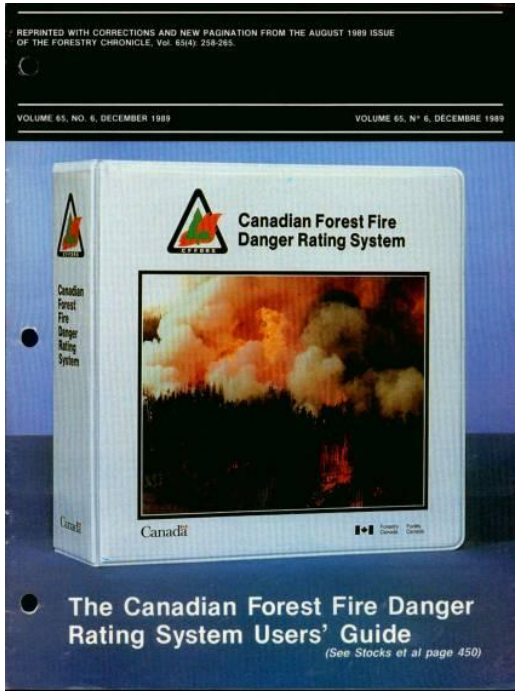
1983 Rosie Creek Fire, Fairbanks, AK

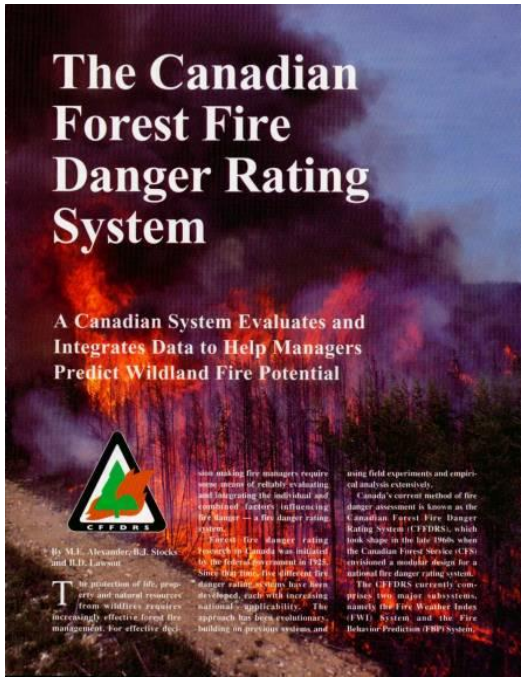


Rosie Creek Fire near Fairbanks, Alaska June 2, 1983

Fire Behavior Characteristic	BEHAVE System	CDN FBP System
Head Fire Rate of Spread (ft/min):	3.9	102
Flame Length (ft):	3.3	35+
Fire Intensity (Btu/sec-ft):	75	12 140

For more information on the CFFDRS





CFS Canadian Forest Fire Danger Rating System website:

http://fire.cfs.nrcan.gc.ca/research/environment/cffdrs/cffdrs_e.htm

Applying the Canadian Forest Fire Danger Rating System to Alaska

http://depts.washington.edu/nwfire/

THE END

ANY QUESTIONS?