THE 1985 BUTTE FIRE IN CENTRAL IDAHO: A CANADIAN PERSPECTIVE ON THE ASSOCIATED BURNING CONDITIONS

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Abstract—During the afternoon of August 29, 1985, the Butte Fire made a high-intensity crown fire run, covering a distance of 2.22 km in one hour and 40 minutes, and forcing 73 fire fighters to deploy their protective fire shelters. This paper presents a retrospective analysis of the fire behavior in terms of the two major subsystems of the Canadian Forest Fire Danger Rating System. The fuel moisture codes (FFMC 94.6, DMC 172, DC 744) and fire behavior indexes (ISI 22.5, BUI 218, FWI 65) of the Canadian Forest Fire Weather Index System were indicative of extreme fire behavior and ignition potential. The predictions of headfire rate of spread (24.6 m/min or 1.48 km/h) and intensity (43,320 kW/m) based on the Canadian Forest Fire Behavior Prediction System were remarkably close to the observed fire behavior characteristics.

INTRODUCTION

The Butte Fire occurred on the Salmon National Forest toward the end of the 1985 fire season in central Idaho. Seventy-three fire fighters were forced to deploy their protective survival shelters in preestablished safety zones when the fire made a major run during the afternoon of August 29 (Mutch and Rothermel 1986). Fortunately, no one was seriously injured. As a result of this incident, the Butte Fire has attained a considerable degree of notoriety in the United States. Several published accounts of the fire's behavior (Aronovitch 1989; Mutch and Rothermel 1986; Rothermel 1991; Rothermel and Gorski 1987; Rothermel and Mutch 1986; Werth and Ochoa 1990) and the shelter deployment (Jukkala and Putnam 1986; Turbak 1986) have already appeared, and there is a 33-minute videotape featuring interviews with those involved and photos taken during the episode (National Wildfire Coordinating Group 1989). Since a great deal of American information on wildland fire behavior finds its way into Canada, some means of relating it to Canadian conditions is often desirable. Thus, this paper offers a hindsight analysis of the Butte Fire in terms of the two primary subsystems of the Canadian Forest Fire Danger Rating System (CFFDRS) (Stocks and others 1989). Emphasis is placed on the documentation of fuel moisture codes and fire behavior indexes of the Canadian Forest Fire Weather Index System and the quantitative prediction of forward rate of spread and frontal intensity based on the Canadian Forest Fire Behavior Prediction System. Some familiarity with the CFFDRS on the part of the reader is presumed.

Table 1.--Analysis of spread rates ass[illegible] the major run of the Butte Fire on Aug[illegible] (after Rothermel and Mutch 1986).

Time interval (hours MDT)	Elapsed time (min)	Forward spread distance (m)	Headfire Rate of Spread (m/min)	(km/h)
1430-1530	60	515	8.6	0.52
1530-1550	20	772	38.6	2.32
1550-1555	5	467	93.4	5.60
1555-1600	5	225	45.0	2.70
1600-1610	10	241	24.1	1.45
1430-1610	100	2,220	22.2	1.33

OBSERVED FIRE BEHAVIOR

The Butte Fire was started by lightning on July 20, 1985. By the afternoon of August 29 approximately 10,500 ha had been burned over and the northern perimeter of the fire was uncontained (fig. 1). On August 29 the Butte Fire made a forward advance of about 2,220 m between 1430 and 1610 hours Mountain Daylight Time (MDT) (table 1). This translates into an average headfire rate of spread (ROS) of 22.2 m/min or 1.33 km/h for the 100-minute run. For short time intervals, the main fire front travelled considerably faster. The maximum observed headfire ROS was 93.4 m/min or 5.6 km/h. The convection column associated with the major run (fig. 2a) was characterized by dense, black smoke and eventually reached an estimated height of nearly 5,000 m above the ground surface. The behavior exhibited by the Butte Fire on the afternoon of August 29 represents a classical case of a high-intensity crown fire event. Flames were observed to stand nearly vertical and greatly exceeded the height of the forest in which the fire was spreading (figs. 2b and 2c). A photograph taken from one of the shelter sites around 1550 hours MDT, about 30 minutes before the arrival

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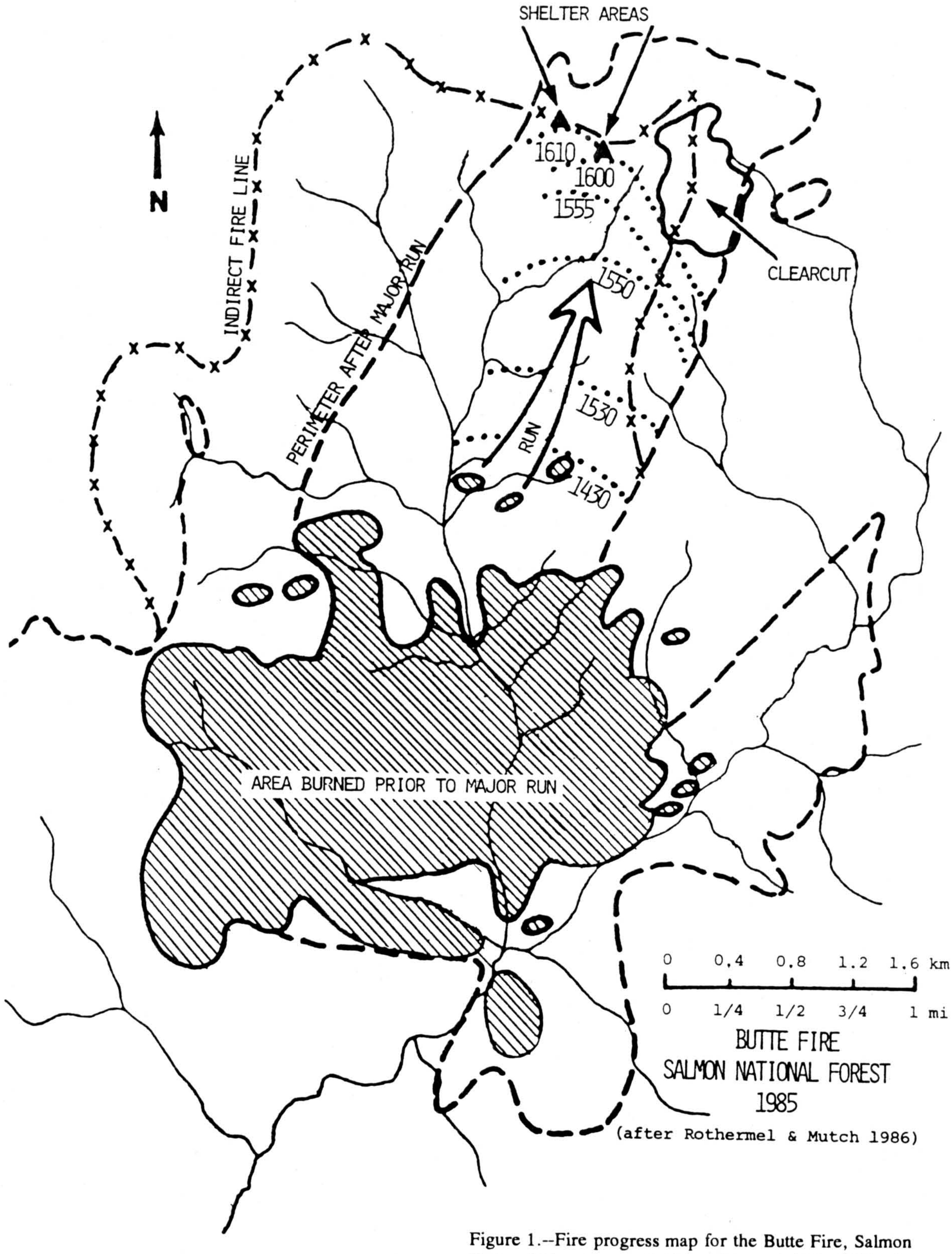
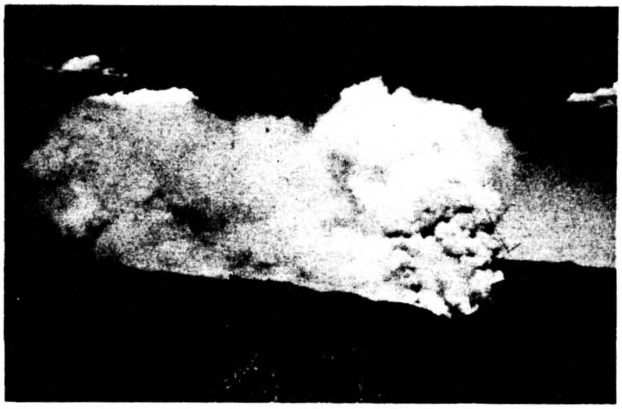


Figure 1.--Fire progress map for the Butte Fire, Salmon National Forest, central Idaho, August 28-29, 1985 (after Rothermel and Mutch 1986).

a



b

c

Figure 2.-- (a) convection column development over the Butte Fire at about 1520 hours MDT on August 29, 1985. (b & c) views of flame front approaching shelter areas (latter photo taken at about 1605 hours MDT). All photos reproduced from 35 mm slides taken by L. Duncan, USDA Forest Service.

of the active flame front, has been reproduced on the cover of Fire Management Notes Volume 46, issue Number 4 in 1986, and certainly attests to the severity of the fire behavior during the major run.

THE FIRE ENVIRONMENT

The fire environment is defined as "the surrounding conditions, influences, and modifying forces of topography, fuel and fire weather that determines fire behavior" (Merrill and Alexander 1987). The fire environment concept (Countryman 1972) as applied to the Butte Fire is described in the following sections.

Fuels

Forest cover types in the area of the major run consisted of Engelmann spruce (Picea engelmanii) - subalpine fir (Abies lasiocarpa) associations in the drainage bottoms and lodgepole pine (Pinus contorta) - subalpine fir stands at higher elevations (Steele and others 1981). The average tree height was considered to be about 18 m (Rothermel 1990) to 23 m (Patten 1990). Surface fuel loads (i.e., downed dead woody and forest floor materials) ranged from about 180 to 225 t/ha in the lower canyon slopes to about 55 to 90 t/ha in the midslope to upper slope areas (Rothermel and Mutch 1986). These figures appear quite reasonable in comparison to other areas in the Northern Rocky Mountains (Brown and Bevins 1986; Brown and See 1981; Fischer 1981). The forest floor depth varied from 2.5 to 10 cm (Patten 1990). Most of the fire area could be categorized by fire behavior fuel models 8 (closed timber litter) and 10 (timber-litter and understory) as described by Anderson (1982).

Topography

The general aspect of the fire area was southerly (fig. 2a). The fire swept up a well-defined north-south drainage that became progressively steeper near the shelter sites. Elevations from the start to the termination of the major run of the fire varied from 2,146 m to 2,341 m above mean sea level (MSL) (fig. 3). This vertical rise of 195 m coupled with the horizontal distance represents an average terrain slope of 9 percent (fig. 3). One unusual feature of the topography in the fire area was the dome-like nature of the upper slopes with continuous forest canopy cover.

Weather

In the spring of 1985, snow-free cover in the fire area probably occurred in early May (Finklin 1988, 1989). The area normally receives about 200 mm of precipitation between early May and late August according to data presented in Finklin (1988). A manually operated fire weather station at the Indianola Guard Station (GS), located 21 km east of the fire area at an elevation of 1,052 m MSL, reported 48.8 mm of precipitation in May but only 8.0 mm in June. The Skull Gulch remote automatic weather station (RAWS) (Warren and

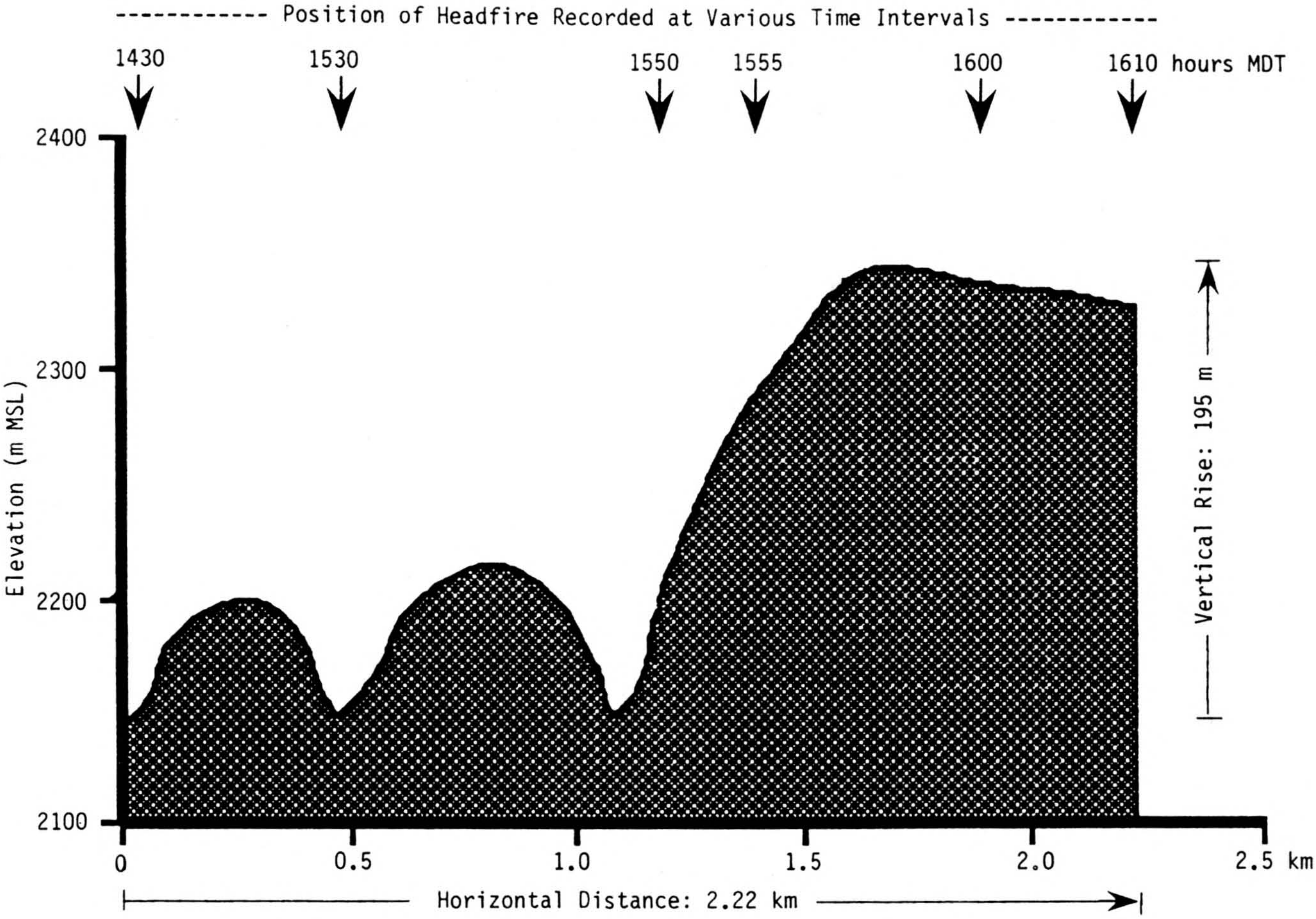


Figure 3.--Topographic profile for the area traversed by the major run of the Butte Fire on August 29, 1985. Note that the differences in the scales for the two axes (5.0:1) does accentuate the terrain relief.

Vance 1981), situated 14 km south of the fire area at 1,554 m MSL, recorded just 2.4 mm and 16.6 mm in July and August, whereas the Indianola GS measured 6.4 mm and 38.0 mm, respectively. The last significant rain (i.e., > 0.6 mm) received at the Skull Gulch RAWS prior to the major run of the Butte Fire occurred on August 2 and 3 (14.8 mm total). At Indianola GS, the last rainfall of any significance occurred on August 19 (3.0 mm).

A U.S. National Weather Service mobile fire weather unit was established at the base camp (2,256 m MSL), approximately 9.1 km southwest of the area involved in the fire run by the early afternoon of August 26. Weather observations taken prior to and on the day of the major run indicate relatively mild air temperatures with fairly low relative humidities but only moderately strong winds (table 2).

Table 2.--Daily 1300 hours MDT observations and extremes recorded at the temporary fire weather station at the Long Tom II Complex base camp (after Gorski 1990).

Calendar date (1985)	Dry-bulb temperature (°C)	Relative humidity (percent)	10-m open wind Speed[a] (km/h)	10-m open wind Direction (from)	24-h rain (mm)	Maximum temperature (°C)	Minimum relative humidity (percent)
August 26	21.7	27	14	south	0.0	23.9	21
August 27	22.8	23	13(31)	southwest	0.0	25.6	17
August 28	21.1	20	14	southwest	0.0	22.8	18
August 29	19.4	20	13(31)	southwest	0.0	23.9	17

[a]1-minute average. Reported gusts noted in parentheses.

Table 3.--Hourly observations recorded at the temporary fire weather station at the Long Tom II Complex base camp on August 29, 1985 (after Gorski 1990).

Local time (hours MDT)	Dry-bulb temperature (°C)	Relative humidity (percent)	10-m open wind Speed[a] (km/h)	10-m open wind Direction (from)
0800	12.2	49	3.7	east
0930	15.0	40	9.3	east
1000	16.1	38	5.6	east
1045	17.2	36	5.6	east
1120	18.9	32	0	-
1200	21.1	29	13.0	southeast
1315	21.1	20	13.0(31)	southwest
1400	21.7	24	22.2(37)	south
1500	21.7	20	18.5	south
1535	22.2	19	23.1	south
1630	23.9	17	14.8	south
1720	23.3	19	15.7	south
1830	21.1	17	7.4	west
2030	16.7	31	11.1	south
2145	15.0	25	0	-

[a]1-minute average. Reported gusts noted in parentheses.

Table 4.--Hourly fire weather observations recorded at the Skull Gulch RAWS site on August 29, 1985.

Local time (hours MDT)	Dry-bulb temperature (°C)	Relative humidity (percent)	10-m open wind Speed[a] (km/h)	10-m open wind Direction (from)
0800	11.2	37	3.0	80
0900	13.9	37	0.7	209
1000	16.3	29	6.3	163
1100	19.8	24	10.0	149
1200	22.6	22	9.3	184
1300	25.7	18	10.7	145
1400	28.1	10	15.9	-[b]
1500	30.0	8	12.6	257
1600	30.4	6	23.0	281
1700	30.0	6	17.0	256
1800	29.6	6	19.8	292
1900	28.1	6	26.7	292
2000	25.3	7	18.0	300
2100	24.1	7	13.9	285
2200	21.8	9	0.2	196

[a]10-minute average.
[b]Not available.

According to the observations made on August 29 (table 3), the following weather conditions would have been representative of the period during the fire run:

Dry-bulb temperature:	22°C
Relative humidity:	19 percent
10-m open wind:	20 km/h
Wind direction:	south
Days since rain:	26

Relative humidities as low as 6 percent and air temperatures of around 30°C were recorded at the Skull Gulch RAWS site during the major fire run (table 4); winds were generally southwest and averaged about 17 km/h.

FIRE DANGER INDICES

The weather data used in calculations of CFFDRS values were obtained from the U.S. National Fire Weather Data Library (Furman and Brink 1975). These data were daily measurements of dry-bulb temperature, relative humidity, wind velocity, and 24-hour accumulated rainfall taken at 1300 hours MDT at Skull Gulch RAWS and Indianola GS during the 1985 fire season. Emphasis was placed on using the Skull Gulch readings since it was more representative of the fire area. The Indianola GS weather record was used for missing observations. Winds measured at the U.S. standard of 6.1 m or 20 ft in the open were adjusted to the CFFDRS standard of 10 m by means of the factor suggested by Turner and Lawson (1978). All weather data were converted to metric units. The standard components of the Canadian Forest Fire Weather Index (FWI) System (Van Wagner 1987) were calculated by computer program (Van Wagner and Pickett 1985). Calculations were begun on May 1, using the standard fuel moisture code starting values (Canadian Forestry Service 1984), and continued until August 25. Calculations for the subsequent period were based on weather observations made at the base camp immediately adjacent to the fire area.

Table 5.--Fire danger indices calculated at 1300 hours MDT for the temporary fire weather station at the Long Tom II Complex base camp.

Calendar date (1985)	Fine Fuel Moisture Code (FFMC)[a]	Duff Moisture Code (DMC)[a]	Drought Code (DC)[a]	Initial Spread Index (ISI)	Buildup Index (BUI)	Fire Weather Index (FWI)
August 26	94.5	160	723	16.4	207	53
August 27	94.5	164	730	15.6	211	52
August 28	94.6	168	737	16.5	215	54
August 29	94.6	172	744	22.5	218	65

[a]The FFMC, DMC, and DC at Skull Gulch RAWS on August 25, 1985, were 97, 157, and 716, respectively.

The three fuel moisture codes and three fire behavior indexes comprising the FWI System are listed in table 5. Readers should consult Canadian Forestry Service (1984) for definitions of the six components. The moisture code values are all indicative of very low moisture contents for the types of fuels they are designed to represent. For example, litter and duff represented by the Fine Fuel Moisture Code (FFMC) and Duff Moisture Code (DMC) would probably have been 6.1 and 25 percent (Van Wagner 1987). A Drought Code (DC) value of 500 is generally considered to be a critical threshold for deep-drying conditions in forest floor and mineral soil layers (Muraro 1975; Muraro and Lawson 1970). The Initial Spread Index (ISI), Buildup Index (BUI), and the Fire Weather Index (FWI) component itself, representing fire spread rate, fuel available for combustion, and fire intensity are all suggestive of extreme suppression difficulty (Alexander and De Groot 1988; British Columbia Ministry of Forests 1983; Muraro 1975). In most regions of Canada, an FWI value of greater than 30 would be rated as an extreme fire danger class (Stocks and others 1989). The fire danger ratings which prevailed on August 29 would also be considered extreme according to the criteria used by the British Columbia Ministry of Forests (1983).

PREDICTED FIRE BEHAVIOR

In an earlier paper by the author (McAlpine and Alexander 1988), a hindsight prediction of the August 29 run of the Butte Fire was made using the interim edition of the Canadian Forest Fire Behavior Prediction (FBP) System (Alexander and others 1984; Lawson and others 1985). This prediction was based on the ISI calculated for the Skull Gulch RAWS and the terrain slope. A crown fire spreading at 24.1 m/min was predicted. In the present paper, the basis for predicted fire behavior is a draft version of the first complete edition of the FBP System (Van Wagner 1989)[2]. The following predictions are based on the most representative FBP System fuel type (C-3: mature jack or lodgepole pine), a 9-percent slope, 10-m open wind of 20 km/h, FFMC 94.6, and BUI 219 for a line-source ignition spreading directly upslope with the prevailing wind during the late afternoon over a period of one hour and 40 minutes:

Headfire rate of spread:	24.6 m/min or 1.48 km/h
Forward spread distance:	2,460 m
Fuel consumption:	58.7 t/ha (surface and crown)
Headfire intensity:	43,320 kW/m
Type of fire:	continuous crowning (>99 percent crown fuel involvement)

In the above calculations, a foliar moisture content (FMC) of 105% (oven-dry weight basis) for lodgepole pine was used based on an on-site sample taken two days after the fire run by Rothermel (1990), and not the computational scheme for determining FMC according to calendar date, geographical location (i.e., latitude and longitude), and elevation. Fire intensity was computed, assuming a low heat of combustion value (reduced for fuel moisture) of 18,000 kJ/kg, on the basis of the predicted rate of advance and amount of fuel consumed (Alexander 1982).

DISCUSSION

The major runs of other well-documented wildfires in the United States such as the 1967 Sundance Fire in northern Idaho, the 1980 Mack Lake Fire in northern lower Michigan, the 1980 Lily Lake Fire in northeastern Utah, the 1983 Rosie Creek Fire in south-central Alaska, and the 1989 Black Tiger Fire in north-central Colorado, all occurred like the Butte

[2]To appear in final published form, authored by the Forestry Canada (ForCan) Fire Danger Group, as an Information Report issued by ForCan headquarters entitled "Development and Structure of the Canadian Forest Fire Behavior Prediction System" in 1991.

Table 6.--Canadian fire danger indices associated with five other major well-known U.S. wildfires.

Name of wildfire	Fine Fuel Moisture Code (FFMC)[a]	Duff Moisture Code (DMC)[a]	Drought Code (DC)[a]	Initial Spread Index (ISI)	Buildup Index (BUI)	Fire Weather Index (FWI)
Sundance[a]	96.1	318	752	23.8	318	68
Mack Lake[b]	94.6	35	59	43.2	35	50
Lily Lake[c]	95.0	66	107	56.2	66	77
Rosie Creek[d]	92.7	114	209	18.0	114	49
Black Tiger[e]	95.2	111	269	24.5	111	59

[a]Reference: Anderson (1968). The FWI System components were calculated on the basis of the 1600 hours Pacific Daylight Time (PDT) fire weather observations for the Priest Lake Experimental Forest, ID (winds were converted to 10-m open standard according to Turner and Lawson 1978); data were kindly provided by A.I. Finklin, Research Meteorologist (retired), USDA Forest Service, Intermountain Fire Sciences Laboratory, Missoula, MT. Dry-bulb temperature and relative humidity were adjusted based on data presented in Finklin (1983), by (-) 1.4°C and (+) 5.0 percent, respectively, in order to approximate the 1300 PDT values. The 1300 hours PDT fire weather observations on September 1, 1967, were: dry-bulb temperature 30.8°C; relative humidity 18%; 10-m open wind 17 km/h; and 25 days since > 0.6 mm of rain.

[b]Reference: Simard and others (1983). The FWI System components were calculated on the basis of the 1300 hours Eastern Daylight Time (EDT) weather data given in Table 1 of Simard and others (1983) for Mio, MI (winds were converted to 10-m open standard according to Turner and Lawson 1978). The 1300 hours EDT fire weather observations on May 5, 1980, were: dry-bulb temperature 26.7°C; relative humidity 24%; 10-m open wind 33 km/h; and 6 days since > 0.6 mm of rain.

[c]Reference: Rothermel (1983, 1991). The FWI System components were calculated on the basis of the 1300 hours MDT fire weather observations for the Bear River Guard Station, Wasatch-Cache National Forest, UT (winds were converted to 10-m open standard according to Turner and Lawson 1978); these data are on file with the National Fire Weather Data Library (Furman and Brink 1975) under station number 420703. The 1300 hours MDT fire weather observations on June 23, 1980, were: dry-bulb temperature 20.6°C; relative humidity 16%; 10-m open wind 37 km/h; and a minimum of 12 days since > 0.6 mm of rain.

[d]Reference: Juday (1985). The FWI System components were calculated on the basis of the 1300 hours Alaska Daylight Time (ADT) weather data for the international airport at Fairbanks, AK; data were kindly provided by P. Perkins, formerly with the USDI Bureau of Land Management, Alaska Fire Service, Fairbanks, AK. The 1300 hours ADT fire weather observations on June 2, 1983, were: dry-bulb temperature 23.5°C; relative humidity 33%; 10-m open wind 21 km/h; and 4 days since > 0.6 mm of rain.

[e]Reference: National Fire Protection Association (1990). The FWI System components were calculated on the basis of the 1300 hours MDT weather data for the Betasso station operated by the Sherrif's Department, Boulder County, CO (winds were converted to 10-m open standard according to Turner and Lawson 1978); these data are on file with the National Fire Weather Data Library (Furman and Brink 1975) under station number 050604. The 1300 hours MDT fire weather observations on July 9, 1989, were: dry-bulb temperature 36.7°C; relative humidity 24%; 10-m open wind 20 km/h (based on an on-site estimate of mid-flame wind speed); and 13 days since > 0.6 mm of rain.

Fire, under exceedingly severe burning conditions according to the FWI component (Table 6)[3]. Although extreme fire behavior was observed in all these cases, there were differences in forward spread rates and frontal intensities. This is to be fully expected given differences in wind velocity, dead and live fuel moisture levels, fuel types (e.g., closed vs. open conifer stands), and the topographic situation (e.g., level ground vs. steep and complex mountainous terrain). The FWI System components offer a general indication of fire potential based largely on short- and long-term surface weather; presently there's no provision made in the FWI System to account for the influences of upper atmospheric conditions on fire behavior such as instability or low-level jet winds (Turner and Lawson 1978). It's the role of the FBP System, which depends in part on the FWI System for input, to consider the differences in fuel characteristics and topography on potential fire behavior.

The FBP System did, although admittedly in retrospect, a remarkably good job of estimating the actual fire behavior characteristics associated with the major run of the Butte Fire on August 29. Headfire ROS and forward spread distance are of course more easily verified in this particular case. A predicted spread rate approaching the maximum observed

[3]The major run of the 1971 Little Sioux Fire (Sando and Haines 1972) in northeastern Minnesota also occurred under an extreme fire danger rating; the FWI System components and 1200 hours local standard time fire weather observations are presented in Alexander and Sando (1989).

value would be possible if a 45 percent slope were used (Van Wagner 1977b), as done by Rothermel and Mutch (1986), and if winds momentarily exceeded the mean value (Crosby and Chandler 1966). Patten (1990) has indicated that surface fuel consumption was perhaps 75 to 100 percent complete, and so the predicted value (47.3 t/ha) is quite reasonable given the fuel moisture levels and preburn fuel loads. The predicted level of frontal fire intensity and type of fire are certainly indicative of a fully-developed crown fire (Alexander 1988; Alexander and Lanoville 1989; Anderson 1968; Simard and others 1983; Stocks 1987; Van Wagner 1977a) and certainly match the general impression obtained by viewing slides taken during the fire run.

CLOSING REMARKS

The CFFDRS can be, if properly applied, a useful tool in research and training for interpreting fire behavior information emanating from wildfire case histories completed in the United States. The present example has in fact been used since 1987 in the annual advanced fire behavior course held at the Forest Technology School in Hinton, Alberta. If the required weather observations are available, then it is possible to redescribe the burning conditions of previously documented forest fires in terms of the weather-dependent components of the FWI System, thereby permitting correlation with observed fire behavior and comparison with predicted fire behavior using the FBP System.

ACKNOWLEDGMENTS

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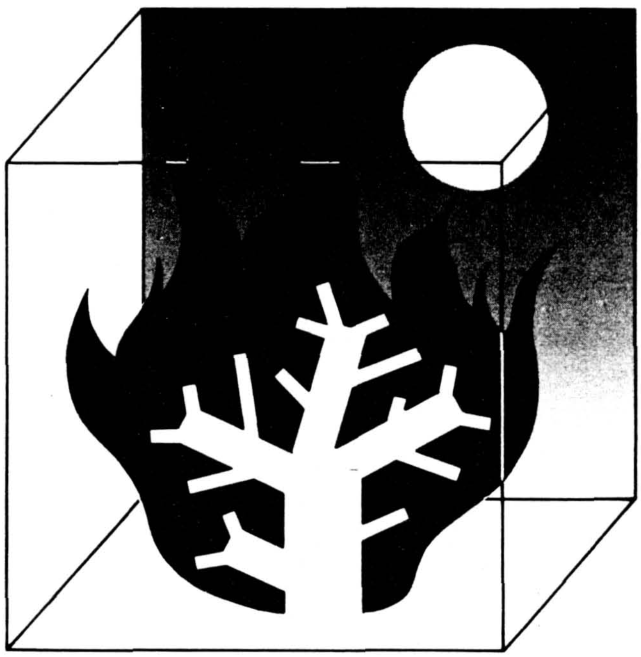

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